European Transport Congress

19th European Transport Congress of the EPTS Foundation e.V

CONFERENCE PROCEEDINGS

ZUM d.o.o.

CARE 4CLIMATE

University of Maribor

European Platform of Transport Sciences

The LIFE IP CARE4CLIMATE (LIFE17 IPC/SI/000007) project is an integrated project, co-financed by the European LIFE programme, the Climate Change Fund and other partners.

ZUM d.o.o.

19th European Transport Congress of the EPTS Foundation e.V

European Green Deal Challenges and Solutions for Mobility and Logistics in Cities

October 7 - 8, 2021, Maribor, Slovenia

Conference Proceedings

Editor

Tomislav Letnik

October 2021

Title 19th European Transport Congress: European Green Deal Challenges and Solutions for Mobility and Logistics in Cities

October 7 – 8, 2021, Maribor, Slovenia, Conference Proceedings

Editor doc. dr. Tomislav Letnik, PhD
(University of Maribor, Faculty of Civil Engineering, Transportation Engineering and Architecture)

Reviewers Prof. Laurent Guihery (CY Cergy Paris University), Prof. Dr. Sönke Reise (University of Applied Sciences, Business and Design Wismar), Assoc. Prof. Borna Abramovic, PhD (University of Zagreb, HRV), Ing. Bc. Vladimír Faltus, PhD (Czech Technical University in Prague (CTU))

Technical editors Metka Dernovšek, MSc.
(University of Maribor)

Cover designer Metka Dernovšek, MSc.
(University of Maribor)

Graphics material Authors

Conference 19th European Transport Congress: European Green Deal Challenges and Solutions for Mobility and Logistics in Cities

Location and date Maribor, October 7 – 8, 2021

Organizing committee Tomislav Letnik (University of Maribor), Zdravko Kačič (University of Maribor), Stane Božičnik (University of Maribor), Eva Schmidt (European Platform of Transport Sciences), Mateja Kukovec (ZUM d. o. o., LIFE IP CARE4CLIMATE), Sebastian Belz (European Platform of Transport Sciences), Katja Hanžič (University of Maribor), Maršenka Marksel (University of Maribor), Florian Polterauer (Plasser & Theurer), Mitja Klemenčič (University of Maribor)

Published by Zum urbanizem, planiranje, projektiranje d.o.o.
Grajska ulica 7, 2000 Maribor, Slovenia

Co-published by University of Maribor
Slomškov trg 15, 2000 Maribor, Slovenia

Edition 1st

Publication type E-Book

Available at www.fgpa.um.si/etc/downloads/

Published Maribor, October 2021

CIP - Kataložni zapis o publikaciji
Univerzitetna knjižnica Maribor

656.1:502/504(082)(0.034.2)

EUROPEAN Transport Congress of the EPTS Foundation e.V (19 ; 2021 ; Maribor)
19th European Transport Congress of the EPTS Foundation e.V [Elektronski vir] : European green deal challenges and solutions for mobility and logistics in cities : conference proceedings : October 7-8, 2021, Maribor, Slovenia / editor Tomislav Letnik. - 1st ed. - E-zbornik. - Maribor : Zum urbanizem, planiranje, projektiranje : University, 2021

Način dostopa (URL): https://www.fgpa.um.si/etc/downloads/
ISBN 978-961-95633-0-4 (ZUM)
COBISS.SI-ID 90733315

ISBN 978-961-95633-0-4 (pdf)

Price Free copy

For publisher Andreja Kuzmanić, ZUM urbanizem, planiranje, projektiranje d.o.o.

19th European Transport Congress: European Green Deal Challenges and Solutions for Mobility and Logistics in Cities

STANISLAV BOŽIČNIK, TOMISLAV LETNIK

On 7th and 8th of October 2021, University of Maribor hosted international scientific congress "European Green Deal – Challenges and Solutions for Mobility and Logistics in Cities". The congress was organized in collaboration with the European Platform of Transport Sciences (EPTS Foundation e.V) and was held under the auspices of the LIFE IP CARE4CLIMATE project.

The audience was addressed by prof. dr. Zdravko Kačič, Rector of the University of Maribor and Darko Trajanov, Director General of the Directorate for Sustainable Mobility and Transport Policy of the Republic of Slovenia.

Mr. Henrik Hololei from the European Commission, Directorate for Mobility and Transport, presented the European Green Deal growth strategy, which aims to transform the European economy through a series of ambitious reforms. The Green Deal can be seen as a comprehensive roadmap that aims to make Europe the first climate-neutral continent by reducing greenhouse gas emissions by up to 55 % by 2030 (Fit for 55) and achieving net zero emissions by 2050. Transport currently accounts for a quarter of the EU's greenhouse gas emissions and is Therefore, one of the cornerstones for achieving the very ambitious targets. Moving towards more sustainable transport means providing innovative, affordable, cleaner, accessible, and healthier alternatives.

Dr. Marcel Rommerts, Head of Unit for Transport Research in the European Climate, Infrastructure and Environment Executive Agency (CINEA), presented the Horizon Europe program and CINEA's mission to support implementation of the European Green Deal. Transport research is part of the second pillar, which delas with challenges and collaborative research. Calls for proposals can be found in Cluster 5

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

of the Horizon Europe Work programme. Within this cluster there are 6 areas, called destinations, two of, which, destination no. 5 and 6, are specifically dedicated to transport. Dr Rommerts invited all researchers to apply for projects and contribute to achieving sustainable transport in Europe.

Experts presented their research results in the field of urban freight and passengers transport under the following conference themes:

- Green Transport Policy and Governance in the European Perspective
- Green Fuels and Vehicles
- Innovations in Urban/Regional Mobility and Freight
- Digitalisation, Automatization and Modelling

The conference was organized in a hybrid form and attended by about 150 researchers (100 of them live) from 18 European countries. A total of 33 scientific papers were presented. All presentations and conclusions are available as recordings on the conference web page https://www.fgpa.um.si/etc./.

Table of Contents

SECTION 1:

GREEN TRANSPORT POLICY AND GOVERNANCE IN THE EUROPEAN PERSPECTIVE

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Smart Solutions for the Problems of City Logistics

SNEŽANA TADIĆ, MLADEN KRSTIĆ, MILOVAN KOVAČ, NIKOLINA BRNJAC

Abstract A European Green Deal strategy set the goal to reduce emissions from transport 90 % by 2050. Transport should become drastically less polluting, especially in cities, the places of the greatest concentration of economic and social activities. The cities are experiencing intensive changes in logistics demands due to the ongoing trends, such as globalization and consumer society growth, the shift in production paradigm, which is based on individualization, personalization, and shorter life cycle, the development of industry 4.0, which is based on technological advancement, automatization, digitalization, networking and new communication forms, the development of e-commerce, sustainability and other social trends. Having this in mind, the goal of this paper was to propose smart sustainable city logistics (CL) solutions as the combinations of different CL initiatives, measures, concepts, and technologies of industry 4.0, with the aim of mitigating emissions, urban congestion and other unsustainable effects of logistics. Such an approach in defining smart CL solutions represents the main contribution of this paper. The defined solutions are evaluated according to different stakeholder groups through the application of a novel hybrid multi-criteria decision-making (MCDM) model, based on BWM (Best-Worst Method) and CODAS (COmbinative Distance-based ASsessment) methods in grey environment, which is another contribution of the paper. The results of the model' application imply that the potentially best sustainable smart CL solution is the one that is based on the combination of the concepts of micro-consolidation centers and autonomous vehicles with the support of artificial intelligence and internet of things technologies.

Keywords: • City Logistics • Smart City • Industry 4.0 • Grey BWM • Grey CODAS

CORRESPONDENCE ADDRESS: Snežana Tadić, Dr., Mladen Krstić, Dr., Milovan Kovač, Mr., University of Belgrade, Faculty of Transport and Traffic Engineering, Vojvode Stepe 305, 11000, Belgrade, Serbia, e-mail: s.tadic@sf.bg.ac.rs, e-mail: m.krstic@sf.bg.ac.rs, e-mail: m.kovac@sf.bg.ac.rs; Nikolina Brnjac, Dr., University of Zagreb, Faculty of Transport and Traffic Sciences, Vukelićeva st. 4, 10000, Zagreb, Croatia, e-mail: nikolina.brnjac@fpz.hr.

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

Transport accounts for a quarter of the EU's greenhouse gas emissions, and the percentage is still growing [24]. This is one of the reasons why EU established the European Green Deal strategy. One of its goals is to reduce emissions from transport further and faster. The EU strives to achieve climate neutrality, i.e., a 90 % reduction in transport emissions by 2050 [24]. Transport should become drastically less polluting, especially in cities. In order to achieve this, the EU transport system and infrastructure should be made fit to support new sustainable mobility services that can reduce congestion and pollution, especially in urban areas [24]. Accordingly, city logistics (CL) represents an important planning domain because of its tight bonds with the sustainable development of urban areas. The growth in CL problems, caused by structural changes of goods flows, political and social changes, new business models, etc. [19], has attracted the attention of many researchers in this field. Although the importance of CL is recognized in the scientific literature, in practice, the impact of logistics activities, especially transportation, has been unsustainable for decades [8]. Neglection and inadequate approach towards the problems of logistics in urban areas results in great traffic congestions, air pollution, time losses, the inefficiency of logistics processes, generating of vibrations and noise, etc., which can be mitigated only through comprehensive and long-term planning of CL [14].

City administration in most cases has a negative attitude towards logistics activities and tries to constrain them by implementing different restrictive measures [13]. City administration should, instead, play the role of integrators and stimulate other stakeholders to cooperate in order to achieve sustainable CL solutions. Attempts to implement individual initiatives, measures in practice have shown that the traditional approach for CL planning is unsustainable [5], [20]. Aside from the understanding of city characteristics, identification of participants, their demands, goals and interactions, successful implementation of CL solutions requires integrated planning, cooperation of stakeholders, removing all barriers, and defining of measures that would support the realization of plans [17]. The application of modern industry 4.0 technologies makes the definition of creative and sustainable CL solutions possible.

The technologies of industry 4.0 are already the topic of scientific discussion [15], however, aside from the analysis of individual technologies and their expected influence on logistics, the analysis of smart CL solutions does not exist. Having in mind the European Green Deal recommendations, that a combination of measures should address emissions and urban congestion [24], the main contribution of this paper is the definition of smart CL solutions, which are based on the combination of existing initiatives, concepts, measures and the technologies of industry 4.0. In addition, this paper provides a framework for the selection of the most appropriate solutions from the aspect of all CL stakeholders, whose attitudes are expressed through 11 criteria. For the ranking of the defined smart CL solutions, a novel hybrid multi-criteria decision-making (MCDM) model, based on BWM (Best-Worst Method) and CODAS (COmbinative Distance-based ASsessment) methods in grey environment, is developed, which represents another contribution of the paper.

The paper is organized as follows. The next section defines and describes the smart CL solutions that are analyzed, as well as the criteria for their evaluation. The novel MCDM model is described in the following 4 sections, while its application for the defined problem is presented in section 4. The same section provides a discussion of the obtained results and the applied model. The last section presents concluding remarks and the direction of future research.

PROBLEM DEFINITION

The European Green Deal strategy foresees that the automated and connected multimodal mobility will play an increasing role, together with smart traffic management systems enabled by digitalisation [24]. Accordingly, this section defines the smart solutions of CL (SSCL) as the combinations of city logistics concepts, initiatives, measures and technologies of industry 4.0. The ongoing phenomenon in CL is the increase of small delivery frequencies [5], [23], which cause most of the problems in the planning and realization of logistics activities [18], [20]. This trend tends to continue in the future Therefore, the focus of this paper is set on such categories of goods flows. The assumption is that all solutions are based on the concept of consolidation and cooperation through urban consolidation centers (UCC) at the outskirt of the urban area. UCCs represent a potential domain for the application of advanced robotics in goods handling processes, order picking, marking, sorting, etc., Therefore, it will not be explicitly repeated in the description of SSCLs. Also, it is assumed that decision supporting systems, as well as blockchain technology, are an integral part of every SSCL.

The first solution (SSCL1) refers to the combination of the ideas of parcel lockers and crowdsourcing. The delivery of goods from the UCC to parcel lockers is realized with road delivery vehicles. Flow generators can collect the goods from parcel lockers. The registered crowd agents can take over the delivery on the relation parcel lockers-generators, or UCC-parcel lockers. The application of crowdsourcing in delivery requires the implementation of a CC platform that would provide system access for crowd agents, the information about deliveries that are available for taking over, and the communication with logistics providers and flow generators. With the application of AR, it is possible to visualize the possibilities for package storage in parcel lockers, as well as to inform the crowd agents about potential delivery routes, traffic conditions, etc. In this case, AR would represent an integral part of the CC platform, while being available to all crowd agents with appropriate hardware (tablets and mobile phones). The application of IoT is apparent because it is required to set up adequate communication between UCC, delivery vehicles, crowd agents, flow generators, parcel lockers, etc. The application of IoT would enable the tracking of deliveries (and goods) at the CC platform in real-time, which would make delivery planning easier for providers and crowd agents. The application of parcel lockers reduces the uncertainties, which exist in classical crowdsourcing models because it makes sure the goods are delivered to the close proximity of flow generators. Furthermore, the providers are relieved from the responsibility in the last phase of the delivery. This solution requires the installation of parcel lockers in the urban area and the development of a CC platform. The development of SSCL1 requires relatively small investments, but its main disadvantage is delivery reliability, which is problematic because of the crowd agents' autonomy.

The solution SSCL2 is based on the concepts of flow micro-consolidation and the application of autonomous vehicles. The development of micro-consolidation centers (MKCs) in the delivery zone aims to shift the transportation work to autonomous vehicles. The delivery at the relation UCC-MKCs is realized with road delivery vehicles, while on the relation MKCs-flow generators, autonomous vehicles are utilized – autonomous road vehicles and drones. AI makes it possible for autonomous vehicles to independently plan and realize their deliveries, and to adapt to the conditions in the environment. Aside from UCCs, advanced robotics could be applied at MKCs for all activities that refer to the handling of goods. IoT makes the communication between system echelons, autonomous vehicles, logistics providers, etc., more efficient. The transformation of the system into a two-echelon system, such as in this solution, makes the delivery process more efficient, but also requires the development of additional infrastructure - MKCs. The application of autonomous vehicles could have positive effects on sustainability because it replaces the traditional delivery approach (road delivery vehicles), but opens a wide variety of questions regarding the regulatory framework of their application.

In the third solution (SSCL3), the delivery is realized through the combination of road delivery vehicles and drones. Road delivery vehicles play the role of moving depots that visit the locations reserved for launching drones for the realization of the last delivery phase. Aside from the drones, the road vehicles are equipped with advanced robotics, which is responsible for the automatization of goods handling and its loading on drones. As in the previous solution, the application of drones is automated through AI and does not require the involvement of humans, while their synchronization is made possible with IoT and real-time tracking. This solution does not require the development of new infrastructure, which is its main advantage but requires the synchronization of road vehicles and drones. The main disadvantage of the solution is still the dominance of road delivery vehicles in the city, while the regulations that refer to the usage of drones for urban deliveries are still absent.

The fourth solution (SSCL4) refers to the application of cargo trams for goods transportation to loading stations in the delivery zone, where the modal shift to light delivery vehicles – bicycles, cycles, and scooters takes place. The application of AR is possible in the last phase of the delivery as support for the drivers of light delivery vehicles, and in combination with IoT, it ensures on-time information about the incoming goods at loading stations. At the loading stations, it is possible to apply advanced robotics to automate the goods handling activities. The disadvantage of this solution is the need for establishing regular tram lines on the relation UCC-loading stations, the development of those stations, and general low flexibility of rail transportation mode. The advantages of the solutions are a high degree of road transportation vehicles elimination from the city and the flexibility in the last phase of delivery performed by the light vehicles.

When solving CL problems, it is necessary to define the criteria in a way to encompass the attitudes, demands, and goals of all stakeholders – local administration, logistics providers, service users, and residents [20] and to cover all three sustainability aspects – social, economic, and environmental [3]. The existing literature considered a broad set of criteria with regard to the nature and the observation level of problems [1], [7], [16], [21], [22]. The following text describes the criteria used for SSCL evaluation.

Efficiency (C1) describes the rationalization level of logistics activities of solutions and refers to the loading space utilization of delivery vehicles, the average travelled distance per delivery, energy and fuel consumption, average delivery time, etc. The modal shift of transport work (C2) refers to the stimulation for the application of alternative transportation modes as a replacement for road delivery vehicles in urban areas. Reengineering level (C3) describes the reorganization complexity of the existing logistics system to transform it into the desired one. The complexity is reflected by the need for structural and organizational changes in logistics systems, the development and improvement of new information systems, the adaptation of business politics to incoming technological and business trends, the procurement and studying of modern industry 4.0 technologies, personnel training, etc. The development of additional infrastructure (C4) refers to the need for developing adequate logistics infrastructure – MKCs, parcel lockers, loading stations, etc. System reliability (C5) refers to the availability of services and goods in acceptable time intervals. The complexity of regulatory framework defining (C7) refers to all procedures, measures, and laws that have to be defined and executed to make the application and exploitation of solutions possible. Effects on mobility (C8) refers to the improvement of conditions that ensure the undisturbed realization of goods and people flows in urban areas, which succeeds the application of the observed solution – the improvement of traffic conditions and safety. Environmental impact (C9) describes at, which level does the observed solution contribute to the reduction of negative environmental impacts of logistics activities – the emission of air pollutants, noise and vibrations. Operational complexity of delivery (C10) depends on the transformation degree of goods flows and the applied technologies. It refers to the complexity of activities that must be realized in the delivery process. Acceptability (C11) refers to the willingness of stakeholders, especially logistics providers and residents, to accept the observed solution.

A HYBRID GREY BWM-CODAS MODEL

For solving the defined problem, a novel hybrid MCDM model that combines BWM and CODAS methods in grey environment is developed. The grey BWM method is used for criteria weight extraction while grey CODAS is used for alternative ranking.

The application steps of the model are as follows.

Step 1: Define the problem structure – form the set of alternatives, the criteria for their evaluation, and identify the stakeholder groups.

Step 2: Define the grey scale for criteria and alternative evaluation by the DMs. Linguistic terms and their corresponding grey values are shown in Table 1.

Table 1. Grey scale used for evaluation

Linguistic term	**Abbreviation**	**Grey scale**
None	N	[0, 2]
Very Low	VL	[1, 3]
Low	L	[2, 4]
Fairly Low	FL	[3, 5]
Moderate	M	[4, 6]
Fairly High	FH	[5, 7]
High	H	[6, 8]
Very High	VH	[7, 9]
Extremely High	EH	[8, 10]

Step 3: Extract the criteria weights by using the grey BWM method. The procedure requires the realization of several steps (3.1-3.3) that are explained in the following text.

Step 3.1: In general, every stakeholder group d $(d=1,...,f)$, where f represents the number of stakeholder groups, chooses the best and the worst element (the most and least important criterion) j_B and j_W respectively $(j=1,...,m)$, where m stands for the number of criteria. Every stakeholder group evaluates other elements (criteria) in comparison with the best and worst elements by using the linguistic terms that can be transformed into grey values through the relations from Table 1. In such a way, grey vectors are extracted – "the best compared to others", $\otimes A_B=(\otimes a_{B1},\otimes a_{B2},...,\otimes a_{Bm})$, and "others compared to the worst, $\otimes A_W=(\otimes a_{1W},\otimes a_{2W},...,\otimes a_{mW})$.

Step 3.2: Regarding every stakeholder group d, optimal grey criteria values (weights) $\otimes w_{d1},\otimes w_{d2},...,\otimes w_{dm},\forall d=1,...,f$ are determined by solving the following nonlinear problem:

$$\min \otimes \xi$$
$$s.t.\begin{cases} P\left\{\left|\frac{\otimes w_B}{\otimes w_{dj}} - \otimes\, a_{Bj}\right| \leq \otimes\, \xi\right\} < 0.5 \\ P\left\{\left|\frac{\otimes w_{dj}}{\otimes w_W} - \otimes\, a_{jW}\right| \leq \otimes\, \xi\right\} < 0.5 \\ \sum_{j=1}^{m} W(\otimes\, w_{dj}) = 1 \\ \underline{w}_{dj} \leq \overline{w}_{dj} \\ \underline{w}_{dj} \geq 0 \\ j = 1, \dots, m \end{cases} \tag{1}$$

where $\otimes\xi = [\underline{\xi}, \overline{\xi}]$ is a grey number whose lower and upper values are $\underline{\xi}$ and $\overline{\xi}$ respectively, $\otimes\xi w_B = [\underline{w}_B, \overline{w}_B]$ is the optimal grey number (weight) of the best element (the most significant criterion), $\underline{w}_B$ and $\overline{w}_B$ are the lower and upper value of the grey number $\otimes w_B$, $\otimes w_w = [\underline{w}_W, \overline{w}_W]$ is the optimal grey number (weight) of the worst element (least significant criterion) with $\underline{w}_W$ and $\overline{w}_W$ as its lower and upper value, $\otimes w_{dj} = [\underline{w}_{dj}, \overline{w}_{dj}]$ is the optimal grey number (weight) of the element (criterion) j, $j = 1, \dots, m$, $j \neq j_B, j_W$, $\otimes a_{Bj} = [\underline{a}_{Bj}, \overline{a}_{Bj}]$ is the grey number that describes how much the best element (most significant) criterion is better than the element (criterion) j, $\otimes a_{jW} = [\underline{a}_{jW}, \overline{a}_{jW}]$ describes, how much the element j is better (more significant) from the worst element (criterion), $W(\otimes w_j)$ is the white value of the grey number $\otimes w_j$, which is determined by the following equation (Osati & Omidvari, 2016):

$$W(\otimes w_{dj}) = (\underline{w}_{dj} + \overline{w}_{dj})/2 \qquad (2)$$

P represents the GPD value, which can be calculated for any two grey values (for example $\otimes p$ and $\otimes q$) in the following way [9]:

$$P\{\otimes p \leq \otimes q\} = \frac{\max(0, L(\otimes p) + L(\otimes q) - \max(0, \overline{p} - \underline{q}))}{L(\otimes p) + L(\otimes q)} \qquad (3)$$

where $L(\otimes p) = |\overline{p} - \underline{p}|$ and $L(\otimes q) = |\overline{q} - \underline{q}|$ are valid. To ensure that $\otimes p$ is lower than $\otimes q$ the inequality $P\{\otimes p \leq \otimes q\} < 0,5$ must be valid.

By solving problem (1), the optimal grey numbers (weights) of elements (criteria) $(\otimes w_{d1}, \otimes w_{d2}, \dots, \otimes w_{dm})$ are extracted, and the procedure is repeated for every stakeholder group d.

Step 3.3: Check the comparison consistency. To control the results of the method, it is necessary to calculate the consistency ratio (CR) with the following equation:

$$CR = R(\otimes \xi)/CI \qquad (4)$$

where $R(\otimes\xi)$ represents the white value of the grey number $\otimes\xi$, calculated by the equation (2), and CI represents the consistency index, which is derived as the largest solution value for the following quadratic equation:

$$CI^2 - (1 + 2\overline{a}_{BW})CI + (\overline{a}_{BW}^2 - \overline{a}_{BW}) = 0 \qquad (5)$$

where $\overline{a}_{BW}$ is the upper value of the grey number $\otimes a_{BW} = [\underline{a}_{BW}, \overline{a}_{BW}]$, which represents the greatest grey number from the comparisons of the best (most significant) element (criterion) with other elements (criteria), and the comparison of other elements (criteria) with the worst (least significant) element:

$$\otimes a_{BW} = \max_j\{\otimes a_{Bj}, \otimes a_{jW}\} \tag{6}$$

The comparison is considered consistent if the CR value is close to 0 [2, 4, 11, 12, 25].

Step 3.4: The final element (criteria) weights are extracted with the following equations [16]:

$$\otimes w_j = [\underline{w}_j, \overline{w}_j], \forall j = 1, \dots, m \tag{7}$$

$$\underline{w}_j = \left(\prod_{d=1}^{l} \underline{w}_{dj}\right)^{1/d} \tag{8}$$

$$\overline{w}_j = \left(\prod_{d=1}^{l} \overline{w}_{dj}\right)^{1/d} \otimes a_{BW} = \max_i\{\otimes a_{Bj}, \otimes a_{jW}\} \tag{9}$$

Step 4: Evaluate the alternatives by applying the extension of the conventional CODAS in grey environment [6].

Step 4.1: Form the grey decision matrix ($\otimes$X) in the following way:

$$\otimes X = [\otimes x_{ij}]_{n\times m} = \begin{bmatrix} \otimes x_{11} & \otimes x_{12} & \cdots & \otimes x_{1m} \\ \otimes x_{21} & \otimes x_{22} & \cdots & \otimes x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \otimes x_{n1} & \otimes x_{n2} & \cdots & \otimes x_{nm} \end{bmatrix} \tag{10}$$

where $\otimes x_{ij} = [\underline{x}_{ij}, \overline{x}_{ij}]$represents the grey evaluation of alternative *i (i = 1, 2, ..., n)* in regard to criterion *j (j = 1, 2, ..., m)*, where $\underline{x}_{ij}$ and $\overline{x}_{ij}$ represent the lower and upper values of the grey number $\otimes x$.

Step 4.2: Form the weighted decision matrix ($\otimes R$) in the following way:

$$\otimes R = [\otimes r_{ij}]_{n\times m} \tag{11}$$

$$\otimes r_{ij} = [\underline{r}_{ij}, \overline{r}_{ij}] = \otimes w_i \times \otimes x_{ij} \tag{12}$$

where $\otimes w_i$ represents the grey value that refers to the weight of criterion i.

Step 4.3: Define the negative ideal solution in the following way:

$$\otimes ns = [\otimes ns_j]_{1\times m} \tag{13}$$

$$\otimes ns_j = [\underline{ns}_j, \overline{ns}_j] = \left[\min_i \underline{r}_{ij}, \min_i \overline{r}_{ij}\right] \tag{14}$$

Step 4.4: Calculate the Euclidean distances of alternatives from the negative ideal solution:

$$\otimes E_i = [\underline{E_i}, \overline{E}_i] \quad (15)$$

$$\underline{E_i} = \sqrt{\sum_{j=1}^{m} \max\left(0, \min(\underline{e}_{ij} \times \underline{e}_{ij}, \underline{e}_{ij} \times \overline{e}_{ij}, \overline{e}_{ij} \times \underline{e}_{ij}, \overline{e}_{ij} \times \overline{e}_{ij})\right)} \quad (16)$$

$$\overline{E}_i = \sqrt{\sum_{j=1}^{m} \max\left(\underline{e}_{ij} \times \underline{e}_{ij}, \underline{e}_{ij} \times \overline{e}_{ij}, \overline{e}_{ij} \times \underline{e}_{ij}, \overline{e}_{ij} \times \overline{e}_{ij}\right)} \quad (17)$$

where $\underline{e}_{ij}$ and $\overline{e}_{ij}$ refer to the lower and upper value of the grey number $\otimes e_{ij}$ derived from the following equations:

$$\otimes e_{ij} = [\underline{e}_{ij}, \overline{e}_{ij}] = \otimes r_{ij} - \otimes ns_j \quad (18)$$

$$\underline{e}_{ij} = \underline{r}_{ij} - \overline{ns}_j \quad (19)$$

$$\overline{e}_{ij} = \overline{r}_{ij} - \underline{ns}_j \quad (20)$$

Step 4.5: Calculate the grey Taxicab distances of alternatives from the negative ideal solution in the following way:

$$\otimes T_i = [\underline{T_i}, \overline{T}_i] \quad (21)$$

$$\underline{T_i} = \sum_{j=1}^{m} |\underline{e}_{ij}| \quad (22)$$

$$\overline{T}_i = \sum_{j=1}^{m} |\overline{e}_{ij}| \quad (23)$$

Step 4.6: Form the grey matrix of relative values in the following way:

$$\otimes Ra = [\otimes h_{ik}]_{n \times n} \quad (24)$$

$$\otimes h_{ik} = [\underline{h}_{ik}, \overline{h}_{ik}] \quad (25)$$

$$\underline{h}_{ik} = (\underline{E_i} - \overline{E}_k) + \left(\psi(\underline{E_i} - \overline{E}_k) \times (\underline{T_i} - \overline{T}_k)\right) \quad (26)$$

$$\overline{h}_{ik} = (\overline{E}_i - \underline{E_k}) + \left(\psi(\overline{E}_i - \underline{E_k}) \times (\overline{T}_i - \underline{T_k})\right) \quad (27)$$

where $k = 1, 2, \ldots, n$ represents the index of the alternative that is compared with all other alternatives i (all alternative pairs are compared), and ψ represents the function, which determines the equality threshold of Euclidean distances of two alternatives, determined in the following way:

$$\psi = \begin{cases} 1 \; if \; |W(\otimes E_i) - W(\otimes E_k)| \geq \tau \\ 0 \; if \; |W(\otimes E_i) - W(\otimes E_k)| < \tau \end{cases} \quad (28)$$

where $W(\otimes E)$ is determined with the equation (2).

In function (29), τ represents the threshold parameter defined by the DM. The recommended values for this parameter are between 0,1 and 0,5. If the difference of Euclidean distances of two alternatives is greater than τ, then the alternative comparison should also include the Taxicab distance values.

Step 4.7: Calculate the GPD values for all alternative pairs ($P\{\otimes h_i \leq \otimes h_k\}, \forall i,k=1,...,n$) by equation (3).

Step 4.8: Perform the final alternative ranking according to the values P. The alternative that has the value $P < 0,5$ in the most number of comparisons is considered the best.

THE APPLICATION OF THE HYBRID MODEL FOR PROBLEM SOLVING

This section presents the application of the developed model for solving the observed problem and the results of its application. In the second part, the discussion of results, their implications, and the analysis of the model are presented.

Hybrid model application

The first application step of the proposed hybrid MCDM model refers to the definition of alternatives and criteria for their evaluation, as well as the identification of stakeholder groups that are interested in solving the observed problem. The considered alternatives and criteria used for their evaluation are described in section 3, while the evaluation is performed by four stakeholder groups: logistics service providers (Pro.), users (Use.), city administration (Adm.), and residents (Res.). The providers want to minimize the costs of collecting and delivery of goods to the customers and maximize their profit. Service users are the senders/receivers of goods that require the maximization of service level in terms of shorter times of goods collecting/delivering, greater reliability and flexibility, better information availability, etc., with lower service price. Administration as a goal has the economic development of the city and improving the employment possibilities while reducing traffic congestions, improving living conditions, and better traffic safety in cities. Residents are the people that live, work, and buy goods in cities, and their goal is the minimization of traffic congestions, noise, air pollution, and traffic accidents in their surrounding [26].

Stakeholder group representatives have chosen the best and worst criteria and evaluated all the remaining criteria according to the linguistic terms from table 1. Stakeholder representative criteria evaluation is shown in Table 2. This way, the vectors "the best compared to others" and "others compared to the worst" are derived.

Table 2. Criteria evaluation by stakeholder groups

	Pro.		Use.		Adm.		Res.	
C_1	best	EH	best	EH	M	M	FL	FH
C_2	FL	FH	VH	VL	FL	FH	L	H
C_3	L	H	FH	FL	L	H	EH	worst
C_4	VL	VH	EH	worst	best	EH	M	M
C_5	FH	FL	VL	VH	H	L	EH	N
C_6	FL	FH	L	H	VH	VL	EH	N
C_7	L	H	EH	N	N	EH	FH	FL
C_8	EH	worst	VH	VL	L	H	VL	VH
C_9	VH	VL	H	L	VL	VH	best	EH
C_{10}	VL	VH	FL	FH	EH	worst	EH	N
C_{11}	N	EH	M	M	VL	VH	H	L

For the derived vectors, optimization problem (1) is solved, considering the GDP values derived by equation (3) and white values derived by equation (2). This way, optimal grey criteria weights for every stakeholder group are derived. Equations (4) – (6) are applied to check the evaluation consistency. Having in mind that all CR values are close to 0, the evaluation is considered consistent. The following final criteria weights are determined by applying the equations (7) – (9): {C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11} = {[0,094, 0,191], [0,057, 0,072], [0,055, 0,082], [0,056, 0,093], [0,046, 0,074], [0,047, 0,061], [0,067, 0,083], [0,034, 0,064], [0,065, 0,093], [0,049, 0,061], [0,086, 0,113]}.

In the next step of model application, the evaluation of alternatives (sustainable smart CL solutions) according to the defined criteria and linguistic terms is performed (Table 3).

Table 3. Alternative evaluation according to the criteria

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}
SSCL1	L	VL	FL	EH	L	VH	VH	FL	L	VH	M
SSCL2	FH	FH	EH	H	VH	H	H	H	H	EH	EH
SSCL3	VL	L	H	VH	M	EH	L	VL	VL	H	FH
SSCL4	H	H	VH	M	H	FH	VH	M	FH	M	VH

By transforming these evaluations into grey values (according to the relations from table 1), the grey decision matrix is formed (10). For the extracted criteria weights, by applying equations (11) and (12), the weighted grey decision matrix is formed. The negative ideal solution is determined by applying equations (13) and (14), while the Euclidean and Taxicab alternative distances from the negative ideal solutions are determined by equations (15) - (20) and (21) – (23) respectively. The grey matrix of relative values is formed by applying equations (24) – (28), for, which the GDP values are determined by applying equation (3) for all alternative pairs. The final ranking of alternatives regarding the GDP values, as an output result of the grey CODAS method, is shown in Table 4.

Table 4. The final ranking of alternatives

$P\{\otimes h_i \leq \otimes h_k\}$	SSCL1	SSCL2	SSCL3	SSCL4	Rank
SSCL1	/	0,5159	0,3797	0,5124	3
SSCL2	0,4841	/	0,3746	0,4957	1
SSCL3	0,6203	0,6254	/	0,6292	4
SSCL4	0,4876	0,5043	0,3708	/	2

Discussion

SSCL2, which represents the combination of the micro-consolidation concept and autonomous vehicles with the application of AI and IoT technologies, is selected as the best smart solution for CL. MKCs are located in the close proximity of flow generators, which compensates for the technical limitation of autonomous vehicles. The application of AI and IoT enables better connectivity of all participants, real-time information sharing, appropriate decision-making in crisis situations, which leads to significant improvement in flow realization efficiency. The application of this solution would have significant positive effects on the sustainability of logistics activities in urban areas: efficient process realization, reduction in air pollutant emissions, noise and vibrations, reduction of traffic congestions caused by delivery vehicles, improving the attractiveness of the city, promoting the application of smart technologies, etc. On the other hand, the application of this solution would be possible only if all relevant problems on strategic and tactical decision-making level are solved (defining the required number of MKCs, their location and capacity, the number and type of autonomous vehicles, regulatory frameworks and ethical norms for their wide application, characteristics of the system that would enable the application of AI and IoT technologies, etc.), as well as on the operational level (vehicle routing, synchronization of activities, etc.). Practical implications of the problem-solving in this paper are in providing guidelines/base points for policy creators and DMs in cities when defining smart solutions for logistics, as well as in providing a framework for the definition, evaluation and selection of new solutions.

For the purpose of solution evaluation and selection, a novel hybrid MCDM model, that combines the BWM and CODAS methods in grey environment, is developed in this paper. Its applicability is successfully demonstrated by solving the observed problem. The practical implications of the developed model are in providing a simple but efficient tool for DMs in problem-solving, in this and also any other area.

CONCLUSION

This paper focused on the problem of defining and ranking sustainable smart CL solutions. The goal was to find a sustainable solution that would meet all modern challenges of goods distribution in urban areas with the application of advanced industry 4.0 technologies. Four feasible solutions are defined and, after their evaluation, the solution that combines the concept of micro-consolidation and autonomous vehicles with the support of AI and IoT technologies, is selected as the best. For solution evaluation and selection, a novel hybrid MCDM model, which combines the BWM and CODAS methods in grey environment, is developed.

The main contributions of the paper are the definition of original smart CL solutions as a combination of modern initiatives and concepts of CL with the technologies of industry 4.0, the creation of a framework and definition of criteria for their evaluation, as well as the development of a novel hybrid MCDM model for ranking and selection of the best solution. Having this in mind, this paper contributes significantly to the research areas of logistics, smart cities, industry 4.0, and MCDM and provides useful tool for developing schemes for transport in urban areas and evidence-based policymaking.

One direction of future research would be in further development of the defined solutions and the identification of new application possibilities for the existing and those in development, technologies of industry 4.0. A significant future research direction would be the development of completely new solutions from the ones that are defined in this paper, as well as the analysis of their practical feasibility in different cities across the world. As the developed MCDM model is universally applicable, with certain adjustments, it could be used for problem-solving in future research in the area of logistics, industry 4.0, and other areas as well. The developed model, or some of its components, could serve as the base for the development of new models.

REFERENCES

[1] Awasthi, A., & Chauhan, S. S. (2012). A hybrid approach integrating Affinity Diagram, AHP and fuzzy TOPSIS for sustainable city logistics planning. Applied Mathematical Modelling, 36(2), 573–584.

[2] Badri Ahmadi, H., Kusi-Sarpong, S., & Rezaei, J. (2017). Assessing the

social sustainability of supply chains using Best Worst Method. Resources, Conservation and Recycling, 126, 99–106.

[3] Deutsch, N., & Berenyi, L. (2018). Personal approach to sustainability of future decision makers: a Hungarian case. Environment Development and Sustainability, 20(1), 271–303.

[4] Guo, S., & Zhao, H. (2017). Fuzzy best-worst multi-criteria decision-making method and its applications. Knowledge-Based Systems, 121, 23–31.

[5] Kauf, S. (2016). City logistics - A Strategic Element of Sustainable Urban Development. Transportation Research Procedia, 16, 158–164.

[6] Keshavarz-Ghorabaee, M., Zavadskas, E. K., Turskis, Z., & Antucheviciene, J. (2016). A new combinative distance-based assessment (CODAS) method for multi-criteria decision-making. Economic computation and economic cybernetics studies and research, 50(3), 25–44.

[7] Lebeau, P., Macharis, C., Van Mierlo, J., & Janjevic, M. (2018). Improving policy support in city logistics: The contributions of a multi-actor multi-criteria analysis. Case Studies on Transport Policy, 6(4), 554–563.

[8] Macharis, C., & Kin, B. (2017). The 4 A's of sustainable city distribution: Innovative solutions and challenges ahead. International Journal of Sustainable Transportation, 11(2), 59–71.

[9] Mukherjee, S., & Ghosh, B. (2015). Application of Grey Possibility Degree in Comparing Poverty. International Journal of Innovative Research in Science, Engineering and Technology, 4(6), 4698–4703.

[10] Osati, M., & Omidvari, M. (2016). Performance measurement of electricity suppliers using PROMETHEE and balance scorecard. Management Science Letters, 6(6), 387–394.

[11] Rezaei, J. (2015). Best-worst multi-criteria decision-making method. Omega (United Kingdom), 53, 49–57.

[12] Rezaei, J., Nispeling, T., Sarkis, J., & Tavasszy, L. (2016). A supplier selection life cycle approach integrating traditional and environmental criteria using the best worst method. Journal of Cleaner Production, 135, 577–588.

[13] Rześny-Cieplińska, J., & Szmelter-Jarosz, A. (2020). Environmental Sustainability in City Logistics Measures. Energies, 13(6), 1303.

[14] Tadić, S., Krstić, M., & Kovač, M. (2021a). Assessment of city logistics initiative categories sustainability. Environment, Development and Sustainability, Article in press.

[15] Tadić, S., Krstić, M. & Zečević, S. (2021b). Technological solutions in logistics 4.0. Ekonomika Preduzeća, Article in press.

[16] Tadić, S., Krstić, M., Roso, V., & Brnjac, N. (2020). Dry port terminal location selection by applying the hybrid grey MCDM model. Sustainability, 12(17), 1–22.

[17] Tadić, S., & Zečevic, S. (2015a). Cooperation and consolidation of flows in city logistics. Tehnika, 70(4), 687–694.

[18] Tadić, S., & Zečević, S. (2015b). Integrated planning aimed at sustainability city logistics solutions. Tehnika, 65(1), 164–173.

[19] Tadić, S., & Zečević, S. (2016a). Global trends and their impact on city logistics management. Tehnika, 71(3), 459–464.

[20] Tadić, S., & Zečević, S. (2016b). Modelling city logistics concepts (in Serbian) (1st ed.). Belgrade, Serbia: University of Belgrade, Faculty of Transport and Traffic Engineering.

[21] Tadić, S., Zečević, S., & Krstić, M. (2014a). A novel hybrid MCDM model based on fuzzy DEMATEL, fuzzy ANP and fuzzy VIKOR for city logistics concept selection. Expert Systems with Applications, 41(18), 8112–8128.

[22] Tadić, S., Zečević, S., & Krstić, M. (2014b). Ranking of Logistics System Scenarios for Central Business District. Promet - Traffic&Transportation, 26(2), 159–167.

[23] Taniguchi, E. (2015). City logistics for sustainable and liveable cities. In B. Fahimnia, M. G. H. Bell, D. A. Hensher, & J. Sarkis (Eds.), Green Logistics and Transportation: A Sustainable Supply Chain Perspective (pp. 49–60). Springer.

[24] The European Green Deal. (2019). Communication from the commission to the European Parliament, the European Council, the Council, the European economic and social committee and the Committee of the regions. European Commission, Brussels.

[25] Wan Ahmad, W. N. K., Rezaei, J., Sadaghiani, S., & Tavasszy, L. A. (2017). Evaluation of the external forces affecting the sustainability of oil and gas supply chain using Best Worst Method. Journal of Cleaner Production, 153, 242–252.

[26] Zečević, S., & Tadić, S. (2006). City logistics (in Serbian). Belgrade, Serbia: University of Belgrade, Faculty of Transport and Traffic Engineering.

Urban Transport Political Measures Based on Lessons Learned from the Basic Principles of the EU ETS

STANISLAV BOŽIČNIK, TOMISLAV LETNIK

Abstract European Green Deal (Fit for 55) is aiming at ambitious target of reducing greenhouse gas emissions by at least 55 % by 2030 for Europe and to become the world's first climate-neutral continent by 2050. The first chapter provides an overview of the basics of environmental economics relevant to the transport sector in context of the European Green Deal initiative, which has chosen tradable permits (TP) as instrument for CO_2 emission control. The Green Deal emissions control concept in transport sector is presented in the second chapter. For solving the problem of externalities of transport in urban environment, which accounts for 40 % of the total road transport CO_2 emissions tradable permits, like in Green Deal, are suggested. New innovative solution consisting of an interconnected system of separate TP markets for each motor vehicle category (cars, vans, LDV, HDV) is likely to solve the problem of road transport externalities in general and indirectly in urban areas. The conclusions provide a critical overview of theoretically and practically questionable solutions of the proposed Green Deal TP system in transport, also showing the expected impact on budget revenues and revenues of fuel suppliers.

Keywords: • Green Deal • Tradable Permits • Emission Trading • Urban Transport • Political Measures

CORRESPONDENCE ADDRESS: Stane Božičnik, Prof. PhD, Tomislav Letnik, Assist. Prof. PhD, University of Maribor, Faculty of Civil Engineering, Transportation Engineering and Architecture, Smetanova 17, 2000 Maribor, e-mail: stane.bozicnik@um.si; e-mail: tomislav.letnik@um.si

 ISBN 978-961-95633-0-4

THEORETICAL BASIC OF ENVIRONMENTAL ECONOMICS

Market failure and externality

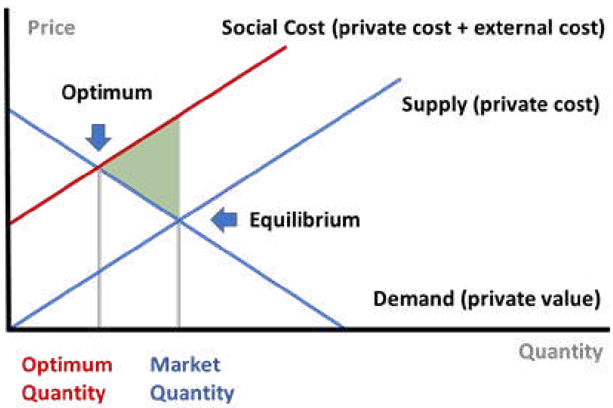
Neoclassical economics introduced the concept of market failure, which is also a basic concept applied in the environmental economics [1]. Market failures are viewed as scenarios where individuals' pursuit of pure self-interest leads to results that are not efficient and should be improved upon from the societal point of view and interest [2].

Market failure is, under the free-market conditions, a situation when the quantity supplied does not equal with the quantity demanded, which causes the undesired imbalance of prices and consequently of consumption/production. Pareto inefficient allocation [3] of goods and services is leading to externalities, which means that it leads to net loss of economic value.

In economic theory, externalities are examples of market failures, in, which the unfettered market does not lead to efficient results.

Externalities occur when production or consumption of a specific good or service impacts not directly related third party. Pollution is according to environmental economists [4] a consequence of absence of prices of certain scarce environmental resources, such as water, air etc. [5]. Environmental goods are subject to the problem known as the tragedy of the commons [6]. Tragedy of commons occurs when individual users, because of the given market conditions, act independently according to their own self-interest, contrary to the common good of all users. It may be stated that in the case of a negative externality the social cost of the good exceeds the private cost. The optimal quantity is Therefore, smaller than the equilibrium quantity as indicated in Figure 1.

Figure 1. Optimal equilibrium after internalization of external costs



Government intervention by means of market-based instruments

As a solution economists suggest internalization of externalities i.e., introduction of surrogate prices by means of government intervention on the market to establish normal market conditions. The idea was first proposed for roads by Pigou in 1920 [7]. As a solution for externalities economists suggest governmental intervention on the market.

There are two basic options for government intervention on the market either command and control instruments (legal regulations) or market-based instruments, such as: taxes, tradable permits, subsidies etc. Government intervention is in theory and practice justified by the argument that voluntary decisions of consumers and businesses fail to achieve efficiency or other goals deemed important by society.

Command-and-control policies regulate behaviour of polluters directly, whereas market-based policies provide incentives for private decisionmakers to change their behaviour. An important characteristic of market-based instruments is that it is an indirect policy instrument. It means that the government does not control individual polluters directly but uses the market mechanism for these purposes.

As indicated on the Figure 1 external costs can be internalized by means of taxes and/ or tradable permits, which consequently increase prices and enable establishment of the new optimal equilibrium of supply and demand with optimal prices and optimal quantity of supply.

The idea of using tradable permits (a market-based instrument) to allocate the rights to produce pollution among firms or individuals was developed by Crocker, Dales and Montgomery [8,9,10].

In case of tradable permits the government decides about the total acceptable volume of pollution (cap) and distributes the pollution quantity rights (tradable permits) to individual polluters.

As soon as tradable pollution permits have been allocated to polluters systematic reduction of marginal abatement costs is enabled, which means that the polluters with high pollution reduction costs may buy pollution permits from the polluters with low cost of pollution reduction. If the permit price exceeds the marginal abatement costs, the emitter would abate emissions. If the marginal abatement costs exceed the permit price, the emitter would cover his emissions with permits purchased on the tradable permits market [11].

When dealing with tradable permits there are few elements of crucial importance, which should be carefully considered by the policy makers: a) any reduction of marginal abatement costs has an impact on cost value ratio, on profitability of polluters operations; b) tradable permits are economic incentive instrument, which achieves its maximum efficiency when it operates at the most decentralized level possible [12]; c) if not carefully prepared and studied government policy interventions may also lead to an inefficient allocation of resources, sometimes called government failure [13].

The European Green Deal

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007a, 2007b) conclude that, it is very likely, that greenhouse gas (GHG) emissions are caused by human activities responsible for most of the observed increases of globally averaged temperatures since the middle of the 20th century [14,15]. The assessment report suggests that the carbon dioxide (CO_2) emissions are among the main causes of global warming. Consequently, is the mitigation of CO_2 emissions from different sectors of the economy a top priority on the national and international political agendas.

In July 2021 European Commission adopted a package of proposals aiming at ambitious target of reducing greenhouse gas (GHG) emissions by at least 55 % by 2030 [16]. These proposals called "Fit for 55" represent only part of a set of legislative tools, legal obligations, and policies constituting the so called "European Green Deal" [17]. European green deal is basically an action plan intended to initiate transformational change of the EU's economy and enable Europe to become the world's first climate-neutral continent by 2050. The chosen policy mix is Therefore, a careful balance between pricing, targets, standards, and support measures [18,19].

EU Emissions Trading Scheme

The EU ETS (Emissions Trading Scheme), which is an important building block of the European Green Deal is covering around 41 % of the EU's total CO_2 emissions of energy intensive industries and air transport [20]. It works on the 'cap and trade' principle. A cap is set on the total acceptable amount of certain greenhouse gases that can be emitted by the companies covered by the system [21]. A "cap" is limited by the number of emission allowances. The limit on the total number of allowances available ensures that they have a value. Each allowance gives the holder the right to emit one tonne of carbon dioxide (CO_2). Within the cap, companies receive or buy emission allowances, which they can trade as needed. The cap decreases every year, ensuring that total emissions fall. Between 2021 and 2030 the overall number of emission allowances was originally planned to decline at an annual rate of 2,2 percent. "Fit for 55" foresees linear reduction factor of 4,2 % cut to ETS emissions cap every year (if started in 2024).

Each polluter needs enough allowances to fully cover all its emissions, otherwise heavy fines are imposed. If the polluter reduces its emissions, it can keep the spare allowances to cover its future needs or sell them to another polluter that is short of allowances.

Tradable permits in the EU air transport

The total number of aviation allowances in the ETS will be capped at current levels and will be reduced annually by 4,2 %. The Commission proposes to phase-out free allocation to aircraft operators and to move to full auctioning of allowances by 2027, because the free allocation is considered as a derogation from the 'polluter pays' principle [22].

On this way a stronger price signal can be created. In order to address aviation emissions at global level, the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) will be implemented through the EU Emissions Trading System Directive [23, 24, 25].

Tradable permits in the EU shipping transport

To strengthen the role of carbon pricing in the transport sector, the Commission proposes to extend the current EU ETS to the maritime sector over the period 2023 to 2025 [26].

Shipping emissions will be included in the ETS for the first time to cover CO_2 emissions from large ships (above 5000 gross tonnage), regardless of the flag they fly. The extension will include all emissions from ships calling at an EU port for voyages within the EU (intra-EU), as well as 50 % of the emissions from voyages starting or ending outside of the EU (extra-EU voyages), and emissions that occur when ships are at berth in the EU ports. The EU ETS would cover around two thirds of maritime transport emissions (90 million tonnes CO_2); shipping owners will have to purchase and surrender ETS emission allowances for each tonne of reported CO_2 [27, 28].

New tradable permits trading system for road transport and buildings sector

The EU Commission proposes in its "Fit for 55" package a new emissions trading system for fuels distribution for road transport and buildings. The system will run separately from the EU ETS and is supposed to start in 2026, with a cap on emissions set from 2026 [28]. This new upstream system will regulate fuel suppliers (rather than households and car drivers). The suppliers will be responsible for monitoring and reporting the quantity of fuels they place on the market and for surrendering emission allowances each calendar year depending on the carbon intensity of the fuels. This approach incentivises the fuel suppliers to decarbonise their product as this will reduce the cost of compliance with the emissions trading system.

Commission expects that emissions trading in road transport and building sector will increase incentives to supply cleaner fuels for existing vehicles. The system is expected to push fuel providers to decarbonise their fuels [28].

Financial aspects of the EU Green Deal

The European Commission estimates that 260 billion euros a year, of private and public sector, are needed for additional investments to achieve the climate targets set for 2030. This means that additional 2,6 trillion euros are needed in the next ten years. There are many macroeconomic, as well as microeconomic questions related to profitability of the green investments and their macroeconomic effects [29].

Parry et al. [30] suggests that the economic costs to the United States of meeting its carbon emissions target under the original Kyoto Protocol would more than double when the costs of reduced employment are taken into account. In contrast, much of this extra social cost could be offset by emissions taxes and auctioned permits if revenues from these policies were used to reduce income taxes [31].

This concept is according to our understanding and available sources in the EU on the above mentioned way not foreseen, which might have significant impact on cost of production of the EU economy and its competitiveness on the world market [32].

URBAN MOBILITY AND FREIGHT TRANSPORT POLITICAL MEASURES BASED ON THE LESSONS LEARNED FROM THE BASIC PRINCIPLES OF THE EU GREEN DEAL

Importance of urban mobility and freight in the EU

Urban mobility accounts for 40 % of the total CO_2 emissions of road transport and up to 70 % of other pollutants from transport. European cities increasingly face problems caused by transport. The question of how to enhance mobility while at the same time reducing congestion, accidents and pollution is a common challenge to all major cities in Europe. Congestion in the EU is located in and around urban areas with an estimated costs nearly EUR 100 billion, or 1 % of the EU's GDP, annually [33].

The European Green Deal (COM(2019)640) [34] and the Sustainable and Smart Mobility Strategy (COM(2020)789) [35], adopted in 2019 and 2020 respectively, provide a new EU framework for the overall direction of EU transport policy for the years to come. It acknowledges the importance of urban mobility in the context of the green and digital transitions.

The results of the evaluation of the EU 2013 Urban Mobility Package (SWD(2021)0047) published in February 2021 demonstrate that further EU action on urban mobility is needed to upgrade the EU sustainable urban mobility toolkit, in order to respond to the growing challenges (CO_2 and air pollutant emissions, congestion, road crashes, resilience of the transport network), and contribute to the increasingly ambitious climate, digital and societal objectives in line with the EU commitments [36].

Also, urban freight /urban logistics are essential to the efficient functioning of cities. This comprises transportation methods, handling and storage of goods, management of inventory, waste and returns, as well as home delivery services. The European Commission has substantially contributed to the development of knowledge, expertise and uptake of sustainable urban logistics concepts. Examples include SMARTFUSION (Smart Urban Freight Solutions) or TURBLOG-WW (Transferability of Urban Logistics Concepts and Practices from a World Wide Perspective), CIVITAS demonstration projects and the best practice and tools to be found on Eltis - The urban mobility observatory [37].

The overarching conclusion of the evaluation was that EU action on urban mobility is still required and is even more crucial now than in 2013 when the Urban Mobility Package was introduced. This is because many of consequences of the problems in urban mobility are of rising severity and gravity for society, the economy and the environment [38].

With the increasingly ambitious objectives of the European Green Deal, the Climate Target Plan 2030 and the Sustainable and Smart Mobility Strategy, the need to decarbonise urban transport whilst ensuring important societal goals of affordability, accessibility, availability and inclusiveness is now the major EU priority [39].

Suggested solutions

Chapter 2 summarises road map and measures of the EU Green Deal referring to all modes of transport. To be in line with the Green Deal (Fit for 55) transport political framework, we shall try to apply the same measures also in the field of transport in urban (functional urban) areas.

Based on theoretical and practical lessons learned and presented in Chapter 1 we are aiming at defining optimal and efficient transport management tool based on the EU Green Deal solution, but adopted according to our understanding of needs.

It may be stated at this stage that tradable emission permits represent the nutshell tool of the EU Green Deal. This is the reason why we are suggesting potentially efficient application of tradable permits system also for solutions in the field of urban transport. The suggested solution, to be successful, requires some conceptual changes of the foreseen EU Green Deal solution for road transport.

Tradable permits for road transport

Contrary to the concept of the EU Green Deal, we consider that out of all transport modes, which are responsible for about one quarter of the total EU CO_2 emissions, road transport as the biggest polluter responsible for 72 % of the total European transport CO_2 emissions is the first transport mode, which should have been regulated within the Green Deal initiative. Air transport and shipping are from the CO_2 emissions point of view (15 % each) of marginal importance.

Tradable permits for road transport and household energy use have been studied already by several authors: Flemning [40], Verhoef et. al. [41], Bozicnik [42], Fawcett [43], Raux and Marlot [44]. Based on practical and theoretical findings, (some of them are summoned up in the Chapter 1), we would suggest for transport, in particular road transport, the following solution. Cap and trade system, free distribution of certain number of tradable permits for fuel to all motor vehicle owners of all type of motor vehicles on annual basis (at the occasion of annual vehicle registration to prevent price fluctuations at the end of the year). Free allocation of permits minimizes problems of social and political acceptability because it enables to consume certain quantity of fuel (driven kilometres) without causing any additional costs.

In case of need the cap can be decreased by the regulating authority on annual basis for each vehicle category separately depending on the transport political and environmental needs. For each vehicle category (personal cars, vans, light duty vehicles, heavy duty vehicles, busses, airplanes, ships etc.) we suggest: the vehicle category specific annual quantity of tradable permits for fuel to be distributed free to each motor vehicle user and establishment of separate tradable permits market for each vehicle category group. The tradable permits markets of individual motor vehicle categories would be interconnected, which means that regulating authority is in a position, in case of need, to enable exchange of available quantities of tradable permits on the single transport market in order to be able to stabilize prices and to achieve the foreseen transport political aims. This solution is different from the concept presented by C. Raux [45] and Verhoef E. [46].

Creation of separate markets for tradable permits of each motor vehicle category enables to the regulating authority to follow the planed transport political aims, such as: increase of load factor, decrease congestion, etc. separately per each motor vehicle category. This means that the cap of each motor vehicle category can be adjusted (increased or decreased) according to the actual transport political needs, while the total cap of transport sector remains unchanged.

One tradable permit would enable the owner/user of motor vehicle to buy one litre of fuel, which equals to fixed quantity for CO_2 emissions (gasoline 2,27kg CO_2/l, diesel 2,63 kg CO_2/l).

Modern IT technology enables today e.g., the use of smart cards at the petrol stations for purchasing fuel within the available quantity of tradable permits. In case of need additional TP can be bought under the daily rate value at the petrol stations and uploaded on the smart card.

The motor vehicles owners have a possibility to sell the excess quantities of tradable permits on the tradable permits market or to buy the needed quantity of tradable permits under the current market prices. If they are selling tradable permits the revenue is a direct stimulation of owner/user of the motor vehicle for rational behaviour, such as: using public transport, grouping cargo, buying environment friendlier motor vehicles etc. The stimulation of individual vehicle owner/user is substantially bigger if tradable permits are not auctioned.

We suggest that a network of brokers would be established that would trade with TP. National road transport TP market should have been organised on regional principles in order to be able to follow also the specific needs of the individual functional urban areas. The brokers would trade on the "TP stock market" in favour of their clients (vehicle owners/users). On this way a daily value of TP would yield as a basis for daily spot market prices. Brokers could perform also "banking" function (e.g., borrowing of TP) for their clients. Motor vehicles coming from other regions/countries, would have the right to buy limited number of tradable permits at the daily TP stock rate (Source - limited reserve quota of the regulating authority).

There are several reasons why we do not agree with the EU Green Deal concept foreseen for road transport suggesting the upstream emissions trading process, which will regulate fuel suppliers. The foreseen upstream concept of the emissions trading process is controlling the total sales and (CO_2) content in the fuel of individual fuel suppliers. The advantage of the foreseen upstream system lies in a simplified monitoring process because of smaller number of fuel suppliers, but it has an unrealistic requirement for decrease of the CO_2 content in the fuel on the yearly basis (see for details also Winkleman et al. [47]).

CO_2 emissions of transport sector do not occur at the refinery level but they occur at the vehicle user level. For rational behaviour vehicle users should be motivated.

The upstream concept brings petroleum fuel industry in difficult position. The carbon content of the fuel cannot be reduced (without big investments) by 4,2 % per year as required by "Fit for 55". The only option the fuel suppliers might have for reducing CO_2 emissions will be decreasing the volume of their output. See also Grubb [48].

Reduction of fuel suppliers' output would increase the price of fuel due to supply constraints and would get characteristics of fuel tax with all its known disadvantages [49]. There is also a potential danger of monopolistic tendences of the small number of large producers aiming to manipulate the fuel prices [50].

The underlying principle in a tradable permit system or tax policy is to provide an incentive for the polluters to change their behaviour. As already mentioned in the transport sector the owner/user of motor vehicle makes the ultimate decision of how to drive, how much to drive and consequently how much CO_2 is emitted. Direct incentive for rational behaviour of vehicle users is the most important argument in favour of downstream emissions trading system [51]. Another argument, which should be considered is the fact that economic incentive instruments achieve their maximum efficiency when operating at the most decentralized way. The more decentralised the system is the more efficient it is [52,53,54].

In any case tradable permits raise firms' production costs and reduce economic activity. If transport company (a polluting firm) increases economic activity, it must either buy permits to cover the extra emissions or improve its environmental performance; either way, there is a financial penalty for producing polluting output. Consequently, grandfathered permits have adverse effects on employment in the same way that emissions taxes do, but auctioned permits do not enable potential benefit from revenue recycling (lowering the labour or other company taxes) on one side but on the other side they have, if the tradable permits are free allocated, stronger motivation effect on the tradable permits' owner for rational behaviour.

Impact of suggested system solution on transport externalities in urban areas

As it can be seen in several EU documents, European commission is supporting big number of different projects aiming at solving, at least partially, some of the problems of transport and transport externalities in urban areas [37]. Up to now, in spite of the big number of different approaches, the problem of transport externalities in urban areas as such remains basically not solved.

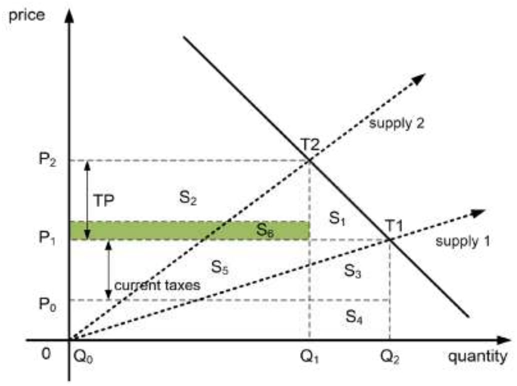
We consider that our suggested concept of introduction of tradable permits for fuel, separately for different categories of motor vehicles, might have been a solution also not only for transport system as such but it might have a direct and indirect impact on transport and its externalities in urban (and functional urban) areas. Flexibility of cap (quantity of available fuel) for different categories of motor vehicles is an instrument in hands of transport policy, which enables management of optimal and desired volume of transport per motor vehicle category. In the downstream distribution system of limited (decreasing) quantity of tradable permits for fuel the system as such forces motor vehicle owners/users in rational behaviour, such as load factor increase, minimal empty drive, more passengers in cars, less transport externalities, increased demand for public transport etc. Regulation of traffic volume (transport externalities) is in this case in the hands of transport political decision makers. This conceptual solution represents, according to our understanding, a universal solution for transport externalities problems.

There are also some specific details, which should be solved before tradable permits are introduced, in particular in the field of low elasticity fuel demand population (need for transport of population from remote areas; urgent transport of common interest: ambulance, police, fire protection service, food and water supply transport etc.).

Financial impact of the suggested solution

The suggested solution has a significant impact on financial flows. As indicated at Figure 2, the decrease of consumed fuel from Q1 to Q2 decrease revenues from fuel industry and services (S4) and decreases inflow of revenues to the governmental budget from fuel taxes and excise duties (S3). We must keep in mind that today that

Figure 2. TP auctioning-division of income



on average in the EU half of the price of the motor vehicles fuel are taxes. Which represents an important revenue for the budget.

There are also other consequences, which must be considered. The cost of transport services will because of the suggested measures grow. The impact on standard of living of the whole population and the impact on costs in the economy (decreased international competitiveness of the EU economy) is in this case inevitable.

CONCLUSIONS

The tradable emission permits system introduced by the EU Green Deal (Fit for 55) can be applied also in the field of regulation of optimal volume and structure of the (urban) transport.

The foreseen concept of use of tradable permits in the transport sector within the Green Deal initiative is far from being optimal. As already pointed out, it is not logical that minor polluters, such as air and waterborne transport, which are contributing each of about 15 % of total CO_2 emissions of transport sector are regulated before road transport, which contributes 72 % of total EU transport CO_2 emissions. Road transport will not be regulated until 2026. The analysis also suggests that foreseen tradable permits system for road transport (upstream concept, auctioning etc.) is far from being optimal and acceptable.

We consider our suggested solution of deployment of tradable emission permits in road transport separately for each motor vehicle category with flexible caps as very efficient, with significant impact also on the volume and structure of transport in general and consequently on the urban transport in particular in the functional urban areas. This holds good if national TP distribution system would be based on regional administrative units, which would have a good overview over the volume and needs of transport on the regional and urban level.

Implementation of suggested system bears with also financial consequences, which might make it less acceptable for the governments. Earning of fuel industry and its services (e.g., petrol stations services) will be decreased. Decreased will be also the budget revenues because of decreasing inflow of revenues from fuel taxes and excise duties. The positive effects are decreased and regulated transport volume, transport structure and CO_2 emissions according to the planned and socially acceptable levels.

We have decided for a solution based on tradable permits, not taxes because in our case the "cap" for certain category of motor vehicles, in particular in urban areas, is very important for conducting efficient transport and environmental policy. In general, as presented in Chapter 2 the decision about optimality of deployment of TP or taxes depends upon the structure of the market and the general conditions on the market concerned. This consideration might have been useful also for the EU Commission in the case of Green Deal. In some areas (e.g., air transport, waterborne transport) environmental taxes might have been more appropriate, in particular if we, besides other arguments, consider also transaction costs of TP [55].

The EU commission has foreseen 260 billion additional annual investments during the next ten years for Green Deal, which will have questionable economic effects according to our belief. (On top on the existing 750 billion of post Covid-19 recovery costs). The consequences will be increased costs of transport services, energy, and other materials, which might ruin European competitiveness on the world market. We must also keep in mind that European CO_2 Emissions represent only 9 % of global CO_2 emissions. Is it realistic to expect that decarbonisation of the EU will solve the world problem of climate change?

REFERENCES

[1] Francis M. Bator (1958). "The Anatomy of Market Failure," Quarterly Journal of Economics, 72(3) pp. 351–79 (press +).

[2] John O. Ledyard (2008). "market failure," The New Palgrave Dictionary of Economics, 2nd Ed. Abstract.

[3] Johnson, Norris O. (1937). The Pareto Law. Review of Economic Statistics 19:20-26.

[4] Maureen L.Cropper, Walace L. Oates, 1992, Environmental Economics : A Survey, Journal of Economic Literature page 675-740.

[5] Fisher, A. C. 1981. Resource and environmental economics. Cambridge University Press, Cambridge, UK.

[6] Coase Roland H, (1960). The problem of social cost, J. Law Econ. Page 1-44.

[7] Pigou, A.C. (1920). The Economics of Welfare, London: Macmillan.

[8] Crocker, T.D. (1966). The structuring of atmospheric pollution control systems, In: The Economics of Air Pollution, New York.

[9] Norton Dales, J. (1968). Pollution, property and prices, Toronto: University Press.

[10] Montgomery, W.D. (1972). Markets in Licenses and Efficient Pollution Control Programs, Journal of Economic Theory 5(4): 395-418.

[11] Mc. Kensie and Trucker (1992). Trading pollution permits, An environmental optimal.

[12] Winkelman, S., Hargrave, T., Vanderlan, C. (2000). Transportation and domestic greenhouse gas emission trading. Center for Clean Air Policy, Washington DC. April 2000, 32 p.

[13] Weimer, D., Vining, A.R., (2004). Policy Analysis: Concepts and Practice. Prentice Hall.

[14] Intergovernmental Panel on Climate Change (2007a). Summary for Policymakers, in: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt K B, Tignor M and Miller H L (eds.) Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge: Cambridge University Press.

[15] Intergovernmental Panel on Climate Change (2007b). Technical Summary, in: Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt K B, Tignor M and Miller H L (eds.) Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge: Cambridge University Press.

[16] EC, European Green Deal: Commission proposes transformation of EU economy and society to meet climate ambitions (https://ec.europa.eu/commission/presscorner/detail/en/ip_21_3541).

[17] EC, A European Green Deal - Striving to be the first climate-neutral continent (https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en).

[18] EC, COM(2021) 550 final; 'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality.

[19] EC, COM(2021) 551 final (https://ec.europa.eu/info/sites/default/files/revision-eu-ets_with-annex_en_0.pdf).

[20] EC, Questions and Answers - Emissions Trading – Putting a Price on carbon (https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3542).

[21] EC, Emissions cap and allowances (https://ec.europa.eu/clima/policies/ets/cap_en).

[22] EC, Revision of the EU Emission Trading System for Aviation (https://ec.europa.eu/info/sites/default/files/revision_of_the_eu_emission_trading_system_for_aviation.pdf).

[23] EC, COM(2021) 552 final (https://ec.europa.eu/info/files/revision-eu-emission-trading-system-aviation_en).

[24] EC, COM(2021) 567 final (https://ec.europa.eu/info/sites/default/files/notification-carbon-offsetting-and-reduction-scheme-international-aviation-corsia_en.pdf).

[25] EC, COM(2021) 567 final (https://ec.europa.eu/info/sites/default/files/notification-carbon-offsetting-and-reduction-scheme-international-aviation-corsia_en.pdf).

[26] Safety4Sea, Parliament greenlights inclusion of maritime transport in EU Emissions Trading System (https://safety4sea.com/parliament-greenlights-inclusion-of-maritime-transport-in-eu-emissions-trading-system/?__cf_chl_jschl_tk__=pmd_Ii260P83vjkPKayWJKXxpVSQF3kpG).

[27] EC, Reducing emissions from the shipping sector (https://ec.europa.eu/clima/eu-action/transport-emissions/reducing-emissions-shipping-sector_en).

[28] EC, EU Emissions Trading System (EU ETS) (https://ec.europa.eu/clima/policies/ets_en#Carbon).

[29] PwC (2020). Financing the European Green Deal - Sustainability - Themes - Insights and publications.

[30] Parry, Ian W.H., Roberton C. Williams, and Lawrence H. Goulder. (1999). When Can Carbon Abatement Policies Increase Welfare? The Fundamental Role of Distorted Factor Markets. Journal of Environmental Economics and Management 37:52–84.

[31] Ian W.H. Parry (2002), Are Tradable Emissions Permits a Good Idea? November 2002, Issues Brief 02–33.

[32] Investing_climate_neutral_circular_economy_en.pdf. Financing Green Deal, A tool box for implementing Green Deal QG0221601ENN.en (4).pdf.

[33] EC (2007), Green Paper "Towards a new culture for urban mobility Mobility" (https://ec.europa.eu/commission/presscorner/detail/en/MEMO_07_379).

[34] EC, COM(2019) 640 final (https://ec.europa.eu/info/sites/default/files/european-green-deal-communication_en.pdf).

[35] EC, COM/2020/789 final, Sustainable and Smart Mobility Strategy – putting European transport on track for the future (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX %3A52020DC0789).

[36] EC, SWD/2021/0047 final, EVALUATION of the 2013 Urban Mobility Package (https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:52021SC0047).

[37] EC, Sustainable Urban Mobility: European Policy, Practice and Solutions (https://civitas.eu/resources/sustainable-urban-mobility-european-policy-practice-and-solutions).

[38] EC, EVALUATION of the 2013 Urban mobility package SWD/2021/0048 final (https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:52021SC0048).

[39] ELTIS (2021). Urban Mobility Package: Evaluation confirms the need to adapt EU urban mobility policy in order to contribute to the increasingly ambitious climate, digital and societal objectives of the EU (https://www.eltis.org/in-brief/news/urban-mobility-package-evaluation-confirms-need-adapt-eu-urban-mobility-policy-order).

[40] Fleming, D., (1997). Tradable quotas: Using information technology to cap national carbon emissions, European Environment, Vol. 7, pp. 139-148.

[41] Verhoef, E., Nijkamp, P., and Rietveld, P., (1997). Tradeable permits: Their potential in the regulation of road transport externalities, Environment and Planning B: Planning and Design, Volume 24, pp. 527-548.

[42] Bozicnik S., Mulej, M., (2010). Corporate social responsibility and requisite holism - supported by tradable permits. Systems research and behavioral science: the official journal of the International Federation for Systems Research. 2010, vol. 27, iss. 1, page. 23-35.

[43] Fawcett, T., (2004). Carbon rationing and personal energy use, Energy and Environment, Vol. 15, No. 6, pp. 1067-1084.

[44] Raux, C., and Marlot, G., (2005). A System of Tradable CO_2 Permits Applied to Fuel Consumption by Motorists, Transport Policy, Vol. 12, No. 3, pp. 255-265.

[45] Raux, C., and Marlot, G., (2005). A System of Tradable CO_2 Permits Applied to Fuel Consumption by Motorists, Transport Policy, Vol. 12, No. 3, pp. 255-265.

[46] Verhoef, E., Nijkamp, P. and Rietveld, P., (1997). Tradeable permits: Their potential in the regulation of road transport externalities, Environment and Planning B: Planning and Design, Volume 24, pp. 527-548.

[47] Winkleman, S., Hargrave, T., and Vanderlan, C., (2000). Transportation and Domestic Greenhouse Gas Emissions Trading, Centre for Clean Air Policy.

[48] Grubb, M., (1990). Energy Policies and the Greenhouse Effect. Volume I: Policy Appraisal.

[49] Felsdstein, M., (2006). Tradeable gasoline rights, the Wall Street Journal, June 5.

[50] Hahn, R. W., (1984). Market power and transferable property rights, Quarterly Journal of Economics, Vol. 99, No. 4, pp. 753-765.

[51] Ahlheim, M., and Schneider, F., (2002). Allowing for Household Preferences in Emission Trading: A Contribution to the Climate Policy Debate, Environmental and Resource Economics, Vol. 21, pp. 317-342.

[52] Raux, C., and Marlot, G., (2005). A System of Tradable CO_2 Permits Applied to Fuel Consumption by Motorists, Transport Policy, Vol. 12, No. 3, pp. 255-265.

[53] Wadud, Z., (2008), Personal tradable carbon permits for road transport: Heterogeneity of demand responses and distributional analysis, PhD thesis, University of Leeds.

[54] Winkelman, S., Hargrave, T., Vanderlan, C, (2000). Transportation and domestic greenhouse gas emission trading. Center for Clean Air Policy, Washington DC. April 2000, 32 p.

[55] Stavins, R., (1995). Transaction Costs and Tradable Permits, Journal of Environmental Economics and Management, Vol. 29, pp. 133-148.

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

The Mobility Compass: A New Way to Find Relevant Researchers and Cooperation Partners in Europe

MATTHIAS FUCHS, STEFAN WOLFF

Abstract Interdisciplinary research groups are an important factor in the development of sustainable solutions in the transport and mobility sector. However, due to the numerous research disciplines and platforms that often require adequate care, identifying relevant network partners can involve a great deal of effort. The Mobility Compass (www.mobility-compass.eu) Therefore, serves to support efficient networking and to provide a better view of the research landscape. First, the objective of the development of this new subject-related current research information system is described. Based on this, the individual functions and exemplary purposes of the Mobility Compass are shown. Then, the technical background of the tool is briefly presented and it is explained how researchers can contribute to the content. The text then concludes with an outlook on the next steps of the development.

Keywords: • Mobility Research • Transport Research c Interdisciplinary Networking • Current Research Information System • VIVO

CORRESPONDENCE ADDRESS: Matthias Fuchs (https://orcid.org/0000-0003-3365-3158), Stefan Wolff (https://orcid.org/0000-0003-0015-9671), Saxon State and University Library Dresden, Zellescher Weg 18, 01069 Dresden, Germany, e-mail: matthias.fuchs@slub-dresden.de, e-mail: stefan.wolff@slub-dresden.de

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

MOTIVATION AND GOALS

Collaboration in interdisciplinary teams and knowledge of the current research landscape are essential success factors for the development of competitive and sustainable solutions. This applies in particular to research in the field of mobility and transport research with its numerous and interrelated disciplines [2]. The European Commission also emphasized the importance of a holistic view and systemic involvement of all stakeholders for research and innovation in the transport sector [1]. One aspect here is certainly also the improved networking of international research, which will thus in turn lead to an increase in the overall efficiency of mobility and transport research. Only in this way can this sector make its contribution to achieving the goals of the Green Deal. At the same time, better networking is of course also in the interest of each individual researcher in terms of personal development and success. After all, it forms the basis for the successful acquisition of research funding and for increasing the quality and acceptance of research by integrating expertise from outside the field.

But before the interdisciplinary exchange, the relevant disciplines and their significant researchers must first be identified. However, there are various challenges associated with this:

- Different terminologies: Different terms are used in different disciplines for the same or similar concepts. In addition, there are national language peculiarities.
- Numerous platforms: Information about the work of researchers is distributed across various platforms, such as institutional websites, ORCID, ResearchGate or Academia.edu.
- Profile maintenance: Numerous platforms also mean numerous profiles, which must be actively maintained, since otherwise no current information is displayed. Thereby additional work for the researcher arises.

These challenges can make networking, especially the search for and identification of new partners very time-consuming and represent a costly factor. All the more so when researchers want to work in a field that is new to them or have limited knowledge and no network partners. However, it can be precisely such cases, where collaboration with the right partners can lead to a career boost.

Against the background of the importance of mobility and transport research and as a substantial contribution to effective networking and interdisciplinary collaboration, a new and free to use tool is being developed within the DFG-funded project FID move21[2]: the Mobility Compass (www.mobility-compass.eu).

---

2 FID move is the acronym for "Fachinformationsdienst Mobilitäts- und Verkehrsforschung" (Specialised Information Service Mobility and Transport Research). In this project, the Saxon State and University Library Dresden (https://ror.org/03wf51b65) and the German National Library of Science and Technology - Leibniz Information Centre for Science and Technology and University Library Hannover (https:// ror.org/04aj4c181) have been working together since 2018 to develop services to support mobility and transport research. The project is founded by the Deutsche Forschungsgemeinschaft (DFG).

TOWARDS MORE INTERDISCIPLINARITY WITH THE MOBILITY COMPASS

The Mobility Compass is a non-commercial tool to effectively and easily find interesting researchers in mobility and transport research in Europe and at the same time to get an insight into the existing research landscape. For this purpose, scientific publications, such as journal articles or research reports, are collected and indexed from various databases. The Mobility Compass is not a classical catalog or a system for ranking people. It is a subject-oriented research information system. The information in the Mobility Compass is linked together and made available via innovative search entry points. Hereinafter, the various search options are briefly explained using exemplary areas of application.

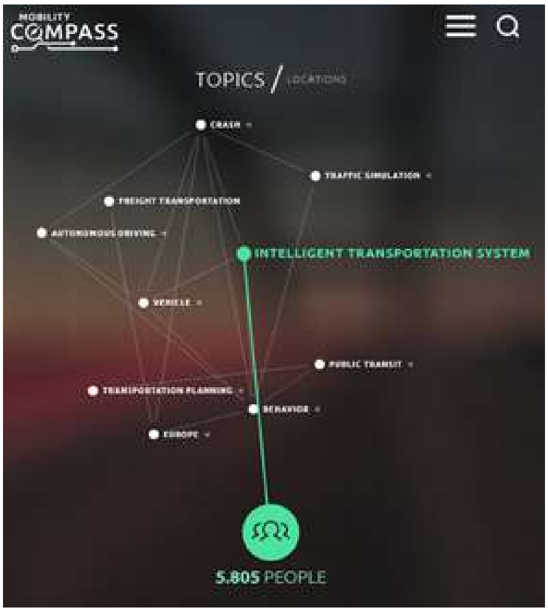
Find your Expert

In order to find suitable network partners, the user has three possible entry points into the search:

TOPICS: The topic graph shows a variety of the topics contained in the current selection. By clicking on a topic, it is added to the filter criteria and the graph is adjusted accordingly (Fig. 1).

LOCATIONS: The map shows all persons for, which location information is available so that a selection of researchers in individual cities or countries is possible.

Figure 1. Topic Graph with one selected topic



Source: www.mobility-compass.eu (mobile view)

SEARCH FIELD: In addition to TOPICS and LOCATIONS, the SEARCH FIELD can also filter by other criteria, such as the names or the institution of the researchers.

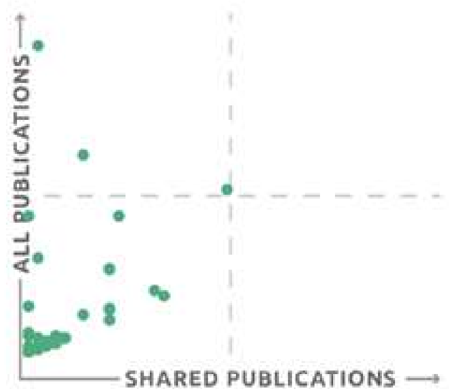
Entry via the topic graph is especially convenient as it offers the possibility to create a suitable search section exploratively and quickly. All search entries are mutually dependent and influence the selection of relevant people. By clicking on the green people-button, the corresponding people are listed and can be sorted by different criteria like number of co-authors or citations.

Selecting a person opens their dashboard. It gives a compact overview of all information available on this researcher in the Mobility Compass, e.g., the linked topics, output and the research network.

See Research Networks

A researcher's dashboard contains a lot of information about his research network. If location information is available, this can be used to estimate locations of work or publication based on a small overview map. The 4-panel-chart below provides information on the number of publications by his co-authors and the proportion of joint publications. This is an indicator of the relative extent of collaboration with active experts in the field of mobility and transport research (Fig. 2). This presentation is completed by listing the co-authors. Thus, the user has all the information at a glance and can assess the relevance of the person to their own needs.

Figure 2. 4-Panel-chart to estimate the collaboration with single co-authors



Source: www.mobility-compass.eu

Get a View on Topic Connections

The Mobility Compass is not only used to search for suitable network partners, but also to gain insight into the connections between the various research fields of mobility and transport research. As a visual support for this purpose, the individual topics are related to each other in the topic graph: topics that are frequently researched in combination are linked by a line. Since the graph is built up and aligned depending on the selected search criteria, topics that are often related to each other can not only be identified and serve as an incentive for explorative search, but also to find focal points in the research landscape on the other hand. In addition, the local distribution of researchers on the map is also a starting point for assessing regional research activities.

A BRIEF LOOK INTO THE MACHINE ROOM

The Mobility Compass is based on the open-source software VIVO. This is a research information system with a large developer community. Therefore, the Mobility Compass can benefit from the development progress. At the same time, its own development results are made available to the community. This also facilitates the transfer and reuse of the Compass approach to other disciplines and communities.

The Mobility Compass relies on the principles of Linked Open Data and Semantic Web. This means that the heterogeneous data from the various source systems is described in a structured way using a data schema (ontology) that is machinereadable and predefined across all systems. The data aggregated in the Mobility Compass can thus be more easily integrated into other systems.

The dataset includes subject-specific extracts from BASE, Springer Nature, ORCID and the Global Research Identifier Database, among others.[2] The publication data loaded from these sources is indexed with the help of an extensive, multilingual, subject-specific, and hierarchically structured dictionary, a thesaurus. This thesaurus also addresses the problem of different semantics between the disciplines and is constantly being improved and adapted [3].[3]

YOUR DATA IN THE MOBILITY COMPASS

The Mobility Compass aims to show all scientists who are actively involved in mobility and transport research. Due to the open and low-threshold applicability of the tool and in order to avoid an additional maintenance effort for the scientists, the possibility of data processing in the Mobility Compass was omitted. Instead, the Mobility Compass uses existing databases. Thus, the quality and quantity of information on scientists depends largely on the availability and accessibility of external data sources, as well as the language of the research.[4] If the data does not meet your expectations, there are two options:

2 A listing of the databases can be found at https://www.mobility-compass.eu/#view=content&page=about.
3 A deeper insight into the technical specifications and functionalities of the tool is provided in the article The Mobility Compass: A VIVO-based approach for exploring interdisciplinary research networks [3] under https://doi.org/10.5282/o-bib/5642.
4 Preferred in English, currently also possible in German.

- ORCID iD: By connecting ORCID, we can directly integrate your publicly available data. In this case, simply let us know your ORCID iD.
- Data-tip: Tell us a data source and we will check if the integration is possible.

In both cases, please contact: contact@mobility-compass.eu.

CONCLUSION AND OUTLOOK

The Mobility Compass provides a new and more efficient way to find interesting network partners in the fields of mobility and transport research. The possible applications range from the search for partners for research projects and the further development of one's own research focus to the search for speakers for a conference or reviewers for journals or funding applications. Especially in research fields with little or no previous contacts, the tool's transparency provides a very good basis for effective networking and can thus contribute to the necessary interdisciplinary cooperation in the transport sector, for example, on its way to implementing the Green Deal.

The Mobility Compass is constantly being further developed for this purpose. In addition to connecting further databases, the development team at Saxon State and University Library Dresden is also working on other features. This includes improving content indexing using AI. The plan is also to develop a widget for embedding the Mobility Compass into other websites. All of this only works in close coordination with the research community. In this respect, the development team is looking forward to your feedback on the tool at www.mobility-compass.eu.

REFERENCES

[1] European Commission (2021). Sustainable and Smart Mobility Strategy – putting European transport on track for the future. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. url: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0789.

[2] Rau, H., & Scheiner, J. (2020). Sustainable Mobility: Interdisciplinary Approaches. In Sustainability 12(23). doi: https://doi.org/10.3390/su12239995.

[3] Wolff, S., & Fuchs, M., Rutschke, M. (2021). The Mobility Compass: a VIVObased approach for exploring interdisciplinary research networks. O-Bib. Das Offene Bibliotheksjournal / VDB, 8(1), 1–9. doi: https://doi.org/10.5282/obib/5642.

Smart Parking Management System: Architecture Design and Technologies Issues

DANIELA KOLTOVSKA NECHOSKA, SONJA CHALAMANI,TOME DIMOVSKI, ILIJA HRISTOSKI

Abstract Smart parking solutions are one of the most popular systems and devices in smart cities due to the availability to detect parking space in real-time, reducing fuel consumption, and traffic emissions. Various types of smart parking systems, such as parking guidance systems, smart payment systems, e-parking, etc., have been deployed worldwide. The experiences of Intelligent transport system application in the Republic of North Macedonia are modest and most of the deployed systems and services are from the area of Real- time Travel Information Service and Urban Traffic Management. The problem issues related to parking demands are present and they have a significant impact on traffic congestion on the city's road network. Specific objectives of the research are to identify and access the most promising, pertinent technology and systems for the design of an integrated, highly functional solution for a smart parking management system for the Macedonian capital city. To meet these objectives, a two-phase research approach has been suggested. In the first phase a comprehensive approach that identifies analysis and selection of smart parking infrastructure and its architecture design are presented. In the second stage development of the new attractive and effective web application (as part of hardware and software components of the proposed system) will be presented. As a crucial component of the overall traffic system, the proposed smart parking management system will play an important tool for municipality authorities in providing effective digital services that will improve traffic customer's needs.

Keywords: • Intelligent Transport Systems (ITS) • Smart Parking • Systems and Services • Architecture Design and Technology

CORRESPONDENCE ADDRESS: Daniela Koltovska Nechoska, PhD, Sonja Chalamani, PhD, St. Kliment Ohridski University – Bitola, Faculty of Technical Sciences, Department of Traffic and Transport Boulevard 1st of May B.B., Bitola 7000, Republic of North Macedonia, e-mail: daniela.koltovska@uklo.edu.mk, e-mail: sonja.chalamani@uklo.edu.mk, Tome Dimovski, PhD, St. Kliment Ohridski University – Bitola, Faculty of Information and Communication Technologies Boulevard 1st of May B.B., Bitola 7000, Republic of North Macedonia, e-mail: tome.dimovski@uklo.edu.mk; Ilija Hristoski, PhD, St. Kliment Ohridski University – Bitola, Faculty of Economics Boulevard 1st of May B.B., Bitola 7000, Republic of North Macedonia e-mail: ilija.hristoski@uklo.edu.mk

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

The concept of a smart city refers to the application of information and communication technology for the more efficient functioning of the city services in the provision of public services, to raise the quality of life of citizens, productivity and efficiency, as well as achieve savings.

A smart city is also defined as a city that meets all the needs of its citizens fully and efficiently following the goals set by local, national, and international sustainability standards. All services and needs, which are included in this concept are traffic management, education, air pollution, internet, and open data, smart health, smart homes and buildings, public safety, smart street lighting, smart parking, smart waste management, smart energy use, etc.

The metropolises, such as London, Paris, Berlin, New York, and others, have been at the top of the list of smart cities due to their innovative solutions and approaches that are integrated into various spheres of everyday life of citizens including the field of stationary traffic.

Why is parking an important segment in the overall concept of a smart city?

In many cities, more and more time is wasted while the vehicles "wander" on the roads looking for a free parking space. The location of the bigger, well- maintained parking lots is not always visibly marked, and then, there is a lack of information regarding their occupancy. Drivers often complain about increased travel time and that when they reach their destination, there is not an available parking space on the parking lot. Therefore, intensive work is being done to improve the process of parking management, which refers to the creation of various policies and programs in creating solutions for more efficient use of parking resources.

Effective programs in parking management in combination with advanced technologies could reduce travel time, as well as the time needed/wasted while looking for a parking space by up to 20-40 % compared to conventional solutions, providing an increase in economic, social, and environmental benefits.

In his comprehensive implementation guide, Littman states that the solutions that are proposed in the process of traffic management tend to be better than the conventional offer expansion (standard increase in the number of parking spaces) because the management supports more strategic goals, such as reduced development costs and increased availability, improved user options and quality of services, etc. [1].

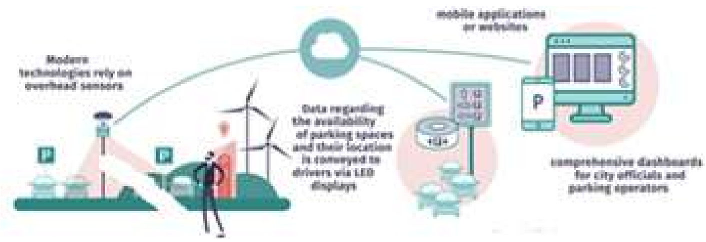
Lan and Shih in their research found that in areas, such as Los Angeles, vehicles looking for a parking space produce more than 730t carbon dioxide (CO_2) and consume about 47 000 liters of gas [2]. The inconvenience created by the need to find a free parking space, not only contributes to increased carbon dioxide emissions, but also causes drivers to park in unmarked parking zones, commit offenses for illegal parking, and most of all, further affect the creation of traffic congestion. Currently, there are numerous parking applications (EasyPark, BestParking, ParkingPanda, Parkopedia, Parclick, ParkMan, Parkomat, PayDo, SplitParking) offering different services.

In addition to the mobile application, as part of the Intelligent Transportation System (ITS) and the Advanced Traveler Information System (ATIS), we can also mention the Parking Guidance and Information (PGI) system. Countries that have implemented the Parking Guidance and Information system in their major cities are Finland, France, Japan, the Netherlands, Germany, Norway, USA, Sweden, UK.

The technology that is behind the smart parking systems can be fully automated, relying on hardware and software. Hardware, such as sensors and traffic signs with variable content, are set up locally – the first to monitor the occupancy of the parking lot and to collect data on the size of the available space and the number of parked vehicles, and the second to transmit parking information and navigation instructions to the free parking spaces.

Smart parking solutions enable city authorities and parking space owners' collection and analysis of input and output data including the availability status, parking duration, as well as parking revenue. In addition to real-time data, historical data and analysis are available to enable optimization of resource and staff planning (Fig. 1).

Figure 1. Parking solutions for Smart Cities



Source: Clever city; The Ultimate Guide to Smart City Parking 2021

Parking operators are expected to significantly increase their investment in the short term through the many benefits offered by smart technologies in this field. Parking operators are already spending more than 3 billion US$ a year on parking management globally, and these investments are projected to grow by 15 % annually by 2025.

Research problem

Skopje is the capital city of North Macedonia with approximately 600 000 inhabitants (one-third of the total population). The City of Skopje has been existing as a center of social life and carrier of the economy within the course of history. Available funding is very restricted and limited, and the space available has become a major obstacle.

The estimated number of people traveling daily to Skopje exceeds 90 000 passengers, causing significant traffic congestion [2]. The concentration of administrative, cultural, political, economic, and educational services further increases the problem not only with the dynamic but also the stationary traffic [2].

The imbalance between the need for parking and the capacity, the pressure on the traffic network from the local traffic due to circling around parking lots, are just a few of the identified problems. Therefore, the research will especially emphasize the need for a comprehensive analysis of parking in the city, to create solutions for the introduction of modern ways of parking management following the example of the European and the world's cities.

The main goal of the analyses and studies that have been done so far is the financial analysis of the toll system, and the intelligent and modern solutions to the parking problem are rarely mentioned by anyone.

In recent years, to assist the movement of people and goods, there has been a general call that "something has to be done".

Therefore, the idea of this research is to improve the management of stationary traffic and parking services by creating modern and "smart" solutions.

METHODOLOGY APPROACH

The city of Skopje is to be understood to work as an organic whole. Thus, we come to the term of sustainability. The management process rooted in sustainability should represent the interests of future generations.

The strategic objective is to develop a transportation system that maintains or improves human and ecosystem well-being together - not at the expense of the other.

Data analysis

According to the analysis of the current GUP (General Urban Plan) for Skopje, in the city center alone there is a need for 15 000 parking lots, but currently there are only 5 000. The prognosis given in the existing GUP is that in the center of the city, by 2020 the need for parking lots will be between 18 000 and 31 000. The existing GUP for Skopje does not provide an overview of the impact of parking on achieving the defined goals of traffic policy and its importance in choosing a means of transport in realizing daily mobility. The IDOM survey shows that the total number of declared parking lots in the City of Skopje (including parking garages and outdoor parking) is 165 914 lots, 103 371 of, which are private garages (Table 1) [3].

Table 1. Number of parking lots

Municipalities	Classification/parking lots				
	On street/ sidewalks	Parking zones	Private parking garage	Rented parking garages	Total
Center	3846	5934	6152	123	16 054
Kisela Voda	2795	4094	15336	86	22 310
Aerodrom	1177	15049	11727	73	28 026
Butel	986	1293	9950	0	12 230
Gjorche Petrov	1129	1760	14427	0	17 316
Karposh	6345	4216	14717	42	25 320
Chair	4635	3031	4824	45	12 535
Saraj	156	50	6903	50	7159
Gazi Baba	2119	3251	18395	0	23765
Shuto Orizari	182	77	939	0	1 198
Total	23370	38 755	103371	419	**165914**

Source: IDOM, 2009.

This shows that approximately 63 % of the parking lots are privately owned garages, 23 % are in the parking zones and 14 % are on the streets and the sidewalks.

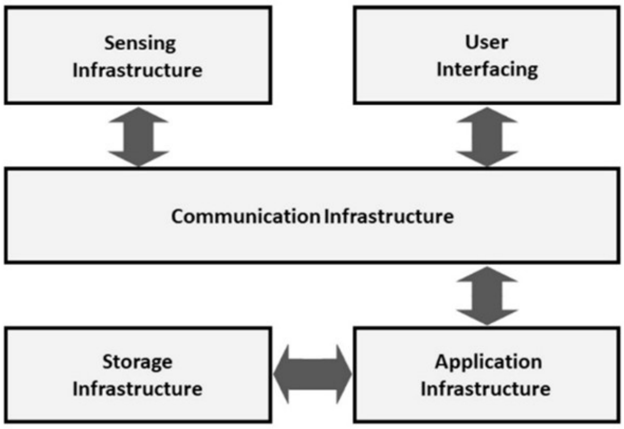
According to the analysis of the current GUP for Skopje, there is a need for 15 000 parking lots in the city center alone, and 5 000 of them have been registered. The forecasts given in the existing GUP are that by 2020 the demand for the Center will be from 18 000 to 31 000 parking lots.

The city authorities need to start solving the parking problems in a systematic approach. The parking policy has to meet the vision and add a vision that underscores prospective scientific, technological, and societal trends. Decisions on the development of the parking systems and activities involve a number of different actors (universities, governments, transport planners, businesses, citizens) and are influenced by factors related to environmental concerns, prices and quality of services, the availability of modal choices, travel time and the organization of economic and social life.

A model of a parking system

The model of the parking management system we propose is based on the implementation of five subsystems schematically depicted in Figure 2.

Figure 2. Parking solutions for Smart Cities



- Sensing Infrastructure

Sensing nodes are hardware sensors that collect parking location status data and send the acquired data to the application infrastructure using the communication infrastructure. Hardware sensors are installed on each parking location to detect the presence of a vehicle and to send the current status to the application infrastructure.

- Communication Infrastructure

The communication infrastructure is used to connect different constituent subsystems of the parking management system and to allow their mutual communication. The communication infrastructure can be built on different communication technologies, such as Wi-Fi, Bluetooth, infrared, NFC, etc.

- Application Infrastructure

The application infrastructure consists of software modules, a WebAPI (Application Programming Interface), and a Web-based application, used to monitor the status of parking locations, to display and share their status, as well as to access and store data to the storage infrastructure. Besides, it can be used for communication and data sharing with the user interface, Web-based or mobile applications, and also to fulfill other requirements of the parking management system, e.g., parking location reservations, payments, etc.

- Storage Infrastructure

The application infrastructure stores the data received from the sensing infrastructure to the storage infrastructure, which consists of an SQL database server and a file server that are both used for storing, processing, and analyzing data.

- User Interfacing

The user interface, as a part of the parking management system, consists of a user Web application, as well as a user mobile application, both using sensed information to provide parking information to drivers. It also offers an interface for making parking location reservations and payments. Both the user Web application and the user mobile application obtain the needed information from the application infrastructure.

CONCLUSIONS

If we point out that we live in the XXI century where the Internet, the comprehensive wireless coverage, smartphones, sensors, detectors, the continuous development in the information and communication technology is something normal and expected, then, the development and the application of the concept of "smart cities "is quite necessary.

Despite sufficient funding available, it is very likely that the problems still exist because the classical approach of building more roads and parkings makes it difficult for political, financial, social, and environmental reasons. Therefore, the challenge is to identify or develop ways and means to alleviate traffic-related problems without building new roads and parking lots. The two principal ways are through the application of innovative traffic management measures and the development of new smart parking technologies.

In this paper, a comprehensive approach that identifies analysis and selection of smart parking infrastructure and its architecture design are presented.

This paper proposes a new model of parking management system to satisfy the needs of the Macedonian capital city.

To implement the intelligent solution pattern, the local government is going to be a valuable partner in this research, since the local transport policy decision-makers should back up and direct smart solutions when sustainable urban development is their ultimate goal. Therefore, it is expected that the outcomes of the research will have a positive impact on the urban transport policy decision-makers who will put valuable input into the course of advanced traffic parking management system policy.

ACKNOWLEDGEMENT

The authors would like to express gratitude to Aleksandra Angelkovska Ognenovska for her collaboration during her master thesis and for this research.

REFERENCES

[1] Litman T. (2020). Parking Management – Comprehensive Implementation Guide, Victoria Transport Policy Institute.

[2] Nechoska K. D., Ivanjko, E., & Pavleski, D. (2018). Creating Infrastructure for Urban Mobility: Case Study of Skopje, PROMET – Traffic&Transportation, 30. (5), 429-443.

[3] Lan, K.C., & Shin, W.R. (2014). An intelligent driver location system for smart parking. Expert Systems with Applications., 41(5), 2443-2456.

[4] IDOM SA. Traffic and Transport System of the City of Skopje Study. Spain: IDOM, SA, 2011.

[5] Melnyk, P., Djahe;, S., & Abdesselam N.F. (2019) Towards a Smart Parking Management System for Smart Cities 5th IEEE International Smart Cities Conference 'ISC2 2019 (pp. 542-546) Casablanca, Morocco.

[6] Biyik, C., Allam, Z., Pieri, G., Moroni, D., O'Fraifer, M., O'Connell, E., Olariu, S., & Khalid, M (2021). Smart Parking Systems: Reviewing the Literature, Architecture and Ways Forward. Smart Cities, 4, 623–642.

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Improving the Attractiveness of MaaS – The European Survey on Public Attitude

MICHAL MATOWICKI, PAVLA PECHERKOVA, ONDREJ PRIBYL

Abstract In the 21st century, cities around the world are dealing with the increasing numbers of vehicles, causing not only frequent congestions, but also a long-term parking problems and smog in urban areas. Traditional means of shared travel mode like public transport or taxi, are often either not flexible enough, provide low comfort or are too expensive. In this paper authors present results of a European research based on the Stated Preference and Choice survey. Over 6000 samples were collected in the United Kingdom, Germany, Czech Republic and Poland. Respondents from urban areas provided insight on sought-after solutions and features of mobility-as-a-service (MaaS). Based on the survey results, the analysis of potential MaaS user preferences and frame for User Behavior Model was established for further research on MaaS attractiveness improvement. Statistical and dependencies analysis were applied to analyze in detail responses of users who were identified in our survey as undecided and neutral towards MaaS.

Keywords: • Mobility as a Service (MaaS) • Undecided Users • Statistical analysis • Survey

CORRESPONDENCE ADDRESS: Michal Matowicki, PhD, Pavla Pecherkova, PhD, Ondrej Pribyl, PhD, Czech Technical University, Na Florenci 25, Prague, Czech Republic, e-mail: matowmic@cvut.cz

 ISBN 978-961-95633-0-4

INTRODUCTION

Along with ambitious goals for reduction of climate change and tackling world urbanization, many steps are taken to tackle this phenomenon while keeping our cities and way of living sustainable. Such steps are taken also in transportation area, where alternative fuels propelling vehicles are introduced, as well as promotion of shared-economy services. The first propagator of MaaS is Sampo Hietanen who presented his ideas at Finnish Science Centre Heureka in 2014 [1]. Soon his ideas were supported by companies like BlaBlaCar, Uber and UbiGo who helped to develop the concept of MaaS as a feasible future of urban transport.

The core idea of Mobility as a Service is to see mobility through the needs of the customers and through the service layer [2]. Hence one of the foundations of MaaS being easy to use and seamless travel service incorporating different provides (transportations companies) using one enabler (usually an MaaS application incorporating different transport services into one).

This concept of sustainable and convenient to use transport option was adopted in numerous cities around the world already. The project MaaS_together founded by European Innovation Council (EIC) focused on identification and standardization of MaaS components and services, as well as on modelling the adoption of MaaS services by various potential users. Together with information gathered by the Smart City – Smart Region – Smart Community (http://smart-mateq.cz/projekty/projekty-smart/smart-iti/) a Czech national project focusing on travel behaviour research of the citizens of the Usti and Labem region, an in depth analysis of the acquired data was performed. A European survey in 4 countries (Czech Republic, UK, Germany and Poland) was performed, with total collected sample of over 6000 answers. In this paper, authors focus on survey respondents who were identified as the potential undecided users, to find out their opinions and potential of convincing them into MaaS use in future installed systems. This way the traveler behavior of specific commuters was identified and provided an important insight for future business planners and service providers and enablers.

LITERATURE REVIEW

To ensure fair and sustainable mobility, new solutions should not be offered as independent services, they need to be planned, designed and implemented in an integrated way. To enable a symbiotic design and integration of new offerings, it will be important to understand and to quantify the value being created through the system components for the relevant stakeholders – the citizens (and thus as users), the society, but also for the mobility providers [3].

Nevertheless, the Mobility as a Service definition is yet not fully standardized and different actors and institutions describe it with more, or less, detail allowing for the inclusion of more, or less, services. In common agreement is the fact that MaaS requires the usage of a single interface that links the users' needs with matching mobility services that provide a door-to-door solution. Guidon et al. [4] further expand MaaS definition as being a service that not only integrates mobility services but also bundles them in packages that better match supply to demand with the intention to make multimodal trips more efficient. Caiati et al. [5] includes demand responsive transportation as a core of MaaS, providing users with higher levels of flexibility and comfort.

When it comes to the user, which is the focus of this research, the current state-of-the-art shows different focus and priorities. Two important topics are the identification of user types and profiling, and users' preferences and intention to use [6][7][8]. Nevertheless, to the best of our knowledge, the body of literature focused on investigating different categories of commuters with respect to MaaS is short. This is precisely why in our study we focus on potential MaaS users as yet undecided in their feelings toward MaaS.

The intended behavior of using is a well-established concept and defined as a measure of the strength of one's intention to act with a determined behavior [9]. Behavioral intention, influenced by attitude, is viewed as a summary consideration of the pros and cons involved in decisions that lead into the performance of a certain behavior; here the usage of MaaS [10]. Thus, one can conclude that the intention to, and use are highly correlated.

Jung et al. [11] examines how perceived trust, perceived ease of use, and perceived usefulness play a role on MaaS acceptance with the focus on the MaaS application based on previous work developed around Information Technology [12]. Yet, the literature does not provide a clear picture of relevant psychological profile, such as environmental views, shared economy affinity and social influence of travelling on multimodal mobility, particularly on the topic of MaaS, which could give leverage to providers to attract more users. Caiati et al. [13] show that the share of individuals (based on a survey with 1078 respondents) willing to adopt MaaS when it comes to its prime offer (i.~e. bundling of services) is still low. Mainly, MaaS adoption is found to be driven by social influence and the core preferences based on flat rates for public transit, while traditional mobility services, such as taxi and rental cars are of low preference.

APPLIED METHODS

To investigate the potential MaaS drivers, an international computer assisted interview through online panels was conducted. The survey was prepared in English language and then translated into Czech, Polish and German languages. The survey was conducted over period of 2 months and from each country over 1600 hundred samples were collected. The structure of the questionnaire comprised five main topic blocks (A to E), enclosed by an introduction and conclusion. In this study we focus on information gathered from block A, which asked about latent variables of personality, and C, which was a stated preference question regarding MaaS. Constructs that were already used in the context of acceptance research and detected as influencing factors in mobility behavior served as a basis to select the right scales and items.

Due to the large number of items, the questions were divided into three groups (groups A1 to A3) and placed at different points in the questionnaire. This process should counteract the fatigue effect, as well as the habitualized response behavior. The other thematic blocks of the questionnaire covered topics regarding MaaS app requirements, mobility package preference, a Stated-Preference design and the willingness to pay. However, the focus of the paper is on the analysis of user-side characteristics of potential MaaS users, which is why the analysis within the paper is concentrated on the latent variables.

The field period of the survey covered ten days, from October 16, 2020 to October 26, 2020. At this point, it needs to be reflected that the survey period fell into the worldwide pandemic situation caused by Covid-19, which could have led to a change in mobility and thus response behavior. This must be considered when interpreting the results.

Collected data were then analyzed with descriptive statistical tools and Pearson's chi-squared tests (χ2). A Chi-square test is a hypothesis testing method developed by Karl Pearson in 1900 [14]. In this study a Chi-square test involve checking if observed frequencies in undecided respondent category match expected frequencies of total collected sample from the survey (see equation 1).

$$\chi^2 = \sum_{i-1}^{n} \frac{(O_i - E_i)^2}{E_i} \qquad (1)$$

Where:

χ^2 – is Pearson test statistic

O_i – is the number of observations of type i

n – is total number of observations

E_i – is the expected count of type i, asserted with the numm hypothesis

The first step included testing whether the ratio of the occurrence of neutral vs others responds in the given category does or does not differ from one another. In other words, taking for example country of origin category, whether the ratio of neutral vs decided respondents is the same in all countries participating in the survey. Since large data sample was analyzed the significance criterion of the $Pvalue$ = 0,01 was set. This was followed by an analysis of the respondent answers regarding the MaaS properties and characteristics with respect to their sociodemographic information. This approached allowed for evaluation of the most valued properties of MaaS among undecided users, which is valuable knowledge for business and policy makers. To visually represent results, techniques like box plot and forest plot were used.

THE ANALYSIS OF POTENTIAL USERS

The main subject of interest in our study was identification and analysis of the undecided users. For this purpose, respondents whose stand toward the use of MaaS was neither positive or negative were identified and analyzed. The responses for 5 Stated Preference questions provided in block C of our survey were constructed as 1 through 5 Likert scale questions. For the purpose of this study, undecided users were defined as respondents who at least 4 of five times responded with value 3 (I do not know, I am not sure, etc.). In order to provide context for this sample, we provide also comparison with overall of collected responses.

The survey results

In the collected sample, there were 1232 of undecided respondents (out of total of 5173 collected surveys). This represents more than 23,8 % of sample population, which is rather a lot and provides very interesting research area. Proportion of undecided respondents among the whole sample in individual countries is provided in Table 1.

In our quotas, 51 % of the participants are female, and 49 % are male. On average, participants are 38,8 years old (SD=12,93). The highest proportion of respondents

Table 1. Proportion of undecided respondents in whole sample for each country of origin

Country	Undecided	Others
Czech Republic	350	1246
Germany	285	1322
Poland	299	1302
United Kingdom	298	1303

Hence with the $Pvalue$ of 0,0015 we can state that there is no significant difference in proportion of undecided respondents among different countries. Similarly, the gender of the respondents proved to be insignificant in regard to their standing toward MaaS use. Overall characteristics of the collected sample and the comparison of undecided drivers with overall respondents' opinions are summarized in Table 2.

Table 2. Basic characteristics of users in collected survey sample

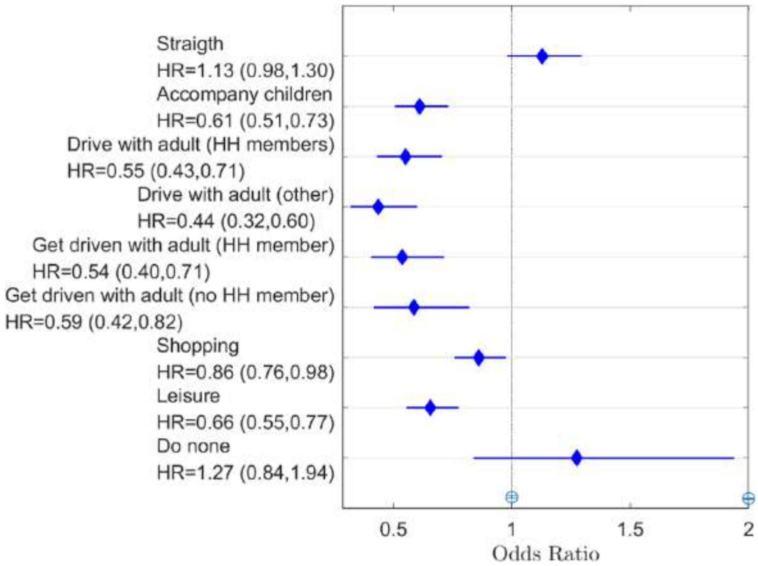
Variable	Overall	Undecided respondents
Age (min, max)	38,76 (18, 74)	42,27 (18,66)
Gender (male, female)	49 % M 51 % F	48 % 52 %
Household size		
1 person	20 %	23 %
2 persons	30 %	32 %
3 persons	24 %	22 %
4 persons	19 %	17 %
5+ persons	7 %	6 %
Household Income		
Level 1	7 %	10 %
Level 2	21 %	22 %
Level 3	38 %	39 %
Level 4	18 %	17 %
Level 5	12 %	9 %
Level 6	4 %	3 %
Residence area		
Village	-	-
Small town	-	-
Town	19 %	20 %
City	27 %	26 %
Large City	28 %	27 %
Megacity	16 %	17 %
Metropolis	10 %	10 %
Profession		
In training	9 %	6 %
Full-time employee	62 %	62 %
Part-time employee	12 %	13 %
Senior executive	3 %	3 %
Self-employed	6 %	7 %
Homemaker	2 %	2 %
Retired	2 %	3 %
Seeking work	3 %	3 %
Other	1 %	1 %

work full-time (62 %) and their household income varies from 799 to 2399 euros monthly. The most common household size is 2 persons (30 %), followed by 3 (24 %). About one in five households are single person. A large proportion of respondents live in a large city (28 %) or city (27 %) with 100 000 to 1 million inhabitants.

The undecided users

According to Broeg and O'Fallon [15][16], the choice of preferred travel mode is strongly influenced by our constrains during discussed travel. E.g, large households with multiple children and/or activities on the way from/to work are less potent for use of alternative travel mode, since high flexibility and reliability on transport mode together with transportation capacity are a must in their cases. This issue was investigated also in our data. With the significance of $p < 0,01$ it was demonstrated that people travelling with at least one from the variety of constrains are much more likely to have strong opinion on their possible intention of using MaaS. These results are presented in Figure 1 where vertical axis represents different constrains a respondent has on his/her way to/from work, and horizontal axis represents an odds ratio of having clear opinion on the potential of MaaS use by this respondent. The blue lines represent the confidence interval for these odds (depicted also on the vertical axis in the brackets). As presented, the odds of being undecided on MaaS use decrease significantly when respondent travels with another household member or adult not being member of common household – just as predicted by O'Fallon [16].

Figure 1. The forest plot of odds ratio decoded vs undecided respondent base on constraints during travel

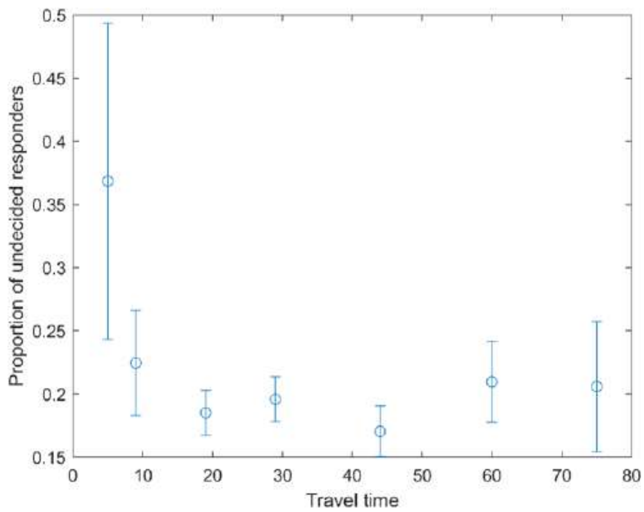


Next investigated property of the respondents' travel was its length in time units in this question, respondents were to answer the typical length of their travel to/from work. The results show that the longer the travel time to work is, the more decided respondent becomes regarding MaaS use. In other words, the least decided users (and thus vulnerable to MaaS advertising policies) are the users who travel relatively shortly every day (see Table 2 and Figure 2).

Table 3. Proportion of undecided respondents in whole sample depending on their work travel time

Proportion of undecided respondents	Travel time
0,583	Less than 5 minutes
0,289	5-10 minutes
0,227	10-20 minutes
0,243	20-30 minutes
0,205	3-45 minutes
0,265	45-60 minutes
0,259	75 or more minutes

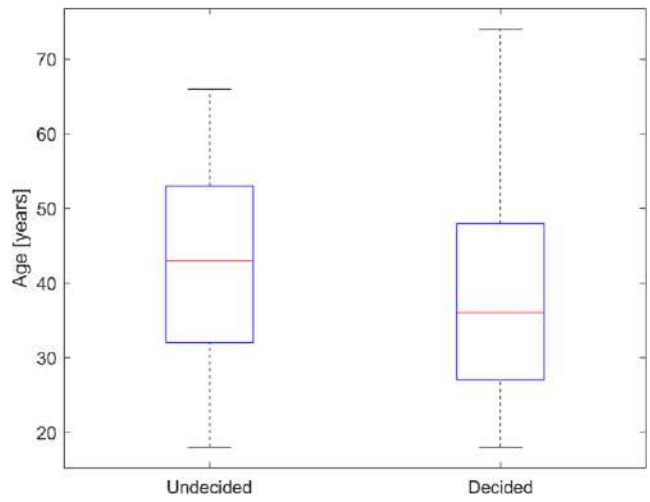
Figure 2. Odds ratio undecided respondent based on their self-estimated travel time to work



Finally, the age of the respondents was tested. In this test, we compared the average and median of neutral respondents (category 1) and decided ones (category 2).

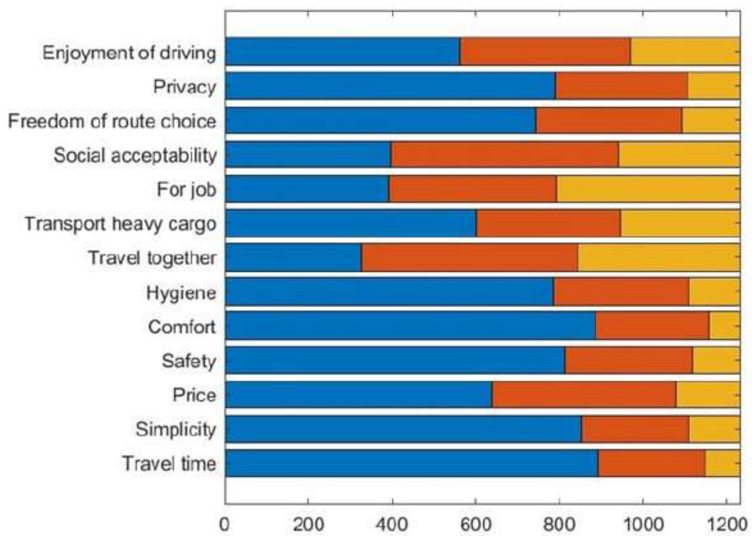
As visible in Figure 3, the undecided drivers are on average older (43 y.o.) than decided ones (36 y. o.). This might be caused by skepticism against new technologies and travel habits among older users.

Figure 3. Box plot of age among undecided and decided respondents toward use of MaaS



Finally, the last investigated issue was importance of chosen MaaS parameters and characteristics for potential MaaS users. In order to analyze this information, we created a layered bar plot for individual MaaS characteristics for hypothesized system and took closer look on assigned importance of individual features. In total there were 13 features to be evaluated with answers on a 5-point scale ranging from very important (1) to not important at all (5). In order to provide clearer representation of the result, we aggregated answers 1-2 and 4-5 in order to achieve a 3-point scale.

Figure 4. Bar plot representing importance of parameters and features of MaaS in eyes of undecided users (in layers left to right)



As presented in Figure 4, the most important features of MaaS according to undecided users are Travel time, Comfort and Simplicity. Close behind are located Safety, Hygiene and Privacy. On the other hand, it is not important whether MaaS is socially acceptable, work travel friendly or suitable for travelling together. These findings provide great insight for future service providers and enablers of MaaS services. The focus during design and development of new system shall be put on short travel times (either through personalized course, or more agile transport means), and simple, straight forward usability. The last point especially, hints toward seamless platform with one application and ticketing system for multiple transport providers. Hygiene, comfort and safety express a need for raised standards in the shared economy where not only users share the responsibility for transport mode but providers also assure the highest possible quality of service. The good news is, that there is no need is sociological leap toward social acceptability and "better image" of shared transport modes as it is not an important factor among people who consider the use of MaaS.

CONCLUSIONS

Performed analysis delivered insight into an important topic related to the intention of using MaaS transportation mode. This insight can help various stakeholders, such as system enablers, service providers, governing bodies of urban areas and urbanists around the world. Accepted criterion for identification of undecided users resulted in a sample of over 1200 respondents who are uniformly distributed in collected respondents of all countries participating in the survey. Careful analysis revealed that undecided users are usually older than decided ones and can be characterized as people with smaller number of constrains and obligations when travelling to or from work. They tend to live in smaller households, although this trend is less significant. These results support the conclusions of Broeg et al. [15] claiming, that travel connected restrains are the main parameter influencing our choice of transport mode and travel habits. Furthermore, the analysis provided insight into the sought-after parameters and characteristics of potential MaaS systems. This offers important insight into, which solutions of MaaS are attractive for undecided users. This has the potential to increase the adoption rate of such travel mode. Interestingly simplicity was found to be one of the three most important characteristics of MaaS systems. In conjecture with the higher age average of the undecided users, this might hint the apprehension of new technologies, such as mobile payment services, mobile applications and others. However, this hypothesis needs to be further investigated and analyzed in further research. On the other hand, information that social acceptability is not important for these respondents is very positive as it indicates that there is no need for further PR campaigns to highlight the perception of MaaS as a transport mode.

ACKNOWLEDGEMENT

The presented study is a result of the research done in the "Smart City – Smart Region – Smart Community" project (CZ.02.1.01/0.0/0.0/17048/0007435) financed by Czech Operational Program "Research, Development and Education" for the implementation of the European Social Fund (ESF) and the European Regional Development Fund (ERDF).

REFERENCES

[1] Luukkainen, P. (2020). Moving on a Whim-Customer Value Creation in MaaS.

[2] Kamargianni, M., & Matyas, M. (2017). The business ecosystem of mobility-as-a-service. In transportation research board (Vol. 96). Transportation Research Board.

[3] A. Polydoropoulou, I. Pagoni, A. Tsirimpa, A. Roumboutsos, M. Kamargianni, I. Tsouros, Prototype business models for mobility-as-a-service, Transportation Research Part A: Policy and Practice 131(2020) 149–162, developments in Mobility as a Service (MaaS) and Intelligent Mobility. doi:https://doi.org/10.1016/j.tra.2019.09.035.URLhttps://www.sciencedirect.com/science/article/pii/S096585641830973X.

[4] S. Guidon, M. Wicki, T. Bernauer, K. Axhausen, Transportation service bundling – for whose benefit? Consumer valuation of purebundling in the passenger transportation market, Transportation Research Part A: Policy and Practice 131 (2020) 91–106, developments in Mobility as a Service (MaaS) and Intelligent Mobility. doi:https://doi.org/10.1016/j.tra.2019.09.023.URLhttps://www.sciencedirect.com/science/article/pii/S0965856418309340.

[5] V. Caiati, S. Rasouli, H. Timmermans, Bundling, pricing schemes and extra features preferences for mobility as a service: Sequential portfolio choice experiment, Transportation Research Part A: Policy and Practice 131 (2020) 123–148, developments in Mobility as a Service (MaaS) and Intelligent Mobility. doi:https://doi.org/10.1016/j.tra.2019.09.029.URLhttps://www.sciencedirect.com/science/article/pii/S0965856418309534.

[6] H. Strömberg, I. M. Karlsson, J. Sochor, Inviting travelers to the smor-gasbord of sustainable urban transport: Evidence from a maas field trial, Transportation 45 (6) (2018) 1655–1670.

[7] M. Matyas, M. Kamargianni, Exploring individual preferences for mobility as a service plans: A mixed methods approach, in: MaaSLab Working Paper Series Paper No. 18-02, 2018.

[8] C. Q. Ho, C. Mulley, D. A. Hensher, Public preferences for mobility as a service: Insights from stated preference surveys, Transportation Research Part A: Policy and Practice 131 (2020) 70–90, develop-ments in Mobility as a Service (MaaS) and Intelligent Mobility.doi:https://doi.org/10.1016/j.tra.2019.09.031.URLhttps://www.sciencedirect.com/science/article/pii/S0965856418311376.

[9] F. D. Davis, R. P. Bagozzi, P. R. Warshaw, User acceptance of computer technology: A comparison of two theoretical models, Management Science35(8) (1989)982–1003.arXiv:https://doi.org/10.1287/mnsc.35.8.982,doi:10.1287/

mnsc.35.8.982.URLhttps://doi.org/10.1287/mnsc.35.8.982.

[10] M. Hunecke, S. Haustein, S. Grischkat, S. Böhler, Psychological, sociodemographic, and infrastructural factors as determinants of ecological impact caused by mobility behavior. Journal of Environmental Psychology 27 (4) (2007) 277–292.doi:https://doi.org/10.1016/j.jenvp.2007.08.001.

[11] S. Jung, H. H. Kum-Biocca, F. Biocca, S. Hong, M. Shin, H. Hu, Evaluating global integrated transportation application for mega event: Role of trust and exchanging personal information in mobility as a service(maas), in: C. Stephanidis, M. Antona, S. Ntoa (Eds.), HCI International 2020 – Late Breaking Posters, Springer International Publishing, Cham, 2020, pp. 575–584.

[12] F. D. Davis, Perceived usefulness, perceived ease of use, and user accep-tance of information technology, MIS Quarterly 13 (3) (1989) 319–340.URL: http://www.jstor.org/stable/249008.

[13] Caiati, V., Rasouli, S., & Timmermans, H. (2020). Bundling, pricing schemes and extra features preferences for mobility as a service: Sequential portfolio choice experiment. Transportation Research Part A: Policy and Practice, 131, 123-148.

[14] K. Pearson, On the criterion that a given system of deviations from the probable in the case of a correlated system of variables is such that it can be reasonably supposed to have arisen from random sampling, Philosophical Magazine. Series 5. 50 (302): (1900) 157–175, doi:10.1080/14786440009463897.

[15] W. Broeg et al., "Evaluation of voluntary travel behavior change: Experiences from three continents", Transport Policy, vol. 16, no. 6, pp. 281-292, Nov. 2009.

[16] C. O'Fallon, C. Sullivan and D. A. Hensher, "Constraints Affecting Mode Choices by Morning Car Commuters", Transport Policy, vol. 11, no. 1, pp. 17-29, Jan. 2004.

Addressing the Challenge of Sustainable Mobility: Accessibility and Low Carbon Emissions Assessment in Lyon Metropolitan Area, France

NICOLAS OVTRACHT, PIERRE LEVIAUX

Abstract Climate change marks the contemporary historical period. It is already having consequences on human populations, and poses a certain number of challenges to our societies. Aware of this context, this article proposes to reflect on the difficult question of sustainable mobility, the transport sector constituting one of the most important sources of GHG emissions in developed societies. More specifically, it focuses on certain aspects of sustainable mobility in French metropolitan areas, and notably in the Lyon metropolitan area. This paper highlights in particular that the political instruments for sustainable mobility must take into account the specificities of territories and populations. Indeed, the social acceptability of measures linked to sustainable mobility is a crucial element for the success of this ecological transition policy.

Keywords: • Low Emission Zone – LEZ • Transport Policy • Sustainable Mobility • Accessibility Indicators • Spatial Modeling

CORRESPONDENCE ADDRESS: Nicolas Ovtracht, Pierre Leviaux, LAET – Transport, Urban Planning & Economy Laboratory- UMR 5593 CNRS- University of Lyon, Lyon, France

PURPOSE

In France, during the last 15 years, urban transport policies have shifted from the objective of offering a higher travel speed to an environment-friendly mobility aimed at optimizing the consumption of urban space. Today, the context of climate change forces us to take into account transport-related greenhouse gas (GHG) emissions. Indeed, in 2017 the total CO_2 emissions in the European Union were 21 % above their 1990 level [1]. Moreover, about 80 % of the increase in global transport emissions since 1970 has been due to road vehicles [2]. This new issue has been increasingly added to discussions relating to the implementation of urban transport policies, and requires the identification of new strategies to achieve the objectives of the low carbon transition. The increasing focus on GHG emissions in spatial land use leads to reconsider travel time gains. More precisely, travel time savings are no longer the main objective of local public policies. Even if it corresponds much more to a rationale of "traffic calming" than a "return to slowness", there is clearly another set of priorities that is changing the relative share of public space attributed to the different modes of transport. Facing both environmental and spatial constraints, an accessibility-based analysis makes it possible to assess urban dynamics by integrating the opportunities reached by individuals when they use the transport system and the urban spatial structure [4], [5].

The last decade has seen the deployment of a growing number of Low Emission Zones (LEZ) in Europe. These low-emission zones are geographic sectors that are most often located in the center of metropolitan areas. They are based on the implementation of various restrictions on the use of private cars, as well as other transport regulation measures. For example, many of these areas aim at reducing exhaust emissions [6]. In April 2020, there were 247 LEZs in Europe, located in 13 different countries. In France, still in 2020, there were 4 active LEZs – Lyon, Paris, Grand Paris and Grenoble – they will be 11 in total in 2022, and the last bill called "Climate & Resilience" adopted in August 2021 will require all agglomerations of more than 150 000 inhabitants to set up an LEZ no later than December 31, 2024.

The Lyon metropolitan area set up its LEZ in 2020. This can be seen as a sign that the fight against polluting emissions and CO_2 emissions have become priorities for a certain number of cities, to improve air quality in the city, to reduce the consequences of pollution on the health of inhabitants, but also to promote other socio-economic activities, as well as a better quality of life and well-being. Finally, the gradual development of these LEZs has also become a political subject for many political parties, well beyond purely environmentalist parties.

Nevertheless, the establishment of these low emission zones is not without its problems. Indeed, they are often seen as unfair by modest households and by the middle classes, who are often forced to live outside city centers (for reasons of the cost of real estate) and who are largely dependent on car. On the other hand, these LEZs sometimes lead to contradictory effects. In the French case, for example, they are first and foremost pollution control devices and insufficiently consider the level of CO_2 emissions from vehicles. Thus, heavy and / or sports vehicles, which meet the most recent anti-pollution standards but emit a lot of CO_2, are allowed to circulate, while vehicles that emit less, but more pollutants, cannot. This situation tends to worsen the feeling of injustice felt by low-income households and must of course be taken into account.

In this context, it is important for researchers to be able to develop tools and instruments that make it possible to inform political decisions in terms of sustainable mobility, taking all the social, economic, and climatic constraints into consideration. Climate change and its effects will be at the heart of most public policies in the years to come, and the academic world has an important role to play in supporting society in the face of this major collective challenge.

Table 1. List of French cities or metropolis concerned by future Low Emission Zone - LEZ

Aix-Marseille	Chambéry	Metz	Reims
Amiens	Clemont-Ferrand	Montpellier	Rennes
Angers	Dijon	Mulhouse	Rouen
Annecy	Dunkerque	Nancy	Saint-Etienne
Annemasse	Grenoble	Nantes	Saint-Nazaire
Avignon	Le Havre	Nice	Strasbourg
Bayonne	Le Mans	Nimes	Toulon
Béthune	Lens	Orléans	Toulouse
Bordeaux	Lille	Paris / Métropole du Grand Paris	Tours
Brest	Limoges	Pau	Valenciennes
Caen	Lyon	Perpignan	

Source: Insee, 2021.

Research Approach

In this project, we are studying the Lyon Metropolitan area. It is a metropolis of 538 km² comprising 59 municipalities. It has 1,4 million inhabitants [12] with an average density of 2 612 inhabitants per km².

One can also note that 71,4 % [12] of households have at least one car. This figure varies in the metropolis. In the central zone, 60,8 % of households are equipped with at least one car. But when looking at home-to-work travel, one can see that the further we move away from the central zone, the more the modal share of private car increases. The Lyon Metropolitan area has been facing pollution peaks for several years. At such times, only the cleanest vehicles equipped with CRIT’Air 0, 1 and 2 stickers can circulate in the central Lyon area. The French CRIT'Air classification constitutes the standard according to, which vehicles are classified according to their level of pollution. It is directly linked to European anti-pollution standards (Euro

1 to Euro 6) and concerns both motorcycles, tricycles and quadricycles, cars, light commercial vehicles and heavy goods vehicles, buses, and coaches. Its level ranges from 0 (green sticker) to 5, 5 being the highest pollution level. Vehicles built before January 1, 1997, are beyond the CRIT'Air 5 sticker and are Therefore, unclassified.

There is currently no harmonization at national level of traffic restrictions applying to vehicles. Each metropolis is currently free to decide who has the right to circulate. Thus, since 2016, the Lyon Metropolitan area has implemented the "Oxygen" plan to improve air quality and reduce polluting emissions from homes, transport and economic activities, for the share of GHG emissions is at its highest level in the transport sector.

In the case of Lyon, the elected officials of the metropolis decided that heavy goods vehicles and light commercial vehicles dedicated to the transport of goods with a CRIT'Air 4 or 5 sticker could no longer circulate inside the ZFE. This driving and parking ban was extended in January 2021 to professional vehicles with a CRIT'Air 3 sticker. If for the moment private vehicles are not affected by the ban on driving in LEZ, the Lyon Metropolitan area intends to include them. Indeed, by 2026, decision-makers also want to progressively ban private vehicles with a CRIT'Air sticker 2, 3, 4, 5. In other words, no diesel vehicle will be authorized to circulate inside this LEZ –, which will probably be extended – in a few years.

If we use data from the 2015 Lyon Household and Displacement Survey (Household Survey 2015), we can see that the modal share of private car is declining. It bends downwards especially in the areas affected by the Urban Transport Perimeter. Thus, the modal share of public transport increases sharply for those located outside the central zone who move to go to work towards the central zone, which concentrates the majority of jobs.

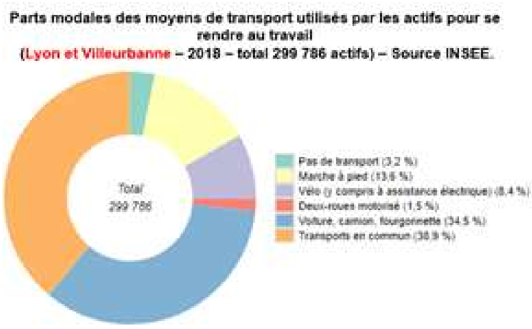
In view of these various contextual elements, the main objective of the paper is to highlight methodological aspects of the new trends in urban transport policies, in order to enrich their analysis, using methods and tools from geomatics, spatial economics and environmental disciplines.

The first part presents the "MOSART" modeling platform. MOSART was first implemented as a Geographical Information System in transportation producing accessibility analysis [7]. In a second version, it has been improved into a modeling platform for planning sustainable mobility by introducing gravity-based analysis. A web-mapping application has been added for the accessibility modeling results. Many databases, such as network data, socio-economic data, whether spatial or not, can be integrated in the GIS. Integration of an urban transport model system associated to updated land-use data at a very detailed zonal division makes it easier to analyze the dynamics of different transport policy scenarios. One of the most innovative aspects of MOSART is the joint analysis of both urban speed issues and land-use patterns. Combining these two interrelated aspects, MOSART is well adapted to assess past and future transport policies.

With the platform, we modelized and simulated traffic for private car and public transport during peak period for each Traffic Analyze Zone (TAZ). Then we can calculate the emissions of Greenhouse Gaz (GHG) with different composition of the vehicles fleet. Today, the biggest part of the fleet of private car are diesel in Lyon metropolitan area [8], [9].

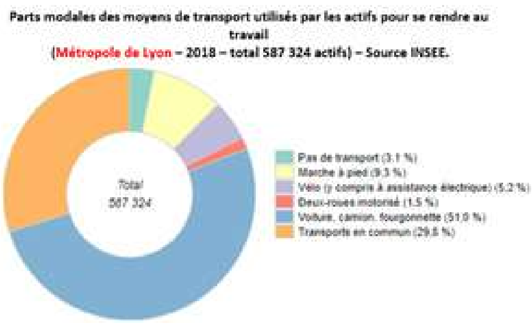
Indeed, the objective of the Lyon Metropolis is to accelerate towards "green mobility" and, as we have seen above, one of the targets is to achieve the ban of diesel private cars in 2026. They want to improve green and soft mobility, for a better quality of life. One of the most important problems is the important fleet of diesel car. As we can see on Figure 2, which is about GHG emissions in various economic sectors in 2015, transport is the most important sector with around 30 % of national GHG emissions.

Figure 1. Lyon-Villeurbanne (CBD) – Modal shares of different modes of transport in home-work journeys



Source: Insee, 2018.

Figure 2. Lyon Metropolis – Modal shares of different modes of transport in home-work journeys



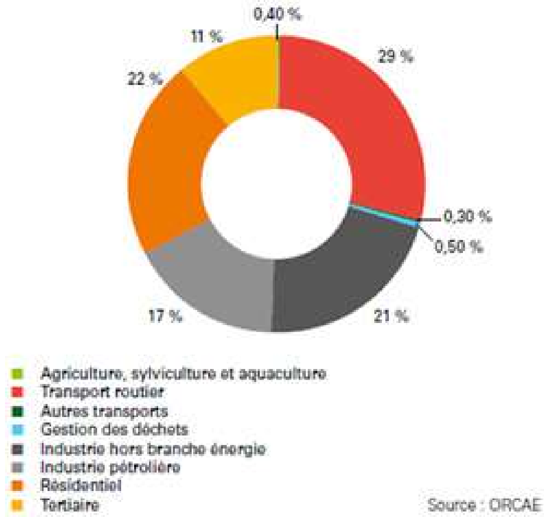
Source: Insee, 2018.

Figure 3. Lyon Metropolis – household car ownership rate

Source: Insee, 2018.

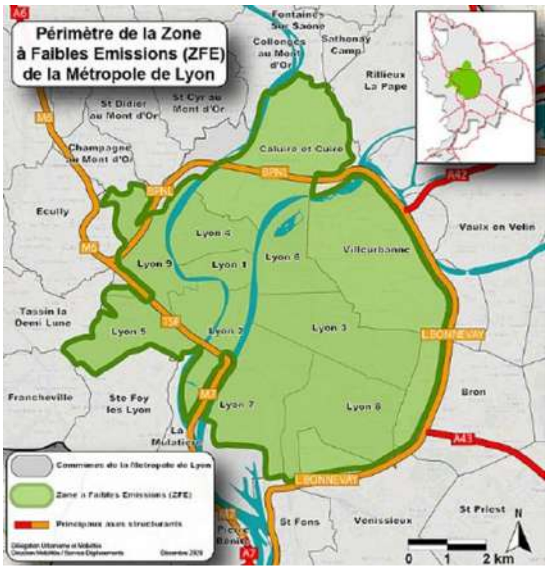
The second part of our paper will aim to show some examples of accessibility analyses that were carried out with the MOSART platform during the Optimod Project (Improve mobility for individuals, professionals and cargo in an urban environment). The main purpose of the Optimod Project is to develop sustainable mobility with ITS systems in Lyon urban area. Facing the challenges of "sustainable mobility paradigm" (Banister 2008), what will be the next developments of the local transport policy? To address this issue, the Optimod project tests different transport policy scenarios using MOSART on Lyon Urban Area and assess their GHG emissions. It can Therefore, propose alternative options for a sustainable mobility under joint environmental, accessibility and economic constraints.

Figure 4. GHG emissions by business sector in 2015 in Lyon Metropolis



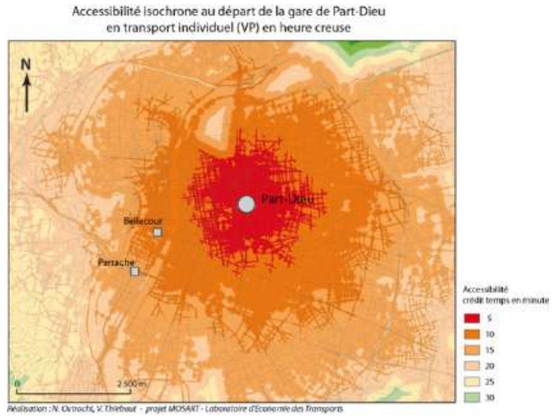
Source: ORCAE.

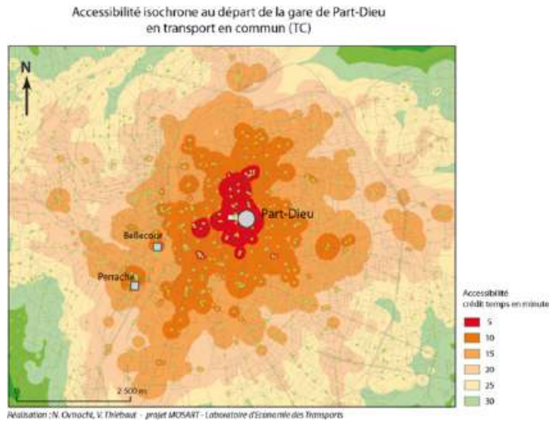
Figure 5. Perimeter of the Low Emission Zone – LEZ – of Lyon Metropole area



Source: Lyon Metropole, 2021.

Figure 6. Isochrones time credit / budget for car and Public Transport. Simulation on peak period without taking account time to drop on / off the car





Source: Mosart PlatForm, LAET 2016.

As we can analyze, the implementation of LEZ in Lyon CBD will reduce traffic on the road. One of the objectives is that population will use soft mode like walking, bicycle or public transport. In that case, it's important to simulate accessibility to amenities with soft mode or public transport.

The assessment of these different policies is made by referring access measures to urban amenities in peak hour and off peak hour, taking into account GHG emissions. Accessibility is measured for different transport mode users (car users, public transports users, bicycle users etc.). The different accessibility maps are displayed based on a specific origin, time, and the mode of transportation (by car, public transport or bike).

CONCLUSION & PRACTICAL IMPACT

The issue of sustainable mobility is a complex matter. Indeed, to be both effective in terms of its environmental and sanitary objectives (fight against pollution and GHG emissions), a sustainable mobility policy must take into account the specificities of the territories to, which it is supposed to apply. Its specificities are of several types: public transport supply, socio-economic characteristics of both territories and households, land and real estate prices.

For the instruments of a sustainable mobility policy cannot be the same in the perimeter of the city-center and in the peri-urban areas that depend on it. More broadly, one of the biggest challenges in the years to come will be to ensure that the behavioral changes that are essential to the implementation of a true ecological and energy transition in the transport sector are accepted by all categories of the population. For all these reasons, the use of modeling tools like the MOSART platform can go a long way in informing policy decisions. Future developments in this direction, integrating both the economic, social and environmental constraints of the different territories, should make it possible to facilitate the design of efficient and socially accepted mobility policies.

The Optimod'Lyon project illustrates the capacity of the MOSART platform to produce scenarios that can inform public decision-making for increasingly sustainable mobility. More precisely, it can provide precise information to public decision-makers to set up new urban mobility policies in line with the challenges of ecological transition.

REFERENCES

[1] O. Juvyns, R. Fernandez, N. Mandl, E. Rigler, "Annual European Union greenhouse Gaz Inventory 1990-2017 and Inventory Report 2019", EEA, Brussels, Belgium, 51, 2019.

[2] R. Sims, R. Schaeffer, F. Creutzig, X. Cruz-Núñez, M. D'Agosto, D. Dimitriu, M. J. Figueroa Meza, L. Fulton, S. Kobayashi, O. Lah, A. McKinnon, P. Newman, M. Ouyang, J. J. Schauer, D. Sperling, and G. Tiwari, "Transport (Chapter 8)", in Climate Change 2014: Mitigation of Climate Change - Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx, Cambridge UK and New York: Cambridge University Press, 2014, pp. 599-670.

[3] K. T. Geurs, B. van Wee, "Accessibility evaluation of land-use and transport strategies: review and research directions", Journal of Transport Geography, vol. 12, 2, pp. 127-140, Jun 2004

[4] J. Gutierrez J. and P. Urbano, "The impact of orbital motorway on intra-metropolitan accessibility: the case of Madrid's M-40", Journal of Transport Geography, vol. 7, 1, pp. 1-15, Mar 1999.

[5] J. Kinigadner, B. Büttner, G. Wulfhorst, D. Vale, "Planning for low carbon mobility: impacts of transport intervention and location on carbon based accessibility", Journal of Transport Geography, vol. 87, pp. 1-13, Jul 2020.

[6] T. Settey, J. Gnap, D. Benova, "Examining the impact of the deployment of low emission zones in Europe on the technological readiness of road freight transport", Transport Research Procedia, vol. 40, pp. 481-488, Jan 2019.

[7] Y. Crozet, A. Mercier, N. Ovtracht, "Accessibility: a key indicator to assess past and future of urban mobility. PART V, Chapter 15", in Accessibility Analysis And Transport Planning. Challenges for Europe and North America, K.T. Geurs, K.J. Krizek, A. Reggiani, Cheltenham: Edward Elgar Publishing Ltd, 2012, pp. 263-279.

[8] K. J. Dueker and J. A. Butler, "A geographic information system framework for transportation data sharing", Transportation Research Part C: Emerging Technologies, vol. 8, 1, pp.13-36, Oct 2000.

[9] H. Määttä-Juntunen, H. Antikainen, O. Kotavaara, J. Rusanen, "Using GIS tools to estimate CO2 emissions related to the accessibility of large retail stores in the Oulu region, Finland", Journal of Transport Geography, vol. 19, 2, pp. 346-354, Mar 2011.

[10] R. Cervero and K. Kockelman, "Travel demand and the 3Ds: density, diversity, and design", Transport Research part D: Transport and Environment, vol. 2, 3, pp. 199-219, Sep 1997.

[11] L. Bertolini, Planning the mobile metropolis: Transport for People, Places and the Planet, London: Palgrave, 2017.

[12] Insee - Institut national de la statistque et des études économiques, 2018. https://www.insee.fr/en/statistiques/series/103088458

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Logistics Trends and Scenarios for Freight Transport Development in Urban Areas

TOMISLAV LETNIK, STANE BOŽIČNIK, KATJA HANŽIČ

Abstract Urban freight transport is growing and so is its impact in terms of congestion, emissions and energy consumption. Policy makers around the world are trying to solve these problems, which are proving to be more complex than the problems of passenger transport. The complexity of urban freight transport arises not only from the different needs of various stakeholders, but also from rapid technological development and changing trends in logistics. Different views and backgrounds of stakeholders lead to low acceptance of implemented measures and lack of results. In this paper, we explore the differences in views and expectations about the future development of urban logistics between public and private stakeholders. As a starting point, a comprehensive literature review on key trends in logistics was conducted, which served as the basis for a stakeholder survey. The survey was used to assess the expected impact of the identified trends on future urban freight transport. Significant differences of opinion between stakeholders were identified, necessitating more active cooperation between them in the policy-making process.

Keywords: • Logistics Trends • Urban Freight • Policy Making • Stakeholders' Perspective

CORRESPONDENCE ADDRESS: Tomislav Letnik, Assist. Prof. PhD, Stane Božičnik, Prof. PhD, Katja Hanžič, BsC, University of Maribor, Faculty of Civil Engineering, Transportation Engineering and Architecture Smetanova 17, 2000 Maribor, e-mail: tomislav.letnik@um.si; e-mail: stane.bozicnik@um.si; e-mail: katja.hanzic@um.si

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

Between the 1990s and the beginning of the twenty-first century, several studies and pilot tests were carried out in European cities with the aim of reducing urban freight traffic and pollution [1]. As a result, more and more policies and restrictive measures were introduced for urban freight transport [2–4]: e.g., Low Emission Zones, Time Windows, Vehicle Weight and/or Size Restrictions, Congestion charging.

Despite all efforts, urban freight transport problems still persist [5]. One possible reason for this inefficiency is the existing approach of policies and measures that mainly target the city centers and the last mile of traditional supply chains [6–9]. To fully understand the opportunities for mitigating urban freight flows and to solve the problem holistically, we would need to address urban freight transport at the level of the entire supply chain, including corporate strategies [10–12]. We should take a further step from a narrow urban planning perspective to a more comprehensive regional and supply chain planning approach.

The other reason is the rapid development of new logistics services supported by advanced IT solutions [13–15]. Policy makers are often unaware of these emerging trends and fail to recognize the real needs and opportunities. This often leads to a conflict of interest between restrictive policies and commercial needs [16]. To solve this problem, a proactive approach is needed to develop policies that take into account the expected evolution of logistics and its emerging trends.

We argue that policy making can only be successful if policy makers fully understand stakeholders’ expectations, as well as emerging trends in logistics. Stakeholders' collaboration in policy making is critical for successful policy creation and implementation.

The main objective of this article is to identify and summarize existing and emerging trends in order to identify the most important ones and assess their impact on the future development of urban freight transport. The assessment is based on an international expert survey among different stakeholders to understand their perceptions and expectations.

REVIEW OF LOGISTICS TRENDS

Today, urban logistics faces numerous challenges and demands for faster and more reliable deliveries [17, 18]. Customer expectations are increasing with demands to make logistics services more efficient, environmentally friendly and cost effective [19]. To understand the motivation for these demands, we need to look for existing and emerging trends and its potential impact on urban freight transport.

For the purpose of the literature review, we have classified the trends in logistics into the following 4 main categories:

- changing consumption and production,
- spatial organization characteristics,
- supply chain and distribution,
- technologies and equipment.

The main trends relevant to each category are briefly described below.

Consumption and production trends

The growth of the e-commerce and the increasingly comprehensive range of services offered by retailers (e.g., click & collect) are leading to changes in the pattern of urban freight flows and vehicle movements in cities [19,20]. Several studies also predict significant increase in demand for products and services related to the elderly. Logistics for an aging society is likely to be a major contributor to urban freight transport in the future. We can assume that home delivery of food and medicines will increase, hospitals will introduce logistics solutions to facilitate patient care, packaging will be adopted for the elderly etc. [21].

In recent years, consumers have become more aware of the environmental sustainability of the products they buy. Companies are doing their best to turn social and environmental challenges into opportunities by creating fair and sustainable solutions that generate both social and business benefits along the supply chain. This trend will increase transparency within supply chains, require new concepts of circular economy in logistics and will impact or perhaps even disrupt the logistics industry over the coming years [12], [21], 22].

In the future, consumers will share access to products or services, rather than owning them individually. Sharing logistics infrastructure and services with competitors is part of collaborative business [23]. Facility and capacity sharing will lead to increased consolidation and capacity utilization, which will reduce the number of freight movements, fleet size, and empty runs in collaborative logistics services. On-demand brokerage platforms will bring together demand and supply for logistics services, such as Uber Rush for on demand delivery services in cities [23].

Consumer driven concept leads to a pull logistics strategy and requires responsive production with highly optimized and streamlined processes.

Spatial organization trends

Most customers and retailers are in inner urban areas while logistics facilities are located on the periphery of metropolitan areas. This phenomenon, referred to as "logistics sprawl", is expected to continue and consequently increase the distances travelled by freight vehicles serving retail, commercial and residential areas in inner cities [17].

The spatial centralisation of stockholding continues to be driven by manufacturers and retailers to achieve cost savings in their supply chains. This is leading to an increased use of few, large national and regional distribution centers serving a much larger geographic area [24]. As a result, urban areas will be supplied from these large centers increasing deliveries to urban centers while eliminating smaller distribution centers within urban areas.

It is expected that the deployment of urban consolidation centers (UDCs) with new business models that can cover infrastructure investments will continue [25]. Due to the difficulties in reaching a critical mass of users, only a medium to long-term impact is expected. In the future, a variety of pick-up points (unattended, e.g., locker boxes, or attended, e.g., fuel stations) are expected. The impact of pick-up points on FUA freight transport is expected to be very high, especially in city centers [26].

Road transport remains the predominant mode for transporting goods over short distances (the average distance of national freight transport trip is 85 km), with the main problem being poorly utilized vehicles and empty runs [27]. These problems need to be addressed by the authorities and solved at the regional level. The establishment of Freight Quality Partnerships, Living Labs and other means will help local authorities, businesses, freight operators, environmental groups, local communities and other interested stakeholders to work together to solve specific problems in freight transport [28,29].

Supply chain and distribution trends

As the concept of the "Internet of everything" expands, there are more opportunities to connect supply chains (the trend of connected supply chains) and increase visibility from order initiation to order delivery [30]. Logistics providers (3PLs) will merge and everyone else will increase their willingness to collaborate. Consolidation of logistics providers will also lead to consolidation of freight flows and consequently have a very positive impact on freight flows [31].

While globalization (i.e., the distribution of production across multiple locations around the world, driven by production cost factors) is an ongoing trend, some companies have begun to consider investing in the opposite direction [32]. More and more of the production (manufacturing) will be brought closer to the end users. This will result in less transportation, shorter lead times, and easier planning of logistics flows, as well as corrections to shipping plans.

Demand for a trusted local and regional food supply will grow. This will change regional supply chains and impact transportation/logistics processes within and between FUAs. 3D printing will be used to create specialized products in decentralized locations, such as retail stores or even in homes. 3D printers will, in the long run, reduce freight transport particularly the distribution of goods [6,33]. They will also reduce storage in warehouses and retail outlets, as well as waste, such as packaging.

In recent years, many e-tailers have begun offering same-day delivery to their customers, sometimes within 1-hour from purchase. Omni-channel retailing envisions the integration of multiple online and offline retail channels through, which consumers can purchase, pick up or receive goods and process payments [6]. Logistics is becoming the backbone of the retail industry and will need to provide innovative omni-channel solutions that meet the demand for personalized, dynamic delivery options and services at competitive prices. In recent years, this has led to the development of new solutions that facilitate last-mile delivery, such as same-day and even same-hour delivery models (e.g., Amazon Prime), individual parcel lockers (e.g., DHL Paketkasten), and even delivery-to-car-trunk concepts [7,34].

Technologies and equipment trends

New technologies are changing existing patterns and leading to new solutions including urban freight delivery. The use of electric vehicles (EVs) has been identified as an efficient and promising strategy for urban freight transport and has also been successfully used for deliveries from urban micro-consolidation centers to customers [35]. Improved internal combustion engine vehicles (ICEVs) will still play a predominant role in the short term while hybrid or electric-powered vehicles will take over in the long term.

Regardless of the propulsion technology of urban freight transport vehicles, these can be used more efficiently through the use of advanced information and communication technologies (ICT). The logistics industry has already adopted a wide range of information and communication technologies and is reaping the environmental benefits of shorter journeys, fewer vehicle movements, better matching of vehicles to work and improved levels of load consolidation [19]. The use of ICT in freight transport allows transport users to identify the most appropriate services for their purposes, and logistics operators to strategically manage freight shipments and deliveries [36].

Application of ICT and ITS enables easy collection of various date on pickup-delivery truck movements or goods movements in urban areas at lower costs. The analysis of this big data of truck movements in urban areas allows an insight into the driver behaviour and identification of potential for improvements [37]. An unprecedented amount of data can be collected from multiple sources along the supply chain. Harnessing the value of Big Data offers enormous potential to optimize capacity utilization, improve customer experience, reduce risk, and create new business models.

The use of ICT in urban logistics will lead to price reductions and influence the behaviour of individual companies and consumers, as well as the city's logistics system. The Internet and ITS will not only influence the logistics system, but also B2C and B2B e-commerce, e-logistics, e-fleet management and cooperation opportunities for customers and logistics providers [15].

In addition to the introduction of new vehicle powertrains, ICT and ITS, several technologies have also been developed to support automated road vehicles, some of, which are already in practical use [38]. Urban environment systems are expected to follow a path where the application of highly automated vehicles is initially limited to certain environments and then gradually expands to less controlled ambiances. Unmanned Aerial Vehicles (UAVs), which are designed to deliver parcels from distribution centers directly to customers, are also particularly promising [39].

IMPACT ASSESMENT

If we are to look at logistics trends as a basis for developing logistics policies and measures, we need to understand two very important aspects: to what extent and when these trends will affect urban freight transport. As this is very difficult to assess, we decided to approach different logistics stakeholders and ask for their opinion.

For the survey, the trends were categorized into 4 areas, 9 topics and 13 drivers, as shown in the table below.

The survey briefly described each trend and asked participants to qualitatively rate

Table 1. Categorisation of logistics trends/drivers

Area	Topic	Driver
Consumption	Demographic trend	Grey power logistics
	Consumer behaviour	Environment and sustainability
		E-commerce
		Sharing economy
Spatial planning	Government side	Public planning (regulations, planning of facilities)
	Industry side	Industry plans
Distribution and supply chain management	World production and trade	Globalization trends
	New business models	Desire for speed
		Omni-channel logistics
Technologies and equipment	Clean fuel	CNG and EV
	ITS	IoT and big data
	Frontier technologies	UAV
		Automated vehicles

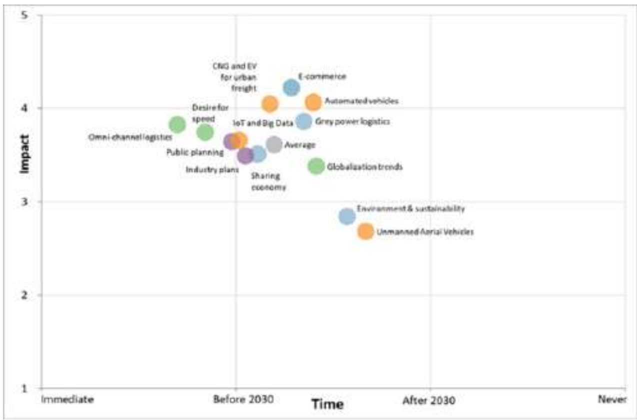
Source: Insee, 2021.

the impact of each driver on a scale of 1 to 5, with 1 representing very low impact / influence / prevalence / likelihood and 5 representing very high impact. Regarding the timeframe in, which the participants believe that the respective driver will have an important impact (is likely to occur), they could choose from the following options: "Immediately", "Before 2030", "After 2030" and "Never".

Altogether 415 stakeholders were identified from four categories of respondents: Business Sector; Authorities; Research; Other (mainly associations). A total of 63 survey responses from 24 countries were obtained.

The results are presented graphically below. The main reference category of each driver is indicated by the dots: blue - consumption; purple - land and road use; green - distribution and supply chain management; orange: technologies and equipment; grey: average.

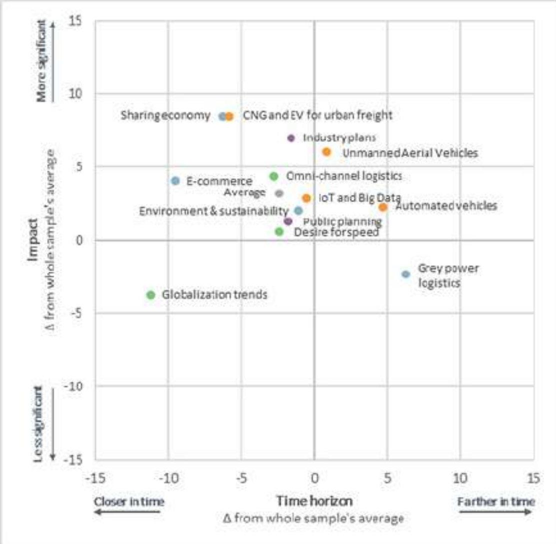
Figure 1. Urban logistics drivers impact and time positioning – whole sample average



According to respondents, "e-commerce", "automated vehicles", "CNG/EV", "grey power logistics", "omni-channel logistics" and the "desire for speed" will have the greatest impact on urban freight transport in the future. On the other hand, "unmanned aerial vehicles", "environmental and sustainability issues", "globalisation trends" and "industry plans" are less important for the future development of logistics in cities.

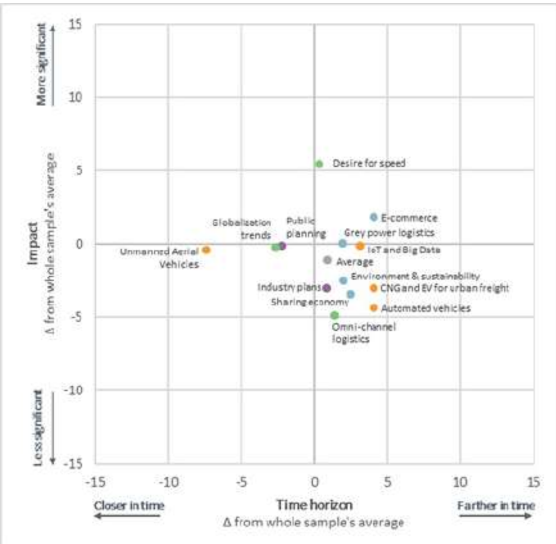
To understand the differences between the stakeholder groups, the deviations from the averages were calculated for each group and are shown in the following figures.

Figure 2. Business sector – Drivers' impact and time horizon, Δ (deviations) from whole sample



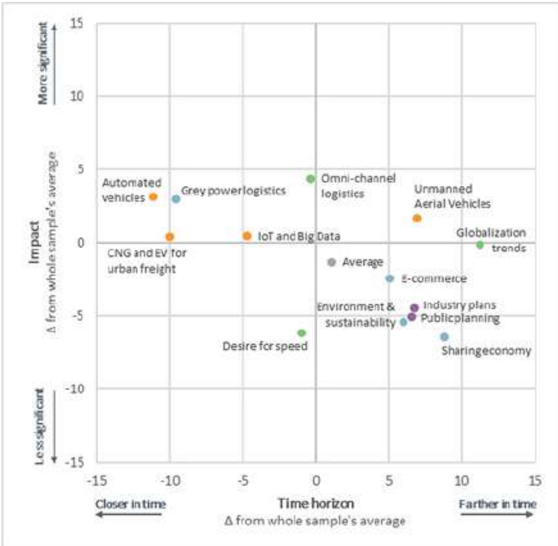
The business community believes that "Globalization trends" are already present and evident, and Therefore, does not expect any additional significant impact on urban areas. On the other hand, significant impacts are expected in a shorter timeframe, especially in the areas of "Sharing economy", "CNG and EV for urban freight", "Industry plans", "E-commerce" and "Omni-channel logistics". Technological solutions, such as "Unmanned Aerial vehicles", "Automated vehicles" and the use of "IoT and Big Data" will play an important role in their opinion, but in a somewhat more distant future. In general, most trends are found in the upper left quadrant of the scatter plot. This means that the business community believes that the indicated trends will have a greater impact on urban logistics, and in shorter period of time than the other stakeholder groups.

Figure 3. Authorities – Drivers' impact and time horizon, Δ (deviations) from whole sample



The stakeholders of the authority group consider the "Desire for speed" as the most important trend that will influence urban freight transport in the future. Another very interesting observation is their expectation that "Unmanned Aerial Vehicles" (e.g., drones) will influence urban freight transport much earlier than the expectations of the other stakeholders' groups. In general, most of the trends are located in the lower right quadrant of the scatter plot, which means that the authorities believe that the indicated trends will have less significant impacts on urban logistics, and in longer period of time.

Figure 4. Research – Drivers' impact and time horizon, Δ (deviations) from whole sample



In the research community, almost all trends belonging to the core area of "Consumption" (blue dots) and "Land use and planning" (purple dots) are located in the lower right quadrant of the scatter plot (less significant). In contrast, almost all drivers belonging to the "Technologies and Equipment" domain (orange dots) are in the upper left quadrant of the scatter plot (more significant).

CONCLUSIONS

The results show that different stakeholders have different views on the importance of certain logistics trends and their impact on urban freight transport in the future. Of particular importance is the difference between public and private stakeholders, who in some cases have completely different perceptions. This could be the main reason why urban freight transport policies have had limited impact despite the enormous efforts made by the public sector in recent years. There is an urgent need for knowledge sharing and closer collaboration in developing urban freight transport policies, solutions, and services. Researchers, on the other hand, seem to have a strong belief in technologies and consider soft approaches to urban logistics problems, as prevalent today, to be less relevant.

REFERENCES

[1] Balm, S., Browne, M., Leonardi, J. in Quak, H. (2014). Developing an Evaluation Framework for Innovative Urban and Interurban Freight Transport Solutions. Procedia - Social and Behavioral Sciences, 125. https://doi.org/10.1016/j.sbspro.2014.01.1482.

[2] Boussier, J., Cucu, T., Ion, L. in Breuil, D. (2011). Simulation of goods delivery process. International Journal of Physical Distribution & Logistics Management, 41(9), 913–930. https://doi.org/10.1108/09600031111175852.

[3] Browne, M., Allen, J. in Leonardi, J. (2011). Evaluating the use of an urban consolidation centre and electric vehicles in central London. IATSS Research, 35(1), 1–6. https://doi.org/10.1016/j.iatssr.2011.06.002.

[4] Browne, M. in Gomez, M. (2011). The impact on urban distribution operations of upstream supply chain constraints. International Journal of Physical Distribution & Logistics Management, 41(9), 896–912. https://doi.org/10.1108/09600031111175843.

[5] Buldeo Rai, H., van Lier, T., Meers, D. in Macharis, C. (2017). Improving urban freight transport sustainability: Policy assessment framework and case study. Research in Transportation Economics. https://doi.org/10.1016/j.retrec.2017.08.005.

[6] Cardenas, I. D., Vanelslander, T. in Dewulf, W. (2015). The e-commerce parcel delivery market : developing a typology from an urban logistics perspective ., (i).

[7] Centobelli, P., Cerchione, R. in Esposito, E. (2018). Environmental Sustainability and Energy-Efficient Supply Chain Management: A Review of Research Trends and Proposed Guidelines. Energies, 11(2), 275. https://doi.org/10.3390/en11020275.

[8] Certomà, C., Corsini, F. in Rizzi, F. (2014). Crowdsourcing urban sustainability. Data, people and technologies in participatory governance. Futures. https://doi.org/10.1016/j.futures.2014.11.006.

[9] Cruz, C. in Montenon, A. (2016). Implementation and Impacts of Low Emission Zones on Freight Activities in Europe: Local Schemes Versus National Schemes. Transportation Research Procedia, 12(June 2015), 544–556. https://doi.org/10.1016/j.trpro.2016.02.010.

[10] Danielis, R., Valeri, E. in Rotaris, L. (2015). Performance evaluation methods for urban freight distribution chains : a survey of the literature. Urbe 2015, 1–21.

[11] Ducret, R. (2014). Parcel deliveries and urban logistics: Changes and challenges in the courier express and parcel sector in Europe — The French case. Research in Transportation Business & Management, 11, 15–22. https://doi.org/10.1016/j.rtbm.2014.06.009.

[12] Ehmke, J. F., Campbell, A. M. in Thomas, B. W. (2016). Data-driven approaches

for emissions-minimized paths in urban areas. Computers & Operations Research, 67, 34–47. https://doi.org/10.1016/j.cor.2015.08.013.

[13] Fiore, G. M. (2020). Space for Cities: Satellite Applications Enhancing Quality of Life in Urban Areas. V Studies in Space Policy (Let. 22, str. 251–263). Springer, Cham. https://doi.org/10.1007/978-3-030-21938-3_22.

[14] Harris, S., Weinzettel, J., Bigano, A. in Källmén, A. (2020). Low carbon cities in 2050? GHG emissions of European cities using production-based and consumption-based emission accounting methods. Journal of Cleaner Production, 248, 119206. https://doi.org/10.1016/j.jclepro.2019.119206.

[15] Hensher, D. A. in Brewer, A. M. (2001). Developing a freight strategy: The use of a collaborative learning process to secure stakeholder input. Transport Policy, 8(1), 1–10. https://doi.org/10.1016/S0967-070X(00)00031-7.

[16] Janjevic, M. in Ndiaye, A. B. (2014). Development and Application of a Transferability Framework for Micro-consolidation Schemes in Urban Freight Transport. Procedia - Social and Behavioral Sciences, 125(0), 284–296. https://doi.org/10.1016/j.sbspro.2014.01.1474.

[17] Jedliński, M. (2016). The Idea of "FQP Projectability Semicircle" in Determining the Freight Quality Partnership Implementation Potential of the City. Transportation Research Procedia, 16, 191–201. https://doi.org/10.1016/J.TRPRO.2016.11.019.

[18] Lagorio, A., Pinto, R. in Golini, R. (2016). Research in urban logistics: a systematic literature review. International Journal of Physical Distribution & Logistics Management, 46(10), 908–931. https://doi.org/10.1108/IJPDLM-01-2016-0008.

[19] Lebeau, P., Macharis, C., Mierlo, J. Van in Janjevic, M. (2015). Implementing an urban consolidation centre : involving stakeholders in a bottom-up approach. Urbe 2015, 1–17.

[20] Letnik, T., Farina, A., Mencinger, M., Lupi, M. in Božičnik, S. (2018). Dynamic management of loading bays for energy efficient urban freight deliveries. Energy, 159, 916–928. https://doi.org/10.1016/J.ENERGY.2018.06.125.

[21] Letnik, T., Mencinger, M. in Bozicnik, S. (2018). Dynamic Management of Urban Last-Mile Deliveries. City Logistics 2, 23–37. https://doi.org/10.1002/9781119425526.ch2.

[22] Lim, S. F. W. T., Jin, X. in Srai, J. S. (2018). Consumer-driven e-commerce: A literature review, design framework, and research agenda on last-mile logistics models. International Journal of Physical Distribution and Logistics Management. Emerald Group Publishing Ltd. https://doi.org/10.1108/IJPDLM-02-2017-0081.

[23] Lindholm, M. (2014). Successes and Failings of an Urban Freight Quality Partnership – The Story of the Gothenburg Local Freight Network. Procedia - Social and Behavioral Sciences, 125, 125–135. https://doi.org/10.1016/j.sbspro.2014.01.1461.

[24] Lisboa, U. De, Engenharia, F. De in Lisboa, U. De. (2015). Analyzing the effects of routing in the sustainability of the city and on the operational efficiency of urban logistics services. Urbe 2015, 1–15.

[25] McLeod, F. N., Cherrett, T. J., Bektas, T., Allen, J., Martinez-Sykora, A., Lamas-Fernandez, C., … Wise, S. (2020). Quantifying environmental and financial benefits of using porters and cycle couriers for last-mile parcel delivery. Transportation Research Part D: Transport and Environment, 82, 102311. https://doi.org/10.1016/j.trd.2020.102311.

[26] Muñuzuri, J., Cortés, P., Grosso, R. in Guadix, J. (2012). Selecting the location of minihubs for freight delivery in congested downtown areas. Journal of Computational Science, 3(4), 228–237. https://doi.org/10.1016/j.jocs.2011.12.002.

[27] Nesterova, N. in Quak, H. (2016). A city logistics living lab: a methodological approach. Transportation Research Procedia, 16(16), 403–417. https://doi.org/10.1016/j.trpro.2016.11.038.

[28] Nordtømme, M. E., Bjerkan, K. Y. in Sund, A. B. (2015). Barriers to urban freight policy implementation: The case of urban consolidation center in Oslo. Transport Policy, 44, 179–186. https://doi.org/10.1016/j.tranpol.2015.08.005

[29] Olsson, J., Hellström, D. in Pålsson, H. (2019). Framework of Last Mile Logistics Research: A Systematic Review of the Literature. Sustainability, 11(24), 7131. https://doi.org/10.3390/su11247131.

[30] Parent, M. (2007). Advanced urban transport: Automation is on the way. IEEE Intelligent Systems, 22(2), 9–11. https://doi.org/10.1109/MIS.2007.20.

[31] Quak, H. in De Koster, R. (2006). The Impacts of Time Access Restrictions and Vehicle Weight Restrictions on Food Retailers and the Environment. European Journal of Transport and Infrastructure Research, 6(2), 131–150.

[32] Roumboutsos, A., Kapros, S. in Vanelslander, T. (2014). Green city logistics: Systems of Innovation to assess the potential of E-vehicles. Research in Transportation Business & Management, 11, 43–52. https://doi.org/10.1016/j.rtbm.2014.06.005.

[33] Ruzzenenti, F. in Basosi, R. (2017). Modelling the rebound effect with network theory: An insight into the European freight transport sector. Energy, 118, 272–283. https://doi.org/10.1016/J.ENERGY.2016.12.011.

[34] Schliwa, G., Armitage, R., Aziz, S., Evans, J. in Rhoades, J. (2015). Sustainable city logistics — Making cargo cycles viable for urban freight transport. Research in Transportation Business & Management, 15, 50–57. https://doi.org/10.1016/j.rtbm.2015.02.001.

[35] Schrampf, J. (2013). ILOS - Intelligent Freight Logistics in Urban Areas: Freight Routing Optimisation in Vienna. Bestfact. Pridobljeno s http://www.bestfact.net/wp-content/uploads/2013/08/CL1_16_QuickInfo_ILOS-26July2013.pdf

[36] Taniguchi, E. (2014). Concepts of City Logistics for Sustainable and Liveable Cities. Procedia - Social and Behavioral Sciences, 151, 310–317. https://doi.

org/10.1016/j.sbspro.2014.10.029.

[37] Taniguchi, E., Thompson, R. G. in Yamada, T. (2014). Recent Trends and Innovations in Modelling City Logistics. Procedia - Social and Behavioral Sciences, 125, 4–14. https://doi.org/10.1016/j.sbspro.2014.01.1451.

[38] Taniguchi, E., Thompson, R. G. in Yamada, T. (2016). New Opportunities and Challenges for City Logistics. Transportation Research Procedia, 12(June 2015), 5–13. https://doi.org/10.1016/j.trpro.2016.02.004.

[39] Ville, S., Gonzalez-Feliu, J. in Dablanc, L. (2013). The Limits of Public Policy Intervention in Urban Logistics: Lessons from Vicenza (Italy). European Planning Studies, 21(10). https://doi.org/10.1080/09654313.2012.722954.

Comparison of the Legal Aspects of Acts of Unlawful Interference in Civil Aviation in the Conditions of the Slovakia and the Czechia

ALENA NOVÁK SEDLÁČKOVÁ, TATIANA REMENCOVÁ, DEANA MIKULOVÁ

Abstract The most important priority of all organizations in the field of air transport is safety and security. It is not only the safety of the flight and passengers, but also protection against acts of unlawful interference. This paper is focused on the issue of protection against acts of unlawful interference in civil aviation. It compares the basic terms of Czech and Slovak L17 (Annex 17), implemented into the Czech and Slovak civil aviation legal system. Subsequently, the document deals with the typology of threats, where not only specific events, which present air transport danger, are described, but also the measures taken in order to prevent these illegal acts. The next part is focused on the international development of legislation, from the oldest legal acts till today. Based on the comparison, the authors point out the differences, shortcomings and weaknesses in the legislation. The final part deals with modern technologies that could be used in the fight against acts of illegal intervention in the future and describes the vision of Smart Security 2040.

Keywords: • Unlawful Act • Annex 17 • L17 • ICAO • Security • Terrorism • Civil Aviation • International Agreements

CORRESPONDENCE ADDRESS: Alena Novák Sedláčková, doc. Ing. JUDr. Phd., Tatiana Remencová, Ing. Deana Mikulová, Bc., Air Transport Department, University of Žilina, Univerzitná 8215/1, 010 26 Žilina, Slovakia, e-mail: alena.sedlackova@fpedas.uniza.sk, e-mail: tatiana.remencova@stud.uniza.sk, e-mail: mikulova16@stud.uniza.sk

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

Given that air transport is one of the most used sectors, the impact of the international pandemic situation has been very significant. Countries around the world have been forced to close their borders in an effort to protect the health of their citizens and thus of society as a whole. A significant reduction in the number of passengers has led to the cancellation of almost all foreign flights, as has the reduction of travelling on domestic routes. Despite the fact that the pandemic has brought the sector of aviation to the bottom, it has faced several threats since its inception. It is air transport that has become the target of many terrorist attacks. At first, there was not much attention given to it, but the gradual development of international air transport brought an increase in terrorist attacks. Therefore, there is a need to feel safer, especially from the side of passengers, and also to be on board an aircraft without feeling threatened. This was why the concept of aviation security had to be placed at the top of the list of priorities, mainly after the attacks of the 11th of September 2001, when the threat of terrorism and crime became the current topic that received the most attention. The aim of this paper is to systematize and characterize the regulation of international civil aviation and to capture selected features that are characteristic of this area, while analysing the legal aspects of the methods used by international civil aviation to manage potential risks and threats. The paper also includes a comparison of the implementation of international standards in the legal systems of Slovakia and the Czechia with its evaluation. Finally, it describes future developments in this area, which is focused on the application of innovative technologies and methods in the field of civil aviation security and in this context, it describes the vision of "Smart Security" for security until 2040.

LITERATURE REVIEW

The issue of security in civil aviation is still current. The legislative framework needs to be regularly updated, because the development of modern technologies is very rapid. But we cannot forget the ingenuity and intelligence of potential perpetrators who threaten air safety. Legislation is thus one of the basic pillars on, which to rely if air transport is under attack and security is at stake. The paper Moravčíková et al. (2019) focused on civil aviation security measures in accordance with general EU legislation. The authors emphasize that the issue of security requires constant attention. The world is evolving very fast, so it is necessary to respond immediately and work to improve security measures and standards to avoid potential risks. In addition, it is necessary to continuously maintain a system of management and control of safety and security procedures [1]. Protection against acts of unlawful interference in air transport is also being investigated by Nowak et al. (2019). According to the authors, the airport security is the most sensitive area. It is the intrusion of unwanted persons and hazardous materials to the air transport that is the result of gaps in the security system, so it is necessary to focus more on this area [2]. The paper Sliwińska (2019) is based on solutions used to protect civil aviation against acts of unlawful interference. The author takes into account the organizational, legal, as well as operational and technical framework adopted in order to prevent illegal acts endangering security [3]. The theoretical-legal aspects of acts of unlawful interference in civil aviation at the international level were investigated by Myronets (2019). The study also deals with the concept of illegal acts in the Aviation Code of Ukraine. The author points to differences and ambiguities in terminology. As part of improving security, it recommends harmonization of legislation and, in particular, terminology at international level [4].

TYPES OF SECURITY THREATS

During the history of aviation security, many crisis situations prompted competent authorities to transform the methods of organization, implementation and evaluation of security issues [5]. Today, the typologies of threats against civil aviation can be broken down into several types. In any case, increasing trend of modern threats can be assumed, with new types of attacks that will threaten air security worldwide. Such threats include the following ones:

- Bomb on board of an aircraft;
- Hijacking of an aircraft;
- Attacks in the airport terminal area;
- Aircraft used as a weapon;
- Attacks from the ground;
- Attacks on airline offices outside airports;
- Sabotages;
- Cyberterrorism;
- Unmanned aerial vehicles [6].

INTERNATIONAL LEGISLATION FROM THE CHICAGO CONVENTION TO THE MONTREAL PROTOCOL

The origins of the need for legislation date back to the 1920s, when legal acts were issued against persons who knowingly endangered human lives and destroyed or damaged aircrafts. Nevertheless, the facts have not been defined from the point of view of crimes, Therefore, courts could not rule on such actions as criminal offenses. Due to the increasing trend of aviation offenses, it was necessary to establish international conventions designed to ensure protection of civil aviation against such acts [7].

The most important milestones in the development of international legislation dealing with protection against acts of unlawful interference include the following ones:

- Chicago Convention (1944) on International Civil Aviation, focusing on provisions governing mutual relations between countries at the international level;
- Tokyo Convention (1963) focusing on criminal or other acts committed onboard aircrafts;
- Hague Convention (1970) was more closely concerned with acts related to the unlawful seizure of aircrafts;
- Montreal Convention (1971) defined unlawful acts. Flight security also applies to aircrafts in service and to equipment used for air traffic control, as well as airports;
- Beijing Convention (2010) unlike its predecessors, it was based on the response to emerging security risks. It contained several significant changes concerning crimes in civil aviation;
- Montreal Protocol (2014) amended the Tokyo Convention and provided a comprehensive response to problems caused by the growing number of undisciplined passengers [7], [8], [9], [10].

INTERNATIONAL CIVIL AVIATION ORGANIZATION (ICAO)

In September 2016, more significant changes took place, when delegates of the 39-th session of the ICAO Assembly agreed acceleration of the development of the Global Aviation Security Plan, the so-called GASEP. It should be a tool for future civil aviation security policy and program in the context with security protection in civil aviation. Replacing the previous ICAO Comprehensive Aviation Security Strategy, it is focused mainly on the needs of states that seek effective ways of aviation security enforcement, through a set of internationally agreed priority actions, objectives and targets. It also provides a basis for the states, as well as for the industry concerned and it is mainly aimed to international cooperation in the area of increased security, with a view to achieving the following five most important key results:

1. Risen awareness in connection with possible risks and subsequent reaction.
2. Development of public security culture and skills.
3. Development of technological resources and support of innovations.
4. Improving the level of supervision and ensuring the required quality.
5. Support and cooperation of stakeholders and actors [11].

This plan can be considered as a kind of "living" document. It should be regularly reviewed and adjusted as necessary, so that emerging civil aviation security risks are adequately addressed [12].

MEASURES ISSUED BY THE EUROPEAN UNION

European Union was also forced to respond to the attacks of the 11-th of September. They did so by accepting aviation security regulation of 2002, also known as Regulation No. 2320/2002/EC, which provided for the introduction of collective rules in the field of security [13].

The following Seven Strategic Objectives has been adopted by the European Union as part of the Action Plan in the area of the fight against terrorist actions:

1. Efforts to improve the fight against terrorism on the international level and deepening international agreements.
2. Preventing access to capital and other economic resources that could be used by terrorists to their advantage.
3. In relation with the authorities of the European Union and its Member States, maximizing the potential to prevent, detect, investigate and prosecute terrorist attacks.
4. Ensuring protection of the security of international traffic and establishment of reliable systems at borders, including namely the following measures: detection of terrorists, finding their equipment, as well as their funds and/or material means. Such measures should be implemented in ports, airports, and border areas.
5. Improving capacity to cope with consequences of terrorist acts.
6. Preventing factors that contribute to the strengthening of illegal acts.
7. Focusing the European Union's action on the third countries in the context with external relations, with a view to deploy anti-terrorist groups in the fights against terrorist actions [7].

Inter alia, regulation in the EU is carried out today through legally binding Community standards, including the Regulation No. 300/2008 of the European Parliament and of the Council (hereinafter "EC") on common rules in the field of civil aviation security and implementing regulations, Commission Regulation (EU) No. 185/2010 laying down detailed measures for the implementation of the common basic standards on aviation security as amended, Commission Decision (EU) No. 774/2010 on laying down detailed measures for the implementation of the common security standards containing the information referred to in Article 18 of Regulation (EC) No. 300/2008, a decision, which is considered confidential with the application of standards not accessible to the public [14]. Currently the most important EU legal act is Commission Implementing Regulation (EU) 2015/1998 laying down detailed measures for the implementation of the common basic standards on aviation security and Commission Implementing Regulation (EU) 2020/910 of the 30-th of June 2020 amending Implementing Regulations (EU) 2015/1998, (EU) 2019/103 and (EU) 2019/1583 as regards the re-designation of airlines, operators and entities providing security controls for cargo and mail arriving from third countries, as well as the postponement of certain regulatory requirements in the area of cyber security, standards for background check of explosive detection systems equipment, and explosive trace detection equipment, because of the COVID-19 pandemic [15].

IMPLEMENTED LEGISLATION IN THE SLOVAK CIVIL AVIATION LEGAL SYSTEM AND THE ROLE OF INTERNATIONAL GOVERNMENT AND STATE ORGANIZATIONS

Slovak Republic is a member of EU since 2004, which means that regulation in the field of civil aviation is also taking place at the level of EU. EU institutions have taken over most of the powers of the Member States and have sought to establish common European rules and compliance with them [16].

Ministry of Transport and Construction of the Slovak Republic decides on the admission of international standards and recommendations of international organizations. The Ministry is also responsible for issuing other generally binding rules [7], [17].

The role of the Civil Aviation Division of the Transport Authority is primarily to ensure the performance of state administration and state professional supervision, compliance with tasks arising from the Aviation Act and amending certain laws as amended, legally binding EU acts and international treaties that commit the Slovak Republic to their implementation [18].

Act No. 143/1998 Coll. on Civil Aviation is the most important normative act dealing with legal regulation of protection against illegal acts. It is divided into twelve parts, the seventh part of, which deals with this issue [19].

Regulations "L" are primary documents in national legislation in terms of protection against illegal acts. They are issued through a regulation of the Ministry of Transport and Construction as the transformation and implementation of ANNEX 17. Their task is regulation of competence of specific subjects and natural persons participating on the organization, implementation and planning of air operations with the intention of the Member States to achieve maximum security and protection not only for passengers but also for crews, staff and the public [20].

National Security Program aims to achieve a high level of security, regularity and efficiency in air transport [21].

IMPLEMENTED LEGISLATION IN THE CZECH CIVIL AVIATION LEGAL SYSTEM

As well as the Slovakia, Czechia is also the part of EU, where the most important are EU regulations and harmonization of the legal acts. Due to Member States' efforts to transfer more powers to the European institutions, activities of national institutions have been significantly suppressed. For a simplified explanation, this concerns implementation and monitoring of the compliance with these rules at the national level, which results in significant restrictions on the creation of own standards [22].

Ministry of Transport of the Czech Republic is one of the most important bodies operating in the Czechia. They are responsible for the creation of state policy in the field of transport and within the scope of their competencies they also participate in their implementation. Air Transport Department deals mainly with the negotiation of international agreements and monitors measures and compliance with these obligations. Department of Civil Aviation Security also has a broad-spectrum function. Firstly, they carry out state coordination and revision of national programs, and secondly, they deal with accreditation for trainings, workshops and activities of the Interministerial Commission for Civil Aviation Security [22].

Civil Aviation Authority is subordinated to the Ministry of Transport. They are responsible for the implementation of substantial steps in civil aviation, in addition to investigating aviation accidents. Given the role of European rules, they play an important role of the national supervisory authority, whose responsibility is to monitor compliance with these regulations and the implementation of European legislation [23], [24].

Civil Aviation Act is the main document in the field of air transport in the Czech Republic. To date, it has been amended twenty-one times, with the last change taking place in 2016. It contains complete arrangement. Its eighth part is primarily devoted to aviation civil protection against illegal actions [25].

National Regulation L17 has been transformed into national legislation by the Ministry of Transport. The aim of this regulation is to ensure the maximum security of passengers, staff and crews in all areas of protection and to regulate the rights and obligations of entities operating in civil aviation [7].

National Security Programs of the Czech Republic initially served as amendments to Regulation L17, but currently they are issued as separate units on the basis of authorization in directly applicable law, which is based on the EU. Formally, the national security programs have been separated from the L17, but the rules are still contained directly in them. At the same time, there are other provisions imposed by the Ministry of Transport and the EU. The following three programs remained in total:

- *National Civil Aviation Security Program ("NBP")* is intended mainly for airport operators, carriers, the Czech Police and also customs authorities;

- *National Program for Security Training in Civil Aviation of the Czech Republic ("NBPV")* includes mainly the obligations of individual entities, procedures for the recruitment of newly hired employees, types of training and principles related to security training;
- *The National Program for Quality Management of Security Measures for the Protection of Civil Aviation of the Czech Republic against Illegal Acts ("NPRK")* ensures qualification, control of security audits, correction in measures if any deficiencies are found and, last but not least, deals with control activities [26].

The Aviation Act can be considered as the framework in terms of civil aviation legislation of both states, other legislation. In the special position are the regulations of the "L" series, which are implementation of the Annexes to the Chicago Convention to the Czech civil aviation legal system and being derived from Aviation Act. If we compare the Czech and Slovak L17, we must declare that the Czech one is suitably structured and all relevant information related to the given issue being clearly contained.

In our opinion, the Slovak Aviation Act is inappropriately systematized and the orientation in it was often quite time demanding. Gradually, there were several amendments in the field of civil aviation at the international level, which could be compared to the "accumulation" of new provisions in the aviation law, which resulted in the creation of an inconsistent system. If we compare the systems of these two mentioned states in terms of efficiency, practicality and better functioning, the Czech system is more suitable than the Slovak one. The role of ratification of the Bejing Convention 2010 is also different. While Czechia finalized the ratification process in 2014, it is still open in Slovakia in 2021; the Convention is in interdepartmental comment procedure.

ASSUMED DEVELOPMENT OF SECURITY MEASURES AND DETECTION METHODS INTO THE FUTURE

The security measures implemented at individual international airports worldwide may differ in several aspects. They depend in particular on the approach of the airport and the staff operating there and participating in their implementation. Ensuring the maximum standard in the field of security is important. The essential measures are complied with unified and innovated. Otherwise, undesirable actions could occur and adversely affects the air transport. The trend of recent years has shown that the practices and methods of perpetrators of illegal acts are increasingly more perfect and dangerous. Therefore, modernization and preparing airports for early intervention is necessary. Measures of airport security should be one step ahead of the perpetrators [27].

Preliminary assessment of passengers

The idea of creating a computer system capable of such an assessment date back to the period before the beginning of the new millennium. The first system of this type is the so-called CAPPS, whose task is to select potential perpetrators of the above-mentioned act and thus ensure increased control of the passengers and their luggage. In 2001 there were significant changes, which pointed to an almost smooth intrusion after overcoming security systems. Proposal for an improved version of CAPPS II came in 2003, which should compare passenger data with the state and commercial databases, and/or verify possible criminal activities or links of the entity to terrorist organizations or groups. Although they are expected to be updated in the coming years to ensure in-flight or airport security, the success of this system in the future is still questionable, as it faces problems from the outset, precisely because of people's concerns about disrupting their privacy [27], [28].

The Malintent device

The device has been developed as a supporting device in the context of illegal acts. Using sensitive sensors, it should be able to identify human behaviour and mind and/or his or her potential intention to harm his or her surroundings. The device should be able to work at a distance, i.e., in a contactless way. The system works on the basis of an analysis of body temperature, heart rate and respiratory rate, which cannot be seen with naked eye. Consequently, the data are sent for comparison with established standards. The system is very sophisticated. It can perform several concurrent activities and it can measure seven primary emotions or stimuli, which can be identified, for example, from micro-movements of muscles in the facial area. The idea of "reading ideas" is still under development in the coming years, and this concept could emerge at public international airports worldwide [28].

Centralized Image Processing (CIP)

Screening of cabin baggage using CIP consists of creating images of baggage that are generated by X-rays or 3D CT machines. This method has been implemented at several European airports and has been shown to potentially increase detection performance, throughput, capacity and/or staff satisfaction. Based on a systematic approach of several methods, the advantages and disadvantages of this system were evaluated on the basis of the knowledge obtained from its pilot operation. One of the main advantages is that security inspectors need not necessarily sit behind X-ray machines to take individual images and they can operate more devices at the same time. This means a more efficient way of working and more spatial flexibility in organizing image analysis. On the contrary, the disadvantage may occur, of placing these devices outside checkpoints and also their time limitation [29], [30].

Unauthorized handling of baggage

In recent years, airport managements were struggling with the problem of illegal handling of passengers' baggage, which mainly concerns its damage, opening or theft of its contents. This applies not only to European routes, but also on flights to the African continent, especially during the summer, when the number of flights to holiday destinations is increasing. However, it is not easy for the airport to determine exactly when and where the incident occurred, and Therefore, steps need to be taken to avoid such situations as much as possible. One of such measures is the employment of only such employees who are unimpeachable. Moreover, employees who work in the so-called sensitive areas, such as the apron, transit area or aircraft deck, are also inspected by the National Security Office. Another possible way to solve this problem is deployment of camera systems in places, where such incidents are likely to occur most often. For employees in these areas, this means continuous control, which is further enhanced by post-loading random checks, which include inspection of personal belongings, lockers in locker rooms or even company cars [28].

Operation measures

From the point of view of operation, it is recommended to introduce a larger number of patrols in the terminal building, around check-in counters or in crisis areas where increased attention is required, as well as to ensure adequate surveillance by means of a camera system, with the aim of prevention of any potential attack in such areas. Monitoring of luggage or items that are unattended and may pose a risk of danger by the staff is also an important measure [31].

Technical measures

There are several ways in, which technical measures can be introduced at an airport. One of them is implementation of camera systems used to identify and monitor potential perpetrators. Thermal cameras are mainly used to detect passengers who could transmit dangerous infectious diseases, so that measures against their subsequent spread can be taken in time. Modern airport perimeter protection technologies include whole perimeter signaling, which works on the principle of buried sensor cables. Such sensors act as high-frequency electromagnetic field emitters. The advantage of this system is the fact that it can filter out signals from any game, various species of birds or adverse weather conditions [31].

SECURITY 2040

Aviation security has changed significantly over the last decade, and new threats in the form of various kinds of chemicals, drones, lasers, and cyberterrorism have emerged. Besides of the flights themselves, airports are today seen as an ideal target, resulting in a gradual blurring of the line between security and security protection, along with an increase in protests and disruptions, not to mention the new challenge that air transport currently faces, i.e., the COVID-19 pandemic. Social networks, together with the Internet, represent a very easy anonymous way of threat, while they allow free cooperation and coordination of the various organized groups that mean danger for the civil aviation [32].

With the rapid advancement of technology in the future, we can predict how the trend in the field of security will develop. The new "Smart Security" vision for security in 2040 focuses mainly on the "whole airport" security system, while examining micro- and macro-level trends affecting airports, such as traffic growth, sustainability, passenger expectations, emerging security threats and consequences for airport infrastructure. Key elements of this vision include the use of data and risk assessment processes, predictive technologies, behavioral analysis, automation and intelligent threat detection. There is also the idea of a separate technology of explosives detection, which could be built into the airport terminal, as well as the idea of intelligent video surveillance, which should help identify threats on land in the event of an unusual behavior of persons or abandonment of items without any surveillance. Checkpoints should largely become automated gateways with intelligent threat detection. It is a likely future in this area, but it will require investment, more technologically advanced systems and, last but not least, regulatory changes. For smaller airports, a more appropriate way must be found to ensure more comprehensive and effective security [32].

ACI's Airport Excellence Programme (APEX)

There are experts from all over the world concentrated in the field of security, whose task is to thoroughly examine airports and select appropriate advice and recommendations based on their experience and expertise. In recent years, ACI has gathered several research and identified in particular those areas where airports have the biggest problem and need help. In this context, one of the key findings was that airports, security authorities and civil aviation approach the issue of security piece by piece. Some of the security issues after are still poorly understood, such as risk analysis, security culture or quality management [32]. But often it is not only about the management, but about the economic situation of the airport, where this kind of transformation can be too expensive for regional airports [33].

Management and organization

In terms of a managerial approach to security, it is not a newly created concept, but with greater emphasis, we will probably be able to withstand the challenges we face today. To ensure effective management, airports need to ensure provision of security services systematically, and this is a business-like approach. The following seven mutually interconnected components are known to have a decisive impact on a proactive, business-focused approach to security:

- management commitment;
- threats and risks management;
- allocation of resources;
- monitoring and performance measuring;
- quality management;
- accident management;
- Security Management System (SeMS) [32].

People and their performance

Ensuring the right human resources should be a cornerstone of security management, which includes, in particular, their recruitment, training, certification, and ensuring that they are sufficiently motivated to stay in the organization [34]. After hiring and training suitable adepts, the task is to monitor and measure their performance to ensure that they meet the security objective of the airport. Performance indicators mostly fall into the following three categories: performance, efficiency and passenger experience. Targets should be put in place, as well as tools to measure this data, as well as reporting systems, such as airport scoreboards and dashboards ensuring monitoring of the performance of security of the overall airport system. Should poorer performance than required is found, it needs to be examined whether more training is needed, or skills mismatch or overload occurred.

Quality control and audit

Individual airport security teams should have quality control programs in place, including audits, inspections, tests and, last but not least, drills. The shortcomings identified should lead to remedial action as a part of security measures, and at the same time it is possible to identify areas through these audits, where performance is not a problem. Then, more audits could be focused on places that need them more. Airports should have contingency plans in place and subsequently use them in the case of security incidents. After their completion, the aim is to examine the individual incidents in detail and learn from them. Priority should be given to continuing operations where the situation allows and where it is safe, as well as effective communication and maintaining confidence of staff and passengers, which can help to deal effectively with both small and large incidents and thus avoid costly evacuations and large losses.

System SeMS

It is important that the above-mentioned components work together so that the airport responds dynamically to ever-changing situations. As an example, new data can be cited, from quality control activities that would participate in the review and assessment of airport risk, which would subsequently lead to a change in the airport security program and the adoption of new measures. The aim of airports could be to focus on continuous improvement, either through their security programs or through the adoption of a security management system, known as SEMS, which is used by many aviation stakeholders. If this system works smoothly, it is much easier to integrate new practices, to face emerging threats and to ensure the smooth running of the business, despite incidents that may occur [32].

CONCLUSION

Air transport has been an ideal target for illegal acts in the last century. Therefore, there is a need to ask, why was it necessary to gradually amend and update the legislation? The answer is hidden in the very nature of air transport, which operates internationally. From the beginning, it was predestined to cross borders because of its global character. Due to non-uniformity of legislative and specific measures in individual states around the world, the risk of mutual conflicts has increased significantly, because the national regulation, which used to be sufficient, was no longer relevant at that time. There were suggested negotiations at international level as a possible solution in order to unify certain rules in air transport. If we want to answer to the question, whether the current state of air traffic is at a sufficient level and the maximum possible blow is ensured, the answer is ambiguous. A high level of safety and security can be achieved by respecting security measures and following methods and procedures in conjunction with the use of state-of-the-art technologies for the use of artificial intelligence [35, 36]. One of the problems that undermines the ideal situation is the fact that offenders are generally one step ahead of measures, and it is Therefore, very important that this difference is kept to a minimum when using innovative equipment. That's why, the last part of this article was focused on the development of technologies for the future, which should contribute to a better system of preventing attackers from committing any illegal activity, whether in airport areas or on-board the aircraft. In this way, we emphasize the necessity and importance of persons, who are involved in the field of civil aviation security, and we also recommend the harmonization of international regulation and possible solutions to ensure a better future in the field of security.

ACKNOWLEDGMENT

This paper was supported by national grant scheme VEGA 1/0695/21 Air transport and COVID-19: Research of the crises impacts with a focus on the possibilities to revitalize the industry.

REFERENCES

[1] Moravčíková, A. et. al. 2019. Protection of civil aviation against unlawful

acts. International Scientific Conference for Doctoral Students, 2019, Košice, Slovakia.

[2] Nowak, J. et. al. 2019. Protection of Air Transport againts acts of unlawful interference – Whats next? Transport Means Conference 2019. Wilnius, Latwia.

[3] Sliwinska, A. 2019. Operational solutions aimed at safeguarding civil aviation against acts of unlawful interference. In: Scientific Journal of Silesian University of Technology. Vol. 105, pp. 201-211.

[4] Myronets, O. et. al. 2019. Theoretical-Legal aspects of acts of illegal interference in civil aviation activity.

[5] Marriot, J. 2020. Todays Turbulence and Securing Tomorrows Skies. In: Aviation Security International. Vol. 26, pp. 18-19.

[6] Smetana, M., Ščurek, R. 2010. Základy boje proti terorismu. (Basics of the fight against terosism.) Ostrava: Ostravská Univerzita, 2010, 149 pages. ISBN 978-80-7368-823-3.

[7] Novák Sedláčková, A., Kandera, B. 2015. Medzinárodná úprava ochrany civilného letectva pred činmi protiprávneho zasahovania. Bratislava: Dolis, s,r.o, 2015. 133 pages. ISBN: 978-80-9191-028-2.

[8] Bína, L., Žihla, Z. 2011. Bezpečnost v obchodní letecké doprave.Akademické nakladatelství CERM s.r.o, 2011. 213 pages. ISBN: 978-80-7204-707-9.

[9] Report submitted to the Parliament of the Czech Republic: Úmluva o potlačovaní protiprávních činu souvisejících s medzinárodním civilním letectvím a Protokolu doplňujúcího Úmluvu o potlačení protiprávneho zmocnení se letadel. (online).

[10] Sipos, A. 2020. The dogmatics and Modernisation of International Conventions on Aviation Security. In: Elte law journal.

[11] ICAO Global Aviation Security plan (GASeP). Available on: https://www.icao.int/Security/Pages/Global-Aviation-Security-Plan.aspx.

[12] Doc 10118. Global Aviation Security Plan, first edition, 2017. [online]. Available at Internet: https://www.icao.int/Security/Documents/GLOBAL %20AVIATION %20SECURITY %20PLAN %20EN.pdf.

[13] REGULATION (EC) No 2320/2002 of the European Parliament and of the Council of 16 December 2002 establishing common rules in the field of civil aviation security [online]. Available at: https://op.europa.eu/sk/publication-detail/-/publication/89fe2ceb-4b2c-4491-b62a-d8cbd77615e0/language-sk

[14] Civil aviation security: EU-wide rules [online]. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM:tr0028.

[15] Commission implementing regulation (EU) 2020/910. [online]. Available at Internet: https://eur-lex.europa.eu/legal-content/SK/TXT/PDF/?uri=CELEX:32020R0910&from=EN.

[16] Pruša, J. et. al. 2015. Svět letecké dopravy. II. Praha: Galileo Training s. r. o., 2015, s. 55. ISBN 978-80-260-8309-2.

[17] Ministry of Transport and Construction of the Slovak Republic. [online]. Available at: https://www.mindop.sk/ministerstvo-1/doprava-3/civilne-letectvo/letecka-doprava.

[18] Transport office SR [online]. Available at: http://letectvo.nsat.sk.

[19] Act No. 143/1998 Coll. on Civil Aviation and amendment of certain acts (Aviation Act) [online]. Available at: https://www.zakonypreludi.sk/zz/1998-143.

[20] Aviation regulation L 17, of the Ministry of Transport.: Aviation regulation for the protection of civil aviation against acts of unlawful interference.

[21] National programme of protection of civil aviation against acts of unlawful interference [online]. Available at: https://www.mindop.sk/ministerstvo-1/doprava-3/civilne-letectvo/legislativa-v-oblasti-civilneho-letectva/pravne-predpisy-slovenskej-republiky-v-oblasti-civilneho-letectva/NPOCLPCPZ.

[22] Ministry of transport of the czech republic [online]. Available at: https://turbo.cdv.tul.cz/mod/page/view.php?id=3117.

[23] Civil aviation authority. Security, protection of international civil aviation against acts of unlawful interference: Aviation regulation L 17. [online]. Available at: https://aim.rlp.cz/predpisy/predpisy/dokumenty/L/L- 1/data/print/L-1_cely.pdf.

[24] Civil aviation authority [online]. Available at: https://www.caa.cz/urad-pro-civilni-letectvi/.

[25] ACT No. 49/1997 Coll., On civil aviation and amendment and adding later regulations to the Act No. 455/1991 Coll. on trade business (The Trade Licensing Act), as amended.

[26] Civil aviation authority. National programmes [online]. Available at: https://www.caa.cz/ochrana-civilniho-letectvi/narodni-programy/.

[27] Maršálek, D. et. al. Předběžné hodnocení cestujících za účelem zvýšení bezpečnosti civilního letectví. (Preliminary assessment of passengers in order to increase the security of civil aviation.) [online]. Available at: http://www.population-protection.eu/prilohy/casopis/20/140.pdf.

[28] Ščurek, R. Ochrana na letišti. (Airport protection.) [online]. Available at: http://abasreport.cz/casopisy/07/ochrana-na-letisti.

[29] Centralised Image Processing: The impact on security checkpoints [online]. Available at: https://www.semanticscholar.org/paper/CENTRALISED-IMAGE-PROCESSING- %3A-THE-IMPACT-ON/13d42d0b22035248462dfcd3aeda0462f52f55a7.

[30] Buser, D., Merks. S. 2020. Centralised Image Processing: challenges, trends and time on task. In: Aviation Security International. Voll. 26, pp. 33-35.

[31] Ščurek, R. Studie analýzy rizika protiprávních činů na letišti. (Airport crime risk analysis study.) [online]. 2009. Available at: https://www.fbi.vsb.cz/export/sites/fbi/060/.content/galerie-souboru/studijni-materialy/analyzy_rizika_letisti.pdf.

[32] Brooks, N. 2020. A new old approach to security? New threats, new challenges. In: Aviation Security International. Vol. 26, pp. 16-17.

[33] Remencová, T., Sedlácková, A.N.2021. Modernization of Digital Technologies at Regional Airports and its Potential Impact on the Cost Reduction. Transportation Research Procedia pp. 18–25.

[34] Novak, A., Badanik, B., Brezonakova, A., & Lusiak, T. 2020. Implications of crew rostering on airline operations. Transportation Research Procedia 44, pp. 2-7. doi:10.1016/j.trpro.2020.02.001.

[35] Novák, A., Havel, K., & Janovec, M. (2017). Measuring and testing the instrument landing system at the airport zilina. Transportation Research Procedia 28.pp.117-126. doi:10.1016/j.trpro.2017.12.176.

[36] Labun, J., Kurdel, P., Novák, A. (2020). Analysis of the Earth's surface influence on the accuracy of ADF. Transportation Research procedia 51. pp. 333-341.

SECTION 2:

GREEN FUELS AND VEHICLES

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Understanding the Financial Impact of Electrification of Small to Medium Fleet Operators

THARSIS TEOH, AAD VAN DEN ENGEL, MANFRED KINDT

Abstract The transition of small to medium fleet operators to battery electric vehicles must be supported in order to achieve decarbonisation targets at the national and EU level. The current bottleneck remains the cost of purchasing vehicles, and the purchase and construction of charging infrastructure. The study provides a transparent comparison with a diesel vehicle of both the investment and total cost of ownership for the switch to electric fleets. The results show the very high cost of investment and the very low level of subsidies currently available to offset the investment. The potential cost for grid upgrades, especially in the case of large fleet sizes, could potentially double the cost of the charging system, thus should be avoided if possible. For heavier vehicles, due to the reliance on external charging, the cost of energy is not lower than for fuel. The evaluation of the impact of a zero-emissions zone fine, toll cost, and ,9-tax on diesel vehicles on the total cost of ownership for the electric vehicle compared to the diesel vehicle show that the ZEZ fine and toll policy would be quite effective in its current state. However, adjustments to fit the vehicle segment could be made to improve its effectiveness, while reducing unintended outcomes. Overall, it is expected that the cost for the entire transport sector will increase, whether due to the policies, the use of the electric vehicles or alternative distribution forms, thus it is important to ensure the safety net for businesses and customers disproportionately affected.

Keywords: • Logistics Fleets • Electric Vehicles • Charging Infrastructure • Total Cost of Ownership

---

CORRESPONDENCE ADDRESS: Tharsis Teoh, Aad van den Engel, Manfred Kindt, Panteia, Bredewater, Zoetermeer, Netherlands, e-mail: t.teoh@panteia.nl

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

The decarbonisation of the road transport sector is a key priority in the European Green Deal and the Sustainable and Smart Mobility Strategy [1]. Besides the overall reduction of greenhouse gas emissions (up to 55 % by 2030 and up to 90 % by 2050 from 1990 levels), the intermediate aim to achieve these targets is to increase the number of zero-emission cars, vans and lorries in operation.

The light duty segment – vehicles with gross vehicle weight (GVW) below 3,5 tonnes - has recently started growing, as in 2020 1,9 % of all vans sold were battery electric [2]. However, the growth of the medium to heavy duty segment is still small compared to the EU fleet, with only 0,4 % new registrations [3].

It is nevertheless expected that the entire transport industry will shift or be made to shift towards the use of ZEVs. Taxes and subsidies have been introduced and may continue to be introduced to reduce the comparative financial burden of the switch. Policies that restrict access to non-environmental modes of transport, such as low or zero emission zones, will strongly impact the transport industry with consequences that are yet, still difficult to predict [4]. The transport industry will need to make strategic fleet management decisions to react to the changing policy landscape and market needs [5]. This affects especially smaller firms, especially in the small to medium fleet range, who do not have as much capital buffer to spare.

This study addresses the financial aspect of a fleet management decisions, in particular the cost for making the switch. Besides the costs of the vehicle purchase, the transport operator will also need to account for the cost of charging system or services, which could be substantial under certain conditions. The study uses the total cost of ownership (TCO) approach to provide a comprehensive view of the costs that would be incurred to a transport operator adopting an electric vehicle for their logistics operation. Aspects that have not yet been introduced in literature are the detailed costs of ownership of the charging system. The study will look at the TCO of several transport scenarios to explore the different sensitivities to the transport policies introduced for the energy transition.

The next section presents an overview of the methods and data used in the study, followed by a section on the results and a discussion about the results. The final section is a conclusion on the work and further research directions.

METHODS AND DATA

The study uses three basic steps:

1. Define the TCO framework that will encompass all key aspects of the vehicle system and all possible interactions with it.

2. Define the cost parameters based on literature and stakeholder input.

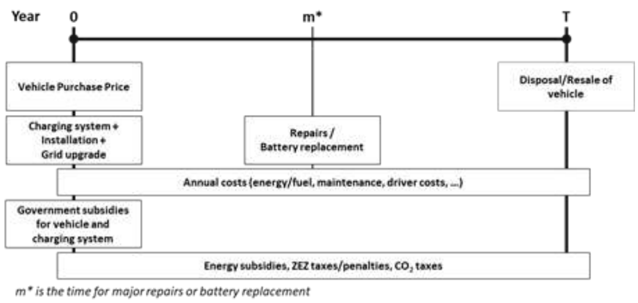
3. Define the scenarios that will be instructive for understanding the challenges facing small and medium fleets.

Total cost of ownership framework

The total cost of ownership (TCO) approach was adopted to balance out the usually heavier costs of capital with the much lower expected operating costs for electric fleets [6]. Figure 1 presents the key costs that will need to be considered while the vehicle is in service of the fleet operator. Some of the usual ones include the purchase price of the vehicle, the cost of operating and maintaining it and finally the potential resale value. Besides the incidental major repairs, electric vehicles may also need to replace their battery once the performance of the battery deteriorates. Some manufacturers offer a battery replacement warranty to cover that cost. The cost of the driver's time might be included if charging activity causes the work shift duration to increase.

The purchase and installation of the private charging system is a significant cost, and could be worse if the grid connection at the parking facility needs to be upgraded, for example from a low voltage to a medium voltage substation. The upgrade strongly depends on the number of vehicles that will need to be simultaneously charged, as well as the charging power level.

Figure 1. TCO framework for electric freight vehicle system



In line with the discussion about government intervention to incentivize the electric mobility transition, various taxes and subsidies might need to be included. They affect the investment costs, as well as the on-going costs. The Netherlands has introduced two subsidies that reduce the investment cost: the *Milieu-investeringsaftrek* (MIA), which provides a deduction of taxes depending on the environmental impact reduction, and the *kleinschaligheidsinvesteringsaftrek* (KIA), which reduces the amount of profit taxed in a year for small-scale investments. Other cost and subsidies that might be relevant are for energy use, whether in diesel excise taxes or in subsidizing electricity, for taxing the entry into a ZEZ or for CO_2 taxes.

Data collection

The cost parameters have been collected in three different research projects and have been validated by stakeholders from the transport and charging industry, research institutes focusing on electric vehicles, charging and grid infrastructure, and policy makers. These are summarized below.

Table 1. Basic parameters specific to vehicle

Vehicle segment	Small rigid truck (7,5 t)	Large rigid truck (18 t)	Tractor-trailer (< 40 t)
Mileage (km)	35 000	70 000	100 000
Fuel efficiency (L/km)	0,10	0,29	0,44
Battery capacity (kWh)	120	200	440
Electricity consumption (kWh/km)	0,48	1,34	2,08
DV maintenance (€/km)	0,05	0,06	0,08

The price of the electric vehicle is an increased price based on the size of the battery and cost per kWh of € 350. The maintenance cost for the electric version is 50 % of the diesel version, although fixed repair costs are also considered: € 1 500 for diesel and € 5 000 for electric. The price of diesel is € 1,30 per litre, while the basic price for electricity is € 0,09 per kWh. For external charging, the costs vary from 30 to 50 cents per kWh. The rate emissions of CO_2 are 3,24 kg per litre of diesel, while it is zero for the electric vehicle. The service lifetime of the diesel vehicle is 7 years, while it is 10 years for the electric vehicle. The resale value percentage is 23 % for the diesel vehicle and 12 % for the electric vehicle.

Scenario definition

The scenarios used in the study are composed of

- Transport operation scenarios, which define how the vehicle is being used.
- Policy scenarios, which define the taxes and subsidies that are relevant.

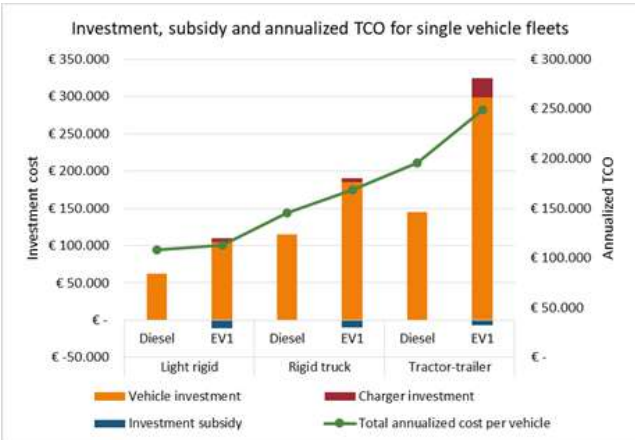
The transport operation scenarios have been presented in Table 1. Three different vehicle types are tested with different mileage values. These are based on standard values used in the Netherlands.

The policy scenarios studied here are the investment subsidies (the MIA and KIA), the diesel excise tax, a unit subsidy for private charging, a per kilometre toll for diesel vehicles, penalty for entering a ZEZ, and a CO_2 tax. The actual values are presented together with the results.

RESULTS AND DISCUSSION

Figure 2 presents for single vehicle fleets the investment, Dutch subsidies and the annualized TCO for the three vehicle sizes. Even with the subsidies the investment difference is 37, 66 and 173 thousand for the three vehicle segments. While it is expected that the investment difference for the heavier vehicles is higher than for the smaller vehicles, the figure also shows that the TCO difference also increases accordingly. Further, the current level of subsidy covers only a very small fraction of the difference between investments for the EV and the diesel vehicle: 23 % for the light rigid, 13 % for the rigid truck, and 4 % for the tractor-trailer. One concludes here that although the transition for the heavier vehicle segment is more financially challenging, the investment subsidies provided are not proportional to that challenge. This problem is compounded, when fleet sizes increase, as will be discussed later.

Figure 2. Investment, subsidy and annualized for TCO for single vehicle fleets



Figures 3 to 5 show the breakdown of the TCO per vehicle without considering the driver and overhead costs for the different vehicle sizes, as well as for different fleet sizes. In the figures, EV1 to EV30 refers to an EV fleet of size 1 to 30, accordingly. The breakdown shows how a single diesel and electric vehicle compares. For the light rigid, the cost of diesel is much higher than the cost of charging and the annualized cost of the charging system. However, the vehicle depreciation, maintenance and repairs, and fixed costs are higher for the EVs. Interestingly, the cost of diesel and charging is approximately the same for the rigid truck and the tractor trailer. This is largely due to the higher reliance on external charging services to ensure that the EV completes the required driving distance. The cost of external charging services are at least 3 times higher than charging on premises. The rigid truck relies on external charging for 56 % of its energy requirement. The share is 62 % for the tractor-trailer. Hence, the intended savings cannot be obtained, unless the en-route charging services are performed at the depot, which only works for short distance trips, or if the charging costs are carefully negotiated to be lower than what the market currently offers passenger cars (i.e., a range of between € 0,30 to 0,50 without VAT).

Figure 3. Light rigid absolute cost and indexed to the diesel vehicle

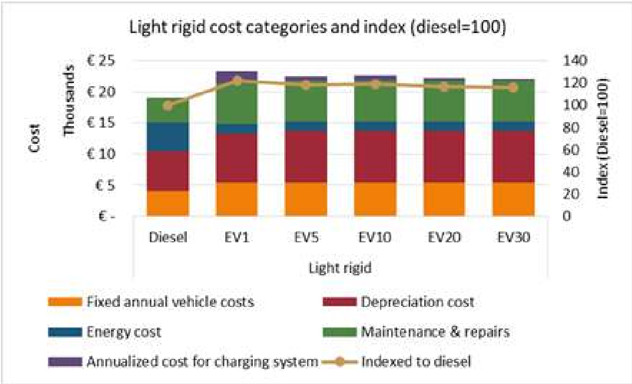


Figure 4. Rigid truck absolute cost and indexed to the diesel vehicle

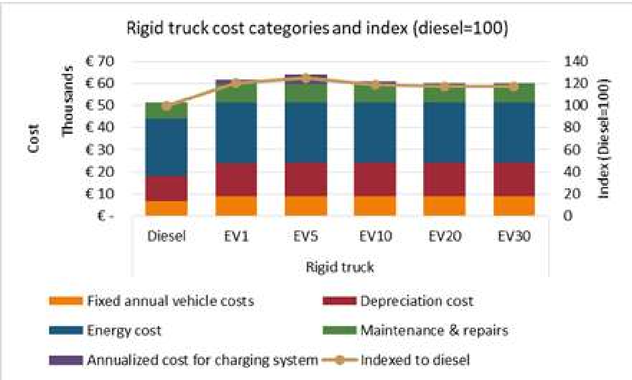
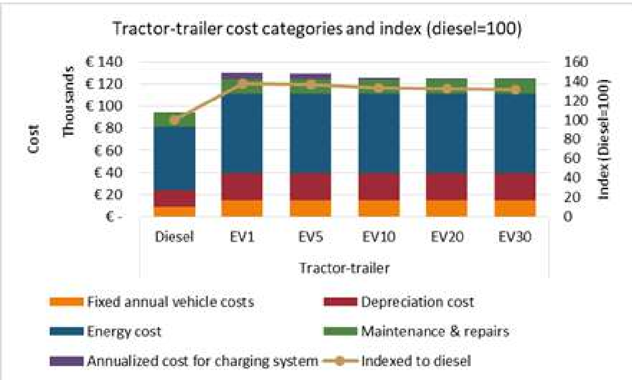


Figure 5. Tractor-trailer absolute cost and indexed to the diesel vehicle



The figures also show how the cost develops with increasing fleet sizes, which is only a very slight downward trend. The main driver of the cost difference is the type and number of charging systems used. The light rigid and the rigid truck could use AC 22 kW charging system, especially if only one vehicle will need to be charged. However, if the DC charging system is required, the cost is much higher. This is the reason for the steep increase for the tractor-trailer combination, as well as for EV5 for the rigid truck. Nevertheless, the more powerful systems could also serve multiple vehicles at the same time or at least during the same charging duration, such as overnight of 8 hours, thus reducing some of the fixed costs.

Adding to the cost of installation of the charging systems is the cost of upgrading the overnight parking facility's grid connection, if necessary. This was necessary for fleet sizes 10 and above for the light rigid vehicle and fleet sizes 5 and above for the other two vehicle segments. The additional capital expenditure ranged from an additional 116 to 590 thousand euros, which approximately equalled the actual cost of the chargers and the on-site installation. While the impact on the TCO is only a small percentage, it is necessary to ensure that the initial investment can be covered by either public or private financing.

Three penalties on the diesel use, besides the excise tax, were evaluated. Table 3 presents the indices for the EV compared to the diesel vehicle with the following penalties considered. The first is the penalty for entering the ZEZ. In the Netherlands, the ZEZ will become a reality, even for freight vehicles, by 2025. In the study, it is assumed that out of the 7 years that the diesel vehicle is in service, the ZEZ penalty will only apply for the last 3 years. In Amsterdam, the penalty could be in the range of € 250, as it currently is for the environmental zone [7]. The annualized cost would be € 27 857 assuming the infraction occurred for 260 days in a year, which as Table 2 shows would strongly improve the comparative business case.

Table 2. Indices for annualized cost for EV1 depending on the policy scenario, indexed to diesel vehicle without any policy

Vehicle segment	Light rigid	Rigid truck	Tractor-trailer
EV1: No policy scenario	123	120	138
EV1: ZEZ fines	50	78	106
EV1: Toll	106	105	123
EV1: CO_2-tax	119	113	128
EV1: All policies	46	69	92

The Netherlands also plans to introduce a toll for each kilometre travelled on a highway, but perhaps exempt zero-emissions vehicles. While this would vary depending on the weight of the vehicle, it is expected to average 14,9 cents per kilometre [8]. The impact is also significant, reducing the percentage increase of the TCO to only less than 10 % for the light rigid and rigid truck. Finally, as we see the

CO_2-tax, currently assumed to be € 50 per CO_2-tonne [9], has only a small impact on the TCO difference, with the assumption that only green electricity is used for charging. Nevertheless, if all policies were in effect, this would significantly reduce the TCO difference.

Table 3. Breakeven analysis for ZEZ fine, toll, and CO_2-tax

Vehicle segment	ZEZ fine (€/day)	Toll (€/km)	CO_2-tax (€/tonne)
Light rigid	38	0,21	360
Rigid truck	90	0,21	160
Tractor-trailer	314	0,47	240

A breakeven analysis was conducted by identifying the point when the TCO of the EV becomes favourable compared to the diesel vehicle. The results are summarized in Table 3. It shows that for the ZEZ, the current fine of € 250 would be sufficient to push the light fleets towards using an electric vehicle, but not the tractor-trailer. The driver could theoretically incur a penalty every working day and the operation would still be cheaper than the TCO of the electric tractor-trailer.

The toll road cost of 14,9 cents seems to be lower than necessary to account for the full TCO difference between the diesel and electric vehicle. Even though the plan is currently to vary the cost by weight, it would be difficult to triple the toll for the tractor-trailer.

Finally, the breakeven analysis of the CO_2-tax shows that the current cost of € 50 would need to triple to help the support the TCO of the rigid truck. This is unlikely to develop in the (free) carbon market. Hence, the CO_2-tax should not be considered an effective tool by itself for the energy transition in the transport sector.

A brief analysis of the increase in transport costs for the diesel vehicle is presented in Table 4. This is an important aspect to consider, as the increase in transport cost due to policy could result in a number of changes in the transport sector, such as increase of utilisation/consolidation or multimodal transport, increase cost to shippers, and reduction of transport demand, besides the investment in EVs [10]. As the table shows, if ZEZ fine is implemented at the expected rate, and the carrier is for some reason, unable to use an EV, the transport cost would more than double, with terrible social effects. Hence, the policy should be sensitive towards the effect and ensure that drivers can actually make the transition.

Table 4. Indices for annualized cost for DV depending on the policy scenario, indexed to diesel vehicle without any policy

Vehicle segment	Light rigid	Rigid truck	Tractor-trailer
DV: No policy scenario	100	100	100
DV: ZEZ fines	246	154	129
DV: Toll	116	114	112
DV: CO_2-tax	103	106	108
DV: All policies	265	175	149

While it is out of scope of the paper to forecast the impact of the policies on other distribution forms, such as the use of cargo bicycles and microhubs, incumbent carriers will unlikely shift towards these forms, as alternative urban logistics forms are also similarly cost prohibitive [11].

CONCLUSION

The paper analysed the effects of the switch from diesel to electric vehicles for 3 vehicle segments using the TCO approach. Some of the key results of analysis show the large difference in investment costs, which translates into a large difference in TCO, both of, which are prohibitive towards large-scale adoption of electric vehicles. The current investment subsidies are only a fraction of the investment differential for the heavy vehicle segment, which points to its ineffectiveness.

The study also considered the potential costs of grid upgrades, which may need to be transferred to the user in some cases, or at least serve to delay construction. The outcome of that analysis showed that the annualized TCO only increases by a little, however the investment cost for the entire charging system could almost double. Carriers will have to consider a piecemeal transition to spread the investment costs, although that will complicate the efficient deployment of the charging infrastructure.

The effect of some policies that are being introduced, namely the ZEZ, the road toll for diesel vehicles, and CO_2-tax, aim to increase the diesel vehicle TCO and thus reduce its advantage over the electric vehicle. Overall, the ZEZ fine for entry seems to have the highest impact on the TCO and can also be introduced stage-by-stage depending on how the electric vehicle market develops. Currently, it would seem that the light rigid of less than 7,5 tonnes, such as the eCanter, or even lighter vans, such as eCrafter or eSprinter, could be easily encouraged with a moderate ZEZ fine of at least € 38.

The ZEZ policy only affects trips to urban areas [12], hence for long distance transport, the toll and CO_2-tax needed to be investigated. Increasing the toll to a level that it tilts the balance towards electric vehicles is more plausible than increasing the CO_2-tax to an effective rate. The estimation of the CO_2-tax also assumes that the electric vehicle uses green electricity, thus producing no well-to-wheel emissions either.

The evaluation did not consider shifting towards hybrid vehicles or fuel cell electric vehicles. The market for fuel cell vehicles is less developed and the costs for vehicle and infrastructure much higher, thus will not strongly affect the study. However, hybrid or range-extended electric trucks is a missing part of the analysis. While, the market for these options is also largely absent, it remains an important option for carriers in the ZEZ [13].

In each option, it would nevertheless seem that the future transport sector would increase in cost to the carriers and ultimately towards shippers and receivers. If the cost propagates towards clients of the transport business, it would affect the long term logistics performance and increase the cost of retail and other services. Current vehicle subsidies are insufficient to make up the difference, the most touted policies in Europe, currently relate to the urban vehicle access regulations, the Eurovignette toll road, and the revamping of the EU emissions trading system [14]. Future policy research will need to develop smarter ways to encourage the use of electric vehicles, while ensuring that the cost in the sector does not increase unfairly.

REEFERENCES

[1] European Commission, Directorate-General for Mobility and Transport (2020). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Sustainable and Smart Mobility Strategy – putting European transport on track for the future. COM/2020/789 final.

[2] ACEA (2021). 2021 Progress Report: Making the transition to zero-emission mobility.

[3] ACEA (2021). Medium and heavy trucks over 3.5 t new registrations by fuel type in the European Union.

[4] Broaddus A, Browne M, Allen J. Sustainable Freight: Impacts of the London Congestion Charge and Low Emissions Zones. Transportation Research Record. 2015;2478(1):1-11. doi:10.3141/2478-01.

[5] Nesbitt, K., & Sperling, D. (2001). Fleet purchase behavior. Decision processes and implications for new vehicle technologies and fuels. Transportation Research Part C: Emerging Technologies, 9 (5), 297–318. doi:10.1016/S0968-090X(00)00035-8.

[6] Teoh, T., Kunze, O., Teo, C.-C., & Wong, Y. (2018). Decarbonisation of Urban freight Transport Using Electric vehicles and opportunity charging. Sustainability, 10(9), 3258. doi:10.3390/su10093258.

[7] Amsterdam, G. (2021, August 31). Milieuzone vrachtauto's. Amsterdam.nl. https://www.amsterdam.nl/veelgevraagd/?productid= %7B01301856-3A38-4B22-88BC-07D278CDBB9A %7D#case_ %7B4BE9EF11-4442-44E5-90C1-

E8344A511815 %7D.

[8] Ministerie van Algemene Zaken. (2021, May 11). Plannen voor INVOERING VRACHTWAGENHEFFING. Goederenvervoer | Rijksoverheid.nl. https://www.rijksoverheid.nl/onderwerpen/goederenvervoer/vrachtwagenheffing.

[9] Thomson Reuters. (2021, May 4). EU carbon price hits record 50 euros per tonne on route to Climate target. Reuters. https://www.reuters.com/business/energy/eu-carbon-price-tops-50-euros-first-time-2021-05-04/.

[10] De Jong, G. C., Schroten, A., van Essen, H, Otten, M, & Bucci, P (2010). The price sensitivity of road freight transport: A review of elasticities. Applied transport economics, a management and policy perspective, De Boeck, Antwerp.

[11] Nallapeta A, Teoh T. (2020) Methodology to evaluate performance of urban transshipment last mile network with electric vehicles in low emission zones. Presentation. 7th International Workshop on Sustainable Road Freight. Online. 28-30 October 2020.

[12] de Bok M, Tavasszy L, Kourounioti I, et al. Simulation of the Impacts of a Zero-Emission Zone on Freight Delivery Patterns in Rotterdam. Transportation Research Record. May 2021. doi:10.1177/03611981211012694.

[13] City of Rotterdam. Roadmap ZECL: Moving towards Zero Emission City Logistics (ZECL) in Rotterdam in 2025. Rotterdam, City of Rotterdam, 2019.

[14] European Commission (2020) Sustainable and Smart Mobility Strategy – putting European transport on track for the future. COM(2020) 789.

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Drones Usage in Urban Areas as an Environmentally-Friendly Solution

LIDIJA TOMIC, OLJA ČOKORILO

Abstract The accelerated technological development, as well as an increasing range of drone applications are highly likely to resolve various urban issues, simultaneously ensuring the safety and sustainability in those urban areas. By performing, a both indoor and outdoor mission in extremely challenging environments, the use of drone technology is cost-effective, available on demand, and environmentally-friendly. Drones will be used for surveillance, delivery and for people mobility in context of air-taxis, as predicted for the near future. The main expected environmental benefit is that, compared with many traditional methods of surveillance, delivery and mobility, drones could reduce CO_2 emissions, as well as other air pollutants. But there are also many other benefits in term of safety and quality of life in urban areas. Moreover, industries need to understand and learn how to manage the risks that may come from drone operations. The aim of this study is to present environmental benefits of using drones in urban areas and to evaluate the risks that their usage poses to other airspace users and third parties on the ground, by using a detailed SWOT analysis, which helped in developing full awareness of all the factors involved in process of drone's integration into urban areas. The paper concludes with an overview of possible and planned drone applications in the urban environment, and by suggesting the requirements for their safe integration.

Keywords: • Drones • Urban Areas Solutions • Delivery • SWOT analysis • Aviation

CORRESPONDENCE ADDRESS: Lidija Tomić, Msci, PhD Student, Olja Čokorilo, PhD, Full Professor, University of Belgrade, Faculty of Transport and Traffic Engineering, Vojvode Stepe 305, 11010 Belgrade, Serbia, e-mail: lidijatomic11@gmail.com; e-mail: o.cokorilo@sf.bg.ac.rs

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

Technology of unmanned aerial vehicle (UAV), commonly known as drone, is evolving at a very fast pace, and has increasing potential to compete successfully with more traditional alternatives in a number of sectors including commercial, governmental and leisure purposes.

The forecast growth in drone's market is also based on the strong interest expressed by large multinational companies, such as Amazon, DHL, and Google (European Environment Agency, 2020).

On the other hand, there have been increasing concerns about the rapid urbanization of population. About a half of total world's population of 7 billion people lived in urban areas in 2010 according to the survey of United Nations and this is predicted to become over 60 % by 2030. Under such demographic conditions mobility and freight transport issues have become more important for supporting a better life for people, as well as a better environment in urban areas [10].

However, logistics activities sometimes generate traffic congestion, air pollution, noise, and crashes in urban areas. Also, in many big cities, because of heavy traffic jam or severe air pollution from vehicle exhaust, vehicle-type restriction is implemented. For example, delivery vehicles are forbidden to run on some roads during defined periods [6].

Compared with traditional vehicles, drone delivery can reduce energy consumption and greenhouse gas emissions, which benefits environmental sustainability [6]. Besides, drones can overcome mentioned traffic restrictions, which are of big influence in terms of delivery time.

Moreover, there are challenges of integrating drones into urban environments. Namely, these areas are already densely used by ground traffic, other types of air traffic –, such as commercial airplanes and military aviation. Also, there are people concerned about emission, privacy and the possibility of low-level flights causing accidental injury.

It is intuitively clear that adequate harmonized regulation and appropriate concept of drone operations are needed for balancing the desire to maximize the commercial benefits of drones against the need to ensure the safety, security and privacy of citizens, and also the potential environmental impact on cities.

DRONES AS ENVIRONMENTALLY-FRIENDLY SOLUTIONS

The academic literature discussing drones' pros and cons or attempting to quantify their emission impact, is increasing day by day. This chapter is based on literature review of conducted research projects regarding drone's emissions.

CO_2 and other greenhouse gas emissions

In their research about environmental impact of drone delivery on an online shopping system Koiwanit (2018) showed that drone delivery is one of the most environmentally friendly transportation options throughout a wide range of scenarios [1].

Authors Park, Kim and Suh (2018) showed in their research [7] that global warming potential (GWP) per 1 km delivery by drone was one-sixth of motorcycle delivery, and that the particulates produced by drone delivery were half that of motorcycle delivery. Also, they showed that actual environmental impact reduction, in consideration of the delivery distance, was 13 times higher in a rural area than in an urban area.

Goodchild and Toy (2017) showed that the relative CO_2 emissions of drones compared to trucks vary according to the drones' energy requirements, travel distances, and number of recipients. This means that in order to increase the advantages of drone delivery in terms of CO_2 emissions, energy requirements should be low, the delivery distance should be short, and the number of recipients should be small [7].

Study [9] looks at the climate impact of a shift from truck-based to drone-based package delivery. It finds that while the small drones carrying packages weighing less than 0,5 kg would reduce greenhouse gas emissions, compared to diesel or electric trucks anywhere in the US, and that the same is not true for larger drones carrying heavier packages.

Namely, Stolaroff et al. (2018) founded in their research that the current practical range of multi-copters to be about 4 km with current battery technology, requiring a new network of urban warehouses or waystations as support [9]. Authors suggested that there are several emission sources that must be considered when evaluating or modeling emission:

- Emissions from fuels;
- Emissions from electricity;
- Emissions from battery production;
- Emissions from warehouses.

Also, Stolaroff et al. (2018) suggested that in order to realize the environmental benefits of drone delivery, regulators and firms should focus on minimizing extra warehousing and limiting the size of drones. The analysis utilizing real-world data indicates that UAVs, presently available in the market, are significantly more CO_2 efficient (around 47 times) than typical diesel delivery vehicles in terms of energy consumption. In terms of emissions the differences are even greater (more than 1000 times). However, the analysis is done in terms of energy consumption and emission per unite distance and per kilogram of payload delivered, so there is a need to consider type of payload and planned delivery distance. Hence, author find that, the UAV is not more efficient than electric vans in delivery scenarios with more than 10 customers per route [2].

Noise emissions

The number of drone operations has strongly increased in the last years and is likely to further grow in the future. Therefore, drones are becoming a growing new source of environmental noise pollution, and reactions to drone noise are likely to occur in urban areas. Schaffer (et al.) in their study established a systematic literature review on drone noise emissions and noise effects on humans. Results suggest that drone noise is substantially more annoying than road traffic or aircraft noise due to special acoustic characteristics, such as pure tones and high-frequency broadband noise. Also, they show that emission strength primarily depends on the drone model and payload, as well as on the operating state or the flight maneuver [8].

SWOT ANALYSIS

SWOT (Strength, Weaknesses, Opportunities and Threats) analysis is a tool primarily used in strategic planning with the aims of creating an overall picture of the advantages and disadvantages that an organization may expect from a certain project. This analysis highlights the "strengths" and "opportunities" on one hand, and "weaknesses" and "threats" on the other [11].

The following Table 1 presents a SWOT analysis that answers the following question: What are the benefits and concerns regarding drone usage in urban areas?

Table 1. SWOT analysis

Strengths	Weaknesses
Shortest operations (delivery) distance Extended connectivity Faster operations (delivery) Real-time information Flexibility Mobility and accessibility to remote areas Available on demand Precision operations	Difficult to use in complex meteorological conditions Common airspace with manned aviation Easily hacked Vulnerable to wild animals Citizen privacy could be violated Drones are not equipped with collision avoidance system Limited on-board accommodation
Opportunities	**Threats**
Reduction of greenhouse gas and noise emission Reduction of traffic jams Reduction of cost Increased efficient of operations Reduction of emergency response time	Common airspace with manned aviation Loss of control over drones Drone malfunction Complex design of urban cities (tall buildings, bridges) Wildlife

Strengths

The main strengths of drone usage in urban areas include: shorter operations distance (which enable faster operations, which then means less greenhouse gas emissions), extended connectivity, real-time information, but also flexibility, mobility and accessibility to remote areas, which enable ad-hoc operations with great level of precision.

Weaknesses

Regarding weaknesses of drone operations in urban areas they cover operational, technical, safety and security concerns. Like a fixed-wing aircraft and helicopters, drone operations depend on current weather condition. Complex weather condition (strong wind, fog, thunderstorms, icing conditions, etc.) may disrupt the planned operation or caused the damage to drone. Also, as drone use common airspace with manned aviation there are possibility of some airspace restrictions that can interfere planned operations.

Technical weaknesses include: limited on-board accommodation (both for required equipment like sensors, and payload) and lack of collision avoidance system for UAV (not developed yet).

The real-time information, enabled by using drone's on-board cameras, presents one of the main strengths of drone usage in urban areas, but at the same time this means weaknesses because citizen privacy could be violated.

Opportunities

Opportunities are external factors in process environment that are likely to contribute to success and positive project outcomes. For drone's usage in urban areas, main opportunity refers to reduction of greenhouse gas and noise emission, as highlighted in previous chapter. Other opportunities cover increased efficiency of operations, better urban environment in term of traffic density, but also safer environment for citizens by taking advantage of drones' ability to respond quickly to emergencies.

Threats

The last part of SWOT analysis includes threats. Threats refer to factors that have the potential to harm some process, environment, or organization. For drone's usage in urban areas, some threats are listed in table below. Firstly, there are factors connect with drone issue: loss of control and vehicle malfunction, which hold with them risk of injury to staff and/or third parties on the ground and damage to critical infrastructure. Additional to drone technical issues, main threats refer to use of common airspace with manned aviation (civil and military aircraft).

The threat to wildlife, especially birds, is also one of the key concerns. Operating at low altitude, usually below 500 meters, drones are likely to come into contact with wild animals. European Environment Agency said that drones can also have a detrimental impact on an animal reproduction and survival and some studies suggest that the essence and intensity of impact will depend on a variety of factors, including the type of drone and its method of operation, the species of animal and many other contextual factors, such as habitat, season and life-stage.

DRONE USES IN URBAN ENVIRONMENT

Drones, originally developed and used for military purposes, have found applications in many civil sectors during the last decade. Mentioned applications have been gradually expanding across leisure, commercial and governmental fields from surveillance and rescue operations to delivery and people mobility.

Drones can be equipped with various sensors and cameras for doing intelligence, surveillance, and reconnaissance missions. On the other hand, when equipped with appropriate equipment (other than camera) drones can be used for missions, such as firefighting, de-icing/anti-icing of infrastructure, gardening support etc. The table below (Table 2) lists some of the possible area of drone application.

Table 2. Possible drone applications in urban areas

Purpose	Area of application	Purpose	Area of application
Remote sensing	Emission detecting	Mapping and surveying	Monitoring illegal waste, damp and transport of toxic water
Real-time monitoring	Situation awareness		Wildlife monitoring
	Inspection of infrastructure		Cartography
	Weather monitoring	Search and Rescue	Firefighting
	News and journalism		Locating survivors
Delivery	Medical supplies	Missions by onboard equipment (other than camera)	Gardening support
	Food		Providing wireless coverage
	Shipment		De-icing/anti-icing of infrastructure
Recreational	For fun		Bird control
	Drone racing and sports	Model in design phase	Determination of object optimal position
	Recording of events	Mobility- Air Taxies	Point to Point travel within a city
	Entertainment and attractions		Shuttle service to airport
Public Safety and Security	Patrolling		Transport of injured person
	Crime prevention / investigation		Sightseeing by air taxi
	Border surveillance		

One of the expected applications is Urban Air Mobility (UAM), which refers to an ecosystem that enables on-demand, highly automated, passenger or cargo-carrying air transport services with particular reference to the urban environment. The UAM industry vision involves new vehicle designs (e.g., low emission / low noise), new system technologies, the development of new airspace management constructs, new operational procedures and shared services to enable an innovative type of transport network [5]. The following chapter discuss about UAM societal acceptance.

UAM societal acceptance

The European Union Aviation Safety Agency (EASA) conducted a comprehensive study on the societal acceptance of Urban Air Mobility across Europe, to measure EU citizens' preparedness to accept this new mode of transport and collect their possible concerns and expectations related to safety, security, privacy and environmental impact.

The online quantitative survey polled 4 000 citizens in six European urban areas - Barcelona, Budapest, Hamburg, Milan, Oresund (Danish-Swedish cross-border area) and Paris. The survey showed that [4]:

- 83 % of respondents have a positive initial attitude towards UAM;
- With 71 % ready to try out UAM services.

Also, survey shows that cases in the common interest, such as in emergencies or for medical transportation received strong support. EASA will use the study results to prepare regulatory proposal for Urban Air Mobility in Europe in 2022.

REQUIREMENTS FOR DRONE SAFE INTEGRATION IN URBAN AREAS

The fast development of drone operations makes legislation and standardization necessary, so the first recommendation is regulatory framework (Table 3). New concept of operations with set of *"easy-to-use"* rules is also required, following requirements of airspace segregation for special type of operations. It should be noted that within the Europe, special concept of operations in term of airspace usage is already developed and more information about *U-space* concept will be provided in the following chapter.

Table 3. Requirements for drone safe integration in urban areas

Requirements for drone safe integration in urban areas
Regulatory framework
Concept of operations
Set of easy-to-use rules
Airspace segregation- zoning
Coverage with essential aeronautical information to fly safely
Reliable communication (C2) link
Reliable tracking and monitoring systems
(Autonomous) detect and avoid solutions for small drones
Emergency Response and Recovery Plan
Risk assessment for any change

Like manned aviation, unmanned flights rely on accurate aeronautical information to stay informed about the weather, airspace restrictions and regulations during a flight. [5] The variety and complexity of drone operations requires a different approach to managing this aeronautical information, but in the first-place adequate coverage with such information is needed.

Drones rely on a high level of digitalization to operate autonomously and depend upon datalink communications to achieve this. So, the reliable C2 link and tracking and monitoring systems are also required.

By authors opinion collision avoidance equipment has been identified as the key requirement regarding the UAV safe access within the airspace, so the appropriate detect and avoid (DAA) solution is needed promptly.

U – SPACE CONCEPT

The rapid growth in use of drones has increased the demand for access to non-segregated airspace. In particular, there is a strong pressure on very low level (VLL) operations where the market is driven by new business opportunities. For VLL operations, many procedural and technological areas require further development, and this lies behind the U-space concept. U-space is a set of new services relying on a high level of digitalization and automation of functions, and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones [3].

Figure 1 and Table 4 shows the U – space concept phases, their objectives and expectations, but also concept implementation plan (timeline).

Figure 1. U–space concept

Source: www.sesarju.eu [10]

Table 4. U- space concept- objectives and expectations

Phase	Objective	Expectations / Benefits
U1	To identify drones and operators and to inform operators about known restricted areas (e-registration, e-identification and pre-tactical geo-fencing)	The range of VLOS routine operations will be extended
U2	Support the safe management of drone operations and a first level of interface and connection with ATM/ATC and manned aviation	The range of operations at low levels will be increased, including some operations in controlled airspace
U3	Unlock new and enhanced applications and mission types in high density and high complexity areas	Significant growth of drone operations, new types of operations, such as UAM
U4	Offering integrated interfaces with ATM/ATC and manned aviation	The full operational capability of U-space based on a very high level of automation

Overall, introduction of U – space concept will enable safe drones' operations and interactions with other entities using the same airspace in any location.

CONCLUSION

Drones will be part of our future. Rapid changes in drone technology hold enormous promise for the future use of airspace.

While the list of application a drone can be used for, continues to increase, more ways to save the planet via a drone will begin.

The delivery of goods in urban areas using drones stands out the most, but there are also equally important applications, such as patrolling, firefighting, checking the surfaces in winter conditions, that could improve the quality, security and safety of life in urban areas. A factor that may significantly favor drone is a shorter travel distance as a shorter distance would result in a less emissions. As the drones is not more efficient than electric vans in delivery with more than 10 customers per route, it is needed to carefully determine warehouse locations (and recharge stations) to provide optimal coverage of customer market and to maximize benefits of drone technology.

The positive results about societal acceptance of Urban Air Mobility across Europe indicate that new concept of people mobility will be seen in the near future.

Regarding noise emission, results of research projects suggests that drone noise is substantially more annoying than road traffic or aircraft noise and depends on the drone model and payload, as well as on the flight maneuver.

Also, it can be concluded that increasing the use of environmentally friendly electricity systems, such as solar and wind power, would further enhance the environmental effects of a drone usage in urban areas.

REFERENCES

[1] Koiwanit, J. (2018). Analysis of environmental impacts of drone delivery on an online shopping system. Advances in Climate Change Research (Vol. 9, Issue 3, pp. 201-207). ISSN 1674-9278, https://doi.org/10.1016/j.accre.2018.09.001.

[2] Figliozzi, M.A. (2017). Lifecycle modeling and assessment of unmanned aerial vehicles (Drones) CO2e emissions, Transportation Research Part D: Transport and Environment (Volume 57, pp. 251-261). ISSN 1361-9209, https://doi.org/10.1016/j.trd.2017.09.011.

[3] Sesar JU website: https://www.sesarju.eu/sites/defa ult/files/documents/reports/European %20ATM %20Master %20Plan %20Drone %20roadmap.pdf.

[4] Ebaa website https://www.ebaa.org/industry-updates/easa-publishes-results-of-their-uam-societal-acceptance-study/.

[5] Sesar JU website:https://www.sesarju.eu/sites/defaul t/files/documents/uspace/Supporting %20Safe %20Secure %20 Drone %20Operations.pdf.

[6] Li, Y., Yang, W., & Huang, B. (2020). Impact of UAV Delivery on Sustainability and Costs under Traffic Restrictions. Mathematical Problems in Engineering (Vol. 2020, Article ID 9437605), https://doi.org/10.1155/2020/9437605.

[7] Park, J., Kim, S., & Suh, K. (2018). A Comparative Analysis of the Environmental

Benefits of Drone-Based Delivery Services in Urban and Rural Areas. Sustainability. 10(3):888. https://doi.org/10.3390/su10030888.

[8] Schäffer, B., Pieren, R., Heutschi, K.et al. (2021). Drone Noise Emission Characteristics and Noise Effects on Humans — A Systematic Review. International Journal of Environmental Research and Public Health. 18(11), 5940. https://doi.org/10.3390/ijerph18115940.

[9] Stolaroff, J.K., Samaras, C., O'Neill, E.R. et al. (2018) Energy use and life cycle greenhouse gas emissions of drones for commercial package delivery. Nat Commun 9, 409. https://doi.org/10.1038/s41467-017-02411-5.

[10] Taniguchi, E. (2014). Concepts of City Logistics for Sustainable and Liveable Cities, Procedia - Social and Behavioral Sciences (Volume 151, pp. 310-317). ISSN 1877-0428, https://doi.org/10.1016/j.sbspro.2014.10.029.

[11] Tomić, L., Čokorilo, O., & Macura, D. (2020). Runway Pavement Inspections Using Drone – Safety Issues and Associated Risks. International Journal for Traffic and Transport Engineering, 10(3), 278 - 285.

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Application Possibilities of Delivery Drones in the Case of Concentrated Sets of Delivery Locations in Budapest

DÁVID LAJOS SÁRDI, KRISZTIÁN BÓNA

Abstract In the last few years, several research projects were investigating the city logistics applications of drones; their suitability has already been tested in several projects. In our research, we examine the concentrated sets of delivery locations in, which large quantities of goods are handled in a relatively small area. In our paper, we examine, which delivery tasks could be suitable for drones in the examined city logistics system and how many drones are needed for these delivery tasks, based on Budapest's example. First, we would like to introduce the existing drone delivery systems and the related research directions. Next, we are going to examine based on the statistical analysis of real data from Budapest, which delivery transaction types could be suitable for drones. After this, we would like to present the new city logistics concepts with drones and the results of a queuing-theory-based methodology to calculate the number of delivery drones, and we are going to show the critical points of the deliveries in the examined city logistics concepts. These results can help in the future the application of delivery drones in the city logistics system of the concentrated sets of delivery locations, as based on real data, we define in our paper those delivery types, where the delivery drones are applicable, and we define the critical points of this system as well.

Keywords: • City Logistics • Drone Delivery • Shopping Mall • Shopping Area • Market

CORRESPONDENCE ADDRESS: Dávid Lajos Sárdi, Krisztián Bóna, PhD, Budapest University of Technology and Economics, Department of Material Handling and Logistics Systems, 1111, Bertalan Lajos utca 7-9., Budapest, Hungary, e-mail: david.sardi@logisztika.bme.hu

 ISBN 978-961-95633-0-4

INTRODUCTION

An important research area in city logistics is the study of the so-called urban concentrated sets of delivery locations (referred to as CSDLs). These are sets of delivery locations, where a significant number of delivery locations with high demands are in a relatively small area, like in the case of markets or shopping malls [1], which are in the focus of the City Logistics Research Group of the Budapest University of Technology and Economics [2]. For this research, we can classify the delivery locations into two main groups: single delivery locations and concentrated sets of delivery locations that include several single delivery locations according to some aspect. In this paper, we will examine how drones can be integrated into the city logistics system of these CSDLs. Within the CSDLs, there are two types of concentration. In the case of open infrastructure, we have an area where roads and squares mark the boundaries of the CSDL, such as a shopping area surrounded by streets. By closed infrastructure, we mean any building that brings together single delivery locations into CSDLs, such as shopping centers [1]. In our research, we have developed several different new system concepts for these CSDLs, collected data from more than 600 stores in 6 CSDLs in Budapest [4], [5], [6], and used them to investigate their logistics system using simulation models. In the new concepts developed, consolidation centers and cross docks are set up to improve the efficiency of the flow of goods, and the simulation results show that performances, emissions, and logistics costs could be reduced in the consolidation-based new systems of CSDLs [3], [4]. In the new city logistics concepts developed, we have modeled environmentally friendly road vehicles, urban railways (cargo trams), and cargo bicycles, but we have also investigated concepts using waterway deliveries [4], [7], [8], [9]. As the city logistics system under study includes many small volume and small size delivery units, which could be handled even by drones, we started to investigate the potential applications of delivery drones in the case of CSDLs. As a first step, we considered it important to examine how drones could fit into these new consolidation-based city logistics systems, which tasks they could perform, how the integration of drones into the system could be implemented and how many drones might be needed in these systems. In this paper, we would like to describe first the current city logistics systems using drones, then present the main directions of related research, and then show the results of our data analysis of CSDLs in Budapest, which can be used to identify the delivery tasks for, which drones could be used in the city logistics system under study. After that, we present our new concepts with drones, the definition of the drone fleet size, and the drone supply chains of the concepts, their critical points, and the related challenges.

DRONE DELIVERY SYSTEMS

In recent years, delivery drones have been used in several pilot systems for various delivery tasks, mainly in suburban or rural environments. Among the systems already developed and operating at least at a pilot level, the Paketkopter concept of DHL is worth mentioning (see Figure 1), which has been successfully used in four pilots [10]. DHL is also involved in a pilot system in Guangzhou, China [11], where the transport cost per transaction has been reduced by 80 %.

Figure 1. The drone of DHL with a parcel machine

Source: [12]

In Daimler's pilot in Zürich, vans and drones were used in combination to deliver e-commerce products on demand [13]. Amazon's concept, under development since 2013, plans to operate autonomously operating drones for home delivery of packages [14], and Google's Project Wing is planned for longer-distance delivery tasks [15]. Also worth mentioning is the delivery drone concept of UPS and Wingcopter, where special drones capable of carrying larger packages are planned to deliver goods [16]. It is important to highlight that the pandemic situation in 2020 has significantly boosted the logistics use of drones due to the potential for contactless delivery. Because of this, many new drone systems were born in 2020 to deliver essential products and medicines [17], [18]. Those drone systems, which will provide technical input for the data analysis in the following parts of our paper, are presented in Table 1, with their weight, capacity, and range of the drones.

Table 1. Most important data of some drone systems to provide technical input for the data analysis

Name and location of the drone delivery system	Weight	Capacity	Delivery distance
AHA, Reykjavík, Iceland	10 kg	3 kg	10 km
DHL, Ukerewe, Tanzania	N/D	4 kg	65 km
DHL, Guangzhou, China	N/D	5 kg	8 km
UPS delivery drone concept	12 kg	6 kg	45 km

It is also worthwhile to discuss the related research directions. The most popular one in the field of drones in city logistics is the development of new algorithms for route planning adapted to drones [19], so if we can identify the delivery tasks that we want to handle with drones in the future in the case of CSDLs, we will have several available algorithms. Closely related to this field is the study of the energy consumption of drones [20] and their batteries, as their range is a key issue in optimal route planning. Another related issue is the study of the location and the optimal number of charging stations [21], as these may also need to be implemented into the route planning algorithms. There are also some papers on solutions using vans and drones together [22], which could help overcome the problems caused by the shorter range of drones. The issue of operation costs [23], which has also been addressed in several articles, is also worth mentioning and will be a significant area for further study in the case of the CSDLs, as well as autonomous operation, technology, and the regulatory environment.

DELIVERY TASKS OF DRONES

In the next part of our paper, we would like to show in detail how drones could be integrated into the examined city logistics system of the concentrated sets of delivery locations based on our data on CSDLs in Budapest. In the data analysis, we were able to analyze data from 6 CSDLs in Budapest, with a total of 627 stores [4], [5], [6]: 377 stores in 4 shopping centers, 163 stores in the "Váci utca" shopping area, and 87 stores in 1 market with closed infrastructure. Most of the stores we could examine are in the categories "Clothes, bags, shoes, accessories" and "Food, beverages". For the stores we examined, we had data on deliveries, deliveries between stores, and home deliveries available for analysis in sufficient depth; these will be described in the next part of the paper.

For the analysis, the suitability of four different drone types (sizes) was investigated: the Flytrex drone of AHA (3 kg payload, 10 km range, application: Reykjavík, Iceland) [24], the DHL Paketkopter version 4 (4 kg payload, 65 km range, application: Ukerewe, Tanzania) [10], the Ehang drone of DHL (5 kg payload, 8 km range, application: Guangzhou, China) [11], and the delivery drone concept of UPS and Wingcopter (6 kg payload, 45 km range) [16].

Supplier deliveries

As a first step, we identified the number of stores where the actual deliveries could be handled by drones without splitting deliveries into more parts. Based on the results, even with UPS&Wingcopter's 6 kg capacity drones, only 9,7 % of all stores could be served. These stores typically handle small volumes of goods, so in a consolidation-based new city logistics system, it is not worth singling them out and transporting them separately from the large volumes. Next, we examined how many deliveries could be made using a drone, based on the weight of the delivery units, investigating not only those cases where a single delivery could be handled by a drone but those deliveries as well where individual delivery units (e.g., single boxes, hangers) could be transported. Using the Wingcopter's drone with a 6 kg payload, 1 919 deliveries would be required on an average day, serving 211 stores, with only 10,5 % of the sum volume of goods. Based on these results, it can be concluded that the volume of goods does not make it worthwhile to manage deliveries with drones, but as more than half of the stores (57,1 %) have drone deliveries, urgent deliveries could be handled by drones between the consolidation center and the CSDLs.

Deliveries between stores

In the next step, we examined the deliveries between stores of CSDLs. This can be divided into two parts, deliveries from another store and deliveries to another store, as the system is not symmetric, with different quantities being delivered in and out of each store. In the first case (from other stores), we were able to work with data from 481 stores, and for deliveries to other stores, we were able to use responses from 548 stores. Of these stores, 121 have deliveries from other stores (25,2 % of the stores), and 181 have deliveries to other stores (33 % of the stores). Regarding the amount of goods to be handled, 67 stores provided sufficient data for the analysis on the incoming side and 88 on the outgoing side. The sum volumes are not large, with a total of 3,7 tons of goods to be handled per day; these are presumably smaller delivery units, most of, which can be handled by drone. Once the volume of goods had been determined, the number of drone deliveries required was calculated. In the analysis, stores that would require more than 10 deliveries per day by drone were classified as not drone-serviceable (so in their case, bigger vehicles are needed). In the analyses, it was assumed that the other store was at a reasonable distance from the CSDL under consideration, with adequate drone range. The number of drone deliveries required to handle the incoming volumes is shown in Figure 2, and the outgoing case is shown in Figure 3. The figures show separately the stores in different types of CSDLs (SM: shopping malls, SA: shopping areas, MA: markets) for the use of drones with various capacities (3 kg, 4 kg, 5 kg, 6 kg).

Figure 2. Daily number of drone deliveries to handle the incoming quantity from other stores

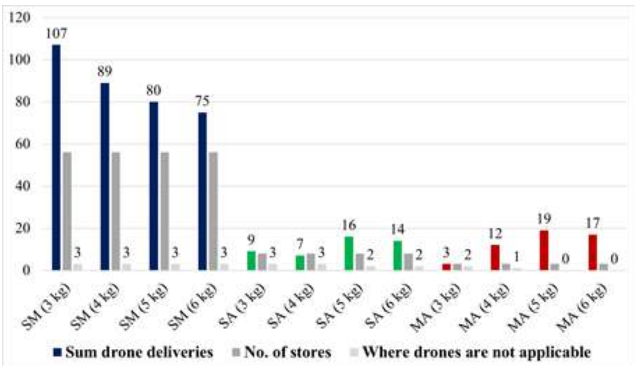
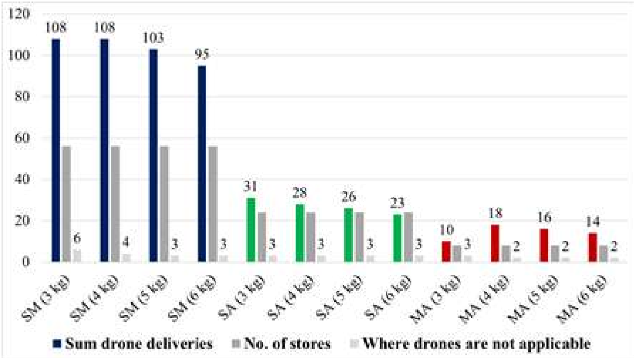


Figure 3. Daily number of drone deliveries to handle the outgoing quantity to other stores



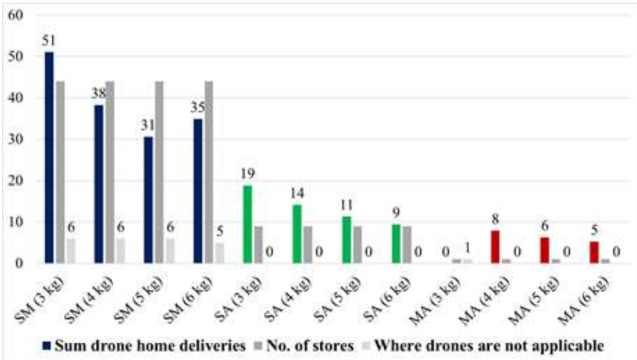
It can be concluded that on the incoming side, based on data from 67 stores, an average day would require 106-119 delivery transactions between stores per day, depending on the drone type, which would mean an average of 1,71-2,02 deliveries per store per day (only considering stores that are suitable for drone delivery), while 5-8 stores would require a larger delivery vehicle, depending on the examined drone type. On the outgoing side, based on the data of 88 stores, on an average day, 132-154 deliveries between stores would be required, depending on the drone type, which would mean an average of 1,65-1,96 deliveries per store per day, while 8-12 stores would require a larger delivery vehicle, depending on the drone type.

In the case of the deliveries between stores, both the volumes to be handled and the frequency of the deliveries allow a significant proportion of deliveries between stores to be made by drones in a city logistics system of the CSDLs, and the number of delivery transactions can be further reduced if inbound and outbound transactions can be combined, minimizing the expected number of empty flights. In addition, although we have been able to analyze data from relatively few stores at present, the responses we have received suggest that the number of stores requiring deliveries between stores is only approximately 2-2,5 times higher, which would not increase the volume of goods to be transported to unmanageable levels.

Home deliveries

Finally, we examined the home deliveries. Regarding them, we received data with sufficient detail for a total of 98 stores, of, which a total of 3,7 tons of goods needs to be delivered to home delivery locations (or to parcel machines) per day. Next, we subtracted the goods of customers located more than 10 km away from the CSDLs, which were classified as not drone-serviceable home delivery locations, as they were typically rural demand points outside the city. This left a total of 1,4 tons of goods to be delivered by drone per day, or 14,5 kg of goods per store per day (considering only stores that have relevant drone deliveries). In the analysis, stores that would require more than 10 deliveries per day by drone were classified here as not drone-serviceable. Based on these, the required daily number of drone home deliveries can be seen in Figure 4.

Figure 4. Daily number of home deliveries with drones



Based on the data from the 54 stores that are capable of drone home delivery and also provided the quantity of goods, it can be estimated that on an average day, depending on the type of the drone, 49-70 drone home delivery (or parcel machine) transactions would be required, which would mean an average of 1,01-1,49 deliveries per day per store (only considering stores that are capable of drone delivery), while the home delivery processes of 5-7 stores would require a larger delivery vehicle, depending on the type of the drone. In addition, in most of the cases, "Food, Beverage" would need to be delivered to home delivery locations, and there are already many examples of this as presented previously in our paper. It can be concluded that both the volumes to be handled at the same time and the frequency of the deliveries allow for a significant proportion of home deliveries to be made by drones in a city logistics system of the CSDLs.

INTEGRATION OF DRONES INTO THE EXAMINED SYSTEM

In the next step, we show the potential role of drones in new consolidation-based concepts for city logistics of the CSDLs, complementing the basic concepts previously published by our Research Group [4], [8]. The current city logistics system under study is the one described in Figure 5, with the delivery vehicles indicated at each stage (notations: red line – supplier delivery, green line – empties delivery, blue and orange line – deliveries between stores in two directions, purple dashed line – home delivery/parcel machine delivery, light blue dashed line – pick-up from parcel machines, factory icon – supplier, warehouse icon – wholesaler/logistics provider, loading icon – CSDL's logistics area, store icon – store, parcel machine icon – parcel machine, house icon – home).

Figure 5. The current city logistics system of the CSDLs

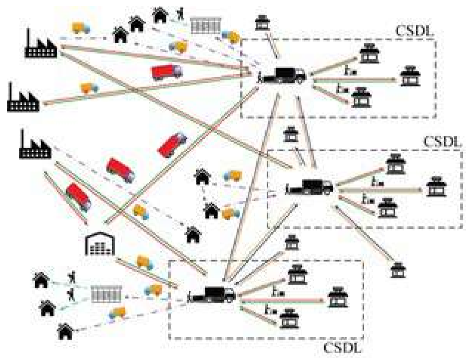


Figure 6 shows how the new, consolidation-based city logistics system will evolve, with road vehicles for regular deliveries and drones for urgent deliveries (new notations: warehouse icon - consolidation center, loading, and warehouse icon – cross dock).

Figure 6. Deliveries from the CC to the CSDLs with road vehicles and drones

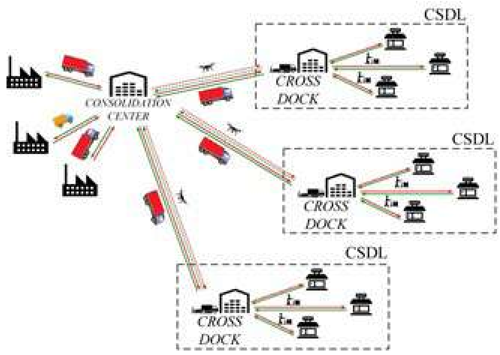


Figure 7 shows how we can manage the deliveries between stores in this system, using drones for the smaller parcels and bigger vehicles for the larger parcels. The more distant stores are served by using the consolidation center in this concept (new notations: parcel icon - small parcel, pallet icon - larger parcel).

Figure 8 shows how home deliveries can be handled and how parcel machines can be served by drones. The more distant home delivery locations are served by using the consolidation center.

Figure 7. Deliveries between stores with road vehicles and drones

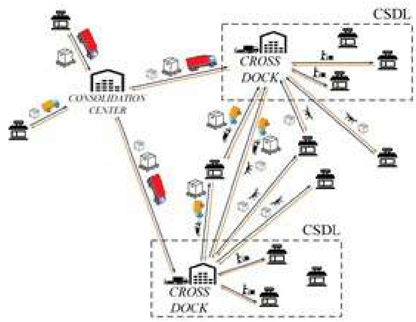
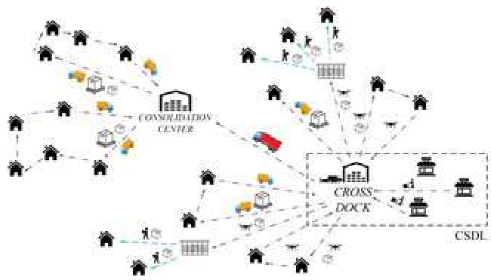


Figure 8. Home deliveries with road vehicles and drones

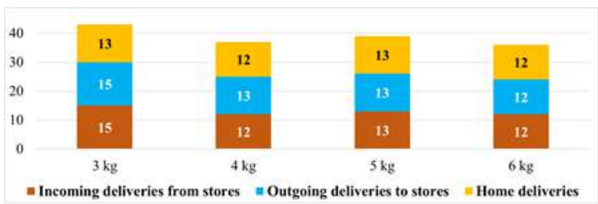


With these figures, we got those city logistics solutions that must be modeled in the next steps of our research. The next important question is how many drones would be needed to perform the given tasks in these systems.

Size of the drone fleet

After developing city logistics system concepts using drones, we estimated how many drones could be used to perform the tasks in the cases under study. For this analysis, the model used was based on queuing theory [25]. Here, the two directions of the deliveries between stores and home deliveries were examined separately for each CSDL and for each of the examined 4 drone types. If all drone-capable delivery tasks are performed by drones, we receive the results shown in Figure 9, with a maximum waiting time of 15 minutes for the delivery needs, and with a 95 % reliability.

Figure 9. Optimal size of the drone fleet (R=95 %)



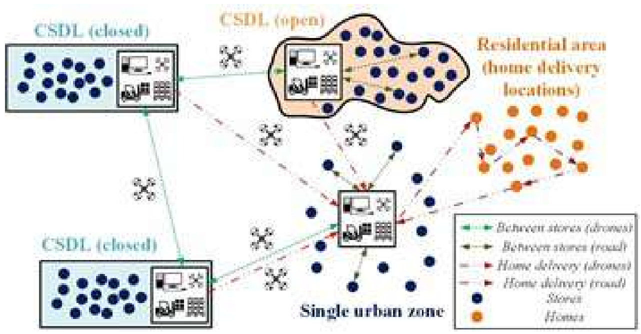
The results show that a total of 12-13 drones is needed for home deliveries (or for parcel machine deliveries), while 12-15 drones would be required for the deliveries between stores in both directions, giving a total of 36-43 drones for the delivery tasks under consideration. For home deliveries, 98 stores would be served by this number of drones (average 7,5-8,2 stores/drone), 67 stores for incoming deliveries from other stores (average 4,5-5,6 stores/drone) and 88 stores for outgoing deliveries to other stores (average 5,9-7,3 stores/drone). In each case, this would give a CSDL 4-9 drones for home delivery and for deliveries between stores, which seems to be a manageable fleet size.

ANALYSIS OF THE SUPPLY CHAIN

As there is currently no existing solution that operates for CSDLs and in a congested city center, e.g., between block of flats, some issues need to be examined. The whole supply chain with drones needs to be explored, looking at where the critical points are, how the drone can land, how it can deliver the package, what areas it needs to fly over, etc. Based on the data available and the new concepts developed, the main parts of the drone supply chain are a sender location, a flight transaction, and a receiver location, with the possibility of including transfer locations between the sender and receiver locations in some cases, for example, due to the range of the drone or the nature of the destination.

When we examine the drone supply chains, the first important step is to define the concept of a drone mini hub, which will be a logistics facility capable of handling drones, i.e., a cross dock capable of handling drones. This will be the term we will use for the drone handling part of the logistics areas of the CSDLs. In the case of CSDLs, these will clearly appear, and we believe that before the mass deployment of drone docking-capable parcel machines and the provision of stores and households with their own drone docking stations, the parcel machines, single stores, and home delivery locations will also need to use drone mini hubs as transhipment points. Some possible locations of these drone mini hubs can be seen in Figure 10.

Figure 10. Drone mini hubs in the drone supply chains

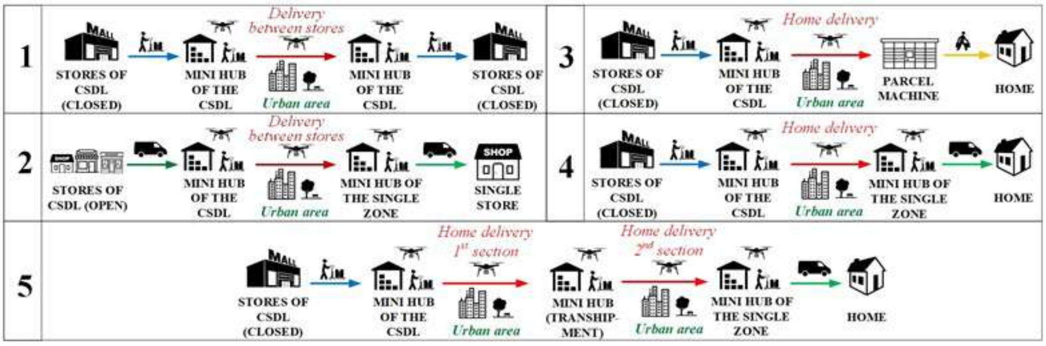


We need to use these mini hubs in the CSDLs with closed infrastructure (here they could be located inside the building, in the logistics areas, or on the roof), in the CSDLs with open infrastructure, and in the simple urban zones (in their cases the area's cross dock should be equipped with a drone mini hub).

The next task was to identify the critical points in the drone supply chain. Figure 11 describes some typical cases, drawing attention to the most typical delivery and material handling tasks. Examples 1 and 2 illustrate the options for deliveries between stores, where there are three types of sender and receiver locations: a store of a CSDL with closed infrastructure, a store of a CSDL with open infrastructure, and a store in a simple urban zone. In the first two cases, the delivery can be made from the drone mini hub of the CSDL, but while in the case of a closed infrastructure, the goods can be delivered to the mini hub from the store or vice versa, in the open case, another short delivery is required between the store and the drone mini hub, like in the simple zone case. Examples 3 and 4 describe the simpler case of home delivery, where the drone mini hub of a CSDL is the sender location (the difference between the closed and open case is like in the case of deliveries between stores), and the receiver point can be a parcel machine or the drone mini hub of the zone to be supplied. In the future ideal case, which requires as few operations as possible, single stores and households will be able to have a drone docking station, so there will be no need to bring in an intermediate station (mini hub or parcel machine). Example 5 describes the most complex case, where a transhipment is required due to the range of the drone, in, which case the delivery is split into two (or more) stages.

It is also important to define how the goods are loaded onto the drone when examining their supply chains. In line with goods protection considerations, three possible solutions can be seen: the drone has its own container; the drone carries a separate delivery unit, into, which the goods can be placed; or the drone delivers the enclosed delivery unit. Accordingly, the loading, which will play a key role in the supply chain, can be done in three ways: picking up a special standard unit automatically; placing a special standard unit manually; or placing a non-standard unit (e.g., bag, box) manually. It is important to note here that non-standard units can be a serious problem because they are not symmetrical, so drone the drone balance can be questionable (and the correctness of the load fixing will be important for the same reason).

Figure 11. Typical drone supply chains in the city logistics system of the CSDLs



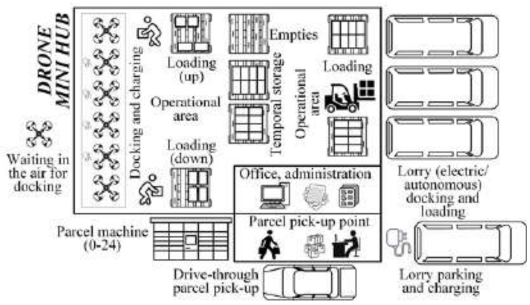
In drone supply chains, it is worth looking at the sender and receiver locations, transhipment points, and urban areas affected by the flight. The sender and receiver locations can be CSDLs of different types, simple stores in simple urban zones, households, and parcel machines. As automatic docking of parcel machines is not expected to become widespread soon, in their case drone mini hubs will be used as well, and all other urban areas will have their own drone mini hubs. These areas will ensure that drones can take off and land in a controlled environment, away from other traffic, and in compliance with safety regulations.

Basically, there are two main elements of the drone supply chains: the drone mini hubs and the urban areas involved in the flight. In the case of drone mini hubs, the logistics infrastructure needs to be built for drones. These facilities will essentially have the classic cross docking functions, with specialized infrastructure for drones. An important question is where these mini hubs can be located, as drones will need to be able to fly in and out of them. This may be problematic for CSDLs with closed infrastructure, as these typically have logistics facilities underground, and it may not be possible to fly into them. In the case of flat roofs, it may be more appropriate to place the drone mini hub on the roof, but in the case of older buildings, such as gable-roofed markets or halls, a special platform is needed on the roof, or the mini hub could be placed in the street, parking area, or loading area next to the building.

In relation to the urban area affected by the flight, it is important to highlight the examination of the new legislative EU framework, but the development of procedures for the deliveries is still ongoing. Among the critical legal issues to be highlighted are autonomous operation and surveillance, which will have to be effectively implemented in the case of a bigger number of drones, and airspace use issues are important as well. There are also critical factors to be considered in terms of drone technology: the fixing of the delivery units, wind, turbulence during take-off and landing, and near walls must be examined too, avoidance of other drones must be a priority, but avoidance of other objects (e.g., trees, wires) is also critical. In addition to these, flight control issues will also be important, as a dedicated air traffic control system is needed, linking it to the traditional air traffic control, as, for example, urban delivery drones may cross paths with rescue helicopters. In addition, there will also be a need to manage take-off and landing, route determination, avoidance of special urban areas, and the possible waiting before landing.

In the next step of the research, it will be essential to examine the development of the drone mini hubs. As a first step, we defined the functional areas of the drone mini hubs, as shown in Figure 12. A docking area for loading, unloading, and charging for the delivery drones will be essential. There will also be an operational area and a temporary storage area to handle the delivery units. If manual handling of packages or handling of other delivery vehicles is required, there will also need to be an operational area for these, and docking, loading facilities, and waiting areas for the other vehicles will be required too. A suitable waiting area for drones will need to be designated in the air. There should also be various facilities for the package handling, where necessary: a parcel machine, a parcel pick-up point, and even drive-through parcel drop-off and pick-up facilities can be required. In the next steps of our research, we will plan this concept in detail.

Figure 12. Functional areas of the drone mini hubs



It will be important as well to model and simulate the developed concepts. We will need to precisely identify the markets for urban drone deliveries, too, considering every aspect; for this, a multicriteria ranking model can be a good way, which could help to identify the break-out points where the developments can be initiated.

CONCLUSION

In our paper, we examined how drones could be integrated into the city logistics system of the urban concentrated sets of delivery locations, for, which delivery tasks these devices could be suitable for inclusion in the delivery tasks based on the volumes of goods and range, how many drones would be needed, and what are the critical points in the drone supply chains. In the first part of our paper, we described the types of urban delivery locations, the existing drone delivery solutions, and the related research directions. Next, we used data from more than 600 stores in CSDLs from Budapest to examine, which delivery transactions could be suitable for drones. For supplier deliveries, drones could be used in some urgent cases; in the case of deliveries between stores and home deliveries, a significant proportion could be handled by drones. Based on these results, we added drones to our previously developed city logistics system concepts and defined the optimal size of the drone fleet in the examined system. Then, we described the drone supply chains to be investigated, explaining the concept of drone mini hubs, as well as the main elements of the drone supply chains and the critical points. The primary outcome of our research is the definition of the developed system concepts using delivery drones in the city logistics system of CSDLs, and the investigation of their supply chain.

ACKNOWLEDGEMENT

The research was supported by the Hungarian Government and co-financed by the European Social Fund through the project "Talent management in autonomous vehicle control technologies" (EFOP-3.6.3-VEKOP-16-2017-00001).

REFERENCES

[1] Bóna, K. & Sárdi, D. L. (2018). Koncentrált városi igénypontok áruellátó logisztikai rendszereinek elemzése és mezoszkópikus szintű modellezése. Logisztikai Évkönyv 2019 (pp. 121-130). Budapest, Magyar Logisztikai Egyesület.

[2] ALRT (2021). City Logistics Research Group URL: https://www.logisztika.bme.hu/citylog/en/ (Accessed: 17. 08. 2021.)

[3] Bóna, K., Lipovszki, Gy. & Sárdi, D. L. (2020). A városi koncentrált igénypont-halmazok city logisztikai rendszereinek Python-alapú szimulációs modellezése. Logisztikai Évkönyv 2021 (pp. 115-127). Budapest, Magyar Logisztikai Egyesület.

[4] Bóna, K. & Sárdi, D. L. (2019). Examination of the logistics systems of concentrated sets of urban delivery points by simulation. The 21th International Conference on Harbour, Maritime & Multimodal Logistics Modelling and Simulation (pp. 1-10). Lisbon, Portugal: Cal-Tek.

[5] Bóna, K. & Sárdi, D. L. (2020). AHP-based multicriterial ranking model for the city logistics analysis of urban areas. 10th International Conference on Logistics, Informatics and Service Sciences (pp. 45-60). Singapore, Springer.

[6] Mészáros, B., Bóna, K. & Sárdi, D. L. (2017). Monitoring, measurement and statistical analysis (MMSA) based methodology for improvement city logistics of shopping malls in Budapest. World Review of Intermodal Transportation Research (Vol. 6, No. 4, pp. 352-371). Geneva, Inderscience Publishers.

[7] Bóna, K. & Sárdi, D. L. (2019). A városi koncentrált igénypont-halmazok áruellátási rendszerének új koncepciói a különböző közlekedési alágazatok lehetőségeinek kihasználásával. XIII. Innovation and Sustainable Surface Transport Conference. Budapest, Hungary: Hungarian Academy of Engineering.

[8] Bóna, K., Sárdi, D. L., Kormos, H., Major, P. & Posta, M. I. (2020). Kötöttpályás városi áruszállítási lehetőségek vizsgálata Budapesten az AHP-módszer alkalmazásával. XIV. Innovation and Sustainable Surface Transport Conference.

Budapest, Hungary: Hungarian Academy of Engineering.

[9] Bóna, K. & Sárdi, D. L. (2019). Áruszállító kerékpárok alkalmazási lehetőségeinek értékelése a bevásárlóközpontok logisztikai rendszerében a hálózat geometriai struktúrája alapján. Logisztikai Évkönyv 2021 (pp. 163-173). Budapest, Magyar Logisztikai Egyesület.

[10] DHL (2021). DHL Paketkopter. URL: https://www.dpdhl.com/de/presse/specials/dhl-paketkopter.html (Accessed: 03. 08. 2021).

[11] DHL (2019). DHL express launches its first regular fully-automated and intelligent urban drone delivery service. URL: https://www.logistics.dhl/tw-en/home/press/press-archive/2019/ (Accessed: 17. 08. 2021).

[12] DHL (2021). DHL Parcelcopter. URL: https://www.dpdhl.com/en/media-relations/specials/dhl-parcelcopter.html (Accessed: 06. 20. 2021).

[13] Daimler (2017). Vans & Drones in Zurich: Mercedes-Benz Vans, Matternet and siroop start pilot project for on-demand delivery of e-commerce goods. URL: https://media.daimler.com/marsMediaSite/en/instance/ko/ (Accessed: 17. 08. 2021).

[14] Amazon (2016). Prime Air. URL: https://www.amazon.com/Amazon-Prime-Air/ (Accessed: 17. 08. 2021).

[15] Murison, M. (2019). Drone Delivery: Google's Project Wing Takes Off In Australia. URL: https://dronelife.com/2019/04/11/google-wing-drone-delivery-australia/ (Accessed: 17. 08. 2021).

[16] UPS (2020). UPS Flight Forward And Wingcopter To Develop Versatile New Drone Fleet. URL: https://pressroom.ups.com/pressroom/ (Accessed: 05. 02. 2021).

[17] Premack, R. (2020). America's largest retirement community can soon receive their prescriptions from CVS via a UPS drone delivery service. URL: https://www.businessinsider.com/ups-cvs-drone-deliveries-the-villages-florida-2020-4 (Accessed: 17. 08. 2021).

[18] Ward, T. (2020). Walmart Now Piloting Drone Delivery of COVID-19 At-Home Self-Collection Kits. URL: https://corporate.walmart.com/newsroom/2020/09/22/ (Accessed: 17. 08. 2021).

[19] Dorling, K., Heinrichs, J., Messier, G. G. & Magierowski, S. (2017). Vehicle Routing Problems for Drone Delivery. IEEE Transactions on Systems, Man, and Cybernetics: Systems (Vol. 47, No. 1., pp. 70-85). Piscataway, IEEE.

[20] Kirschstein, T. (2020). Comparison of energy demands of drone-based and ground-based parcel delivery services. Transportation Research Part D 78 (No. 102209). Oxford, Elsevier.

[21] Hong, I., Kuby, M. & Murray, A. T. (2018). A range-restricted recharging station coverage model for drone delivery service planning. Transportation Research Part C: Emerging Technologies (No. 90, pp. 198-212). Oxford, Elsevier.

[22] Salama, M. & Srinivas, S. (2020). Joint optimization of customer location clustering and drone-based routing for last-mile deliveries. Transportation

Research Part C (No. 114., pp. 620–642). Oxford, Elsevier.

[23] Ha, Q. M., Deville, Y., Phamb, Q. D. & Hà, M. H. (2018). On the min-cost Traveling Salesman Problem with Drone. Transportation Research Part C (No. 86., 597–621.) Oxford, Elsevier.

[24] Flytrex (2021). Iceland, AHA. URL: https://flytrex.com/projects/iceland-aha/ (Accessed: 02. 03. 2021.)

[25] John, A. L. (2017). What's the Buzz? - The City-Scale Impacts of Drone Delivery. RAND Corporation (RR-1718-RC).

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Total Cost of Ownership Model Development for Electric Cars

BÁLINT CSONKA, CSABA CSISZÁR, DÁVID FÖLDES

Abstract Higher market-share of electric cars can be facilitated by several incentives. Our aim was to elaborate a cost model and a calculation method for total cost of ownership (TCO) pertaining to electric vehicles (EVs), as well as an information application, to support new vehicle purchase. Purchase, operation, maintenance, and other cost elements were considered. Based on this method, we developed an information application for customers and other stakeholders. Thus, several vehicle types and operational cases may be compared based on specific and aggregated costs. Findings and Originality: We found that question as 'Under what operating conditions is it worth to buy an EV?' can be answered by our calculation method. Customers' most typical questions, as 'Which vehicle type's TCO is the most favourable?' and 'How much less emission do EVs produce?', can be also answered. We found that above app. 21000 km/year covered distance it is worth to buy an 'average' EV with general features for private use. Our results substantiate further research activities and practical applications. During the research, the novelty and quick development of the EV technology (e.g., lacking operational experiences), the availability, dynamism and reliability of data, and the forecast of cost elements (e.g., future depreciation or specific energy costs) were the most relevant challenges. Consumers and companies may use our decision support tool. We are going to address the following issues: support company fleet purchase, investigation of typical vehicle types, estimation of maintenance and repair costs, sensitivity analysis of variables.

Keywords: • Electric Car Purchase • Decision Support • Total Cost Of Ownership • Technological Change

CORRESPONDENCE ADDRESS: Bálint Csonka, PhD, Csaba Csiszár, PhD habil., Dávid Földes, PhD, Budapest University of Technology and Economics, Faculty of Transportation Engineering and Vehicle Engineering, Department of Transport Technology and Economics, Műegyetem rkp. 3., Budapest, Hungary, e-mail: csonka.balint@kjk.bme.hu, e-mail: csiszar.csaba@kjk.bme.hu, e-mail: foldes.david@kjk.bme.hu

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

Operation of electric road vehicles differs from that of conventional ones. It implies novel decision-making situations for users and other stakeholders of electromobility system. At Department of Transportation Technology and Economics in Budapest University of Technology and Economics (BME), we have been performing research with wide scope regarding planning and operation of transportation systems based on electric vehicles for many years and provide scientific solutions, which are well applicable in practice too.

Price of electric cars are still rather high. All cost elements, their correspondences, their values, and future changes are not transparent for and known by users. Accordingly, they make non-rational decisions in many cases. Further hurdle, that impacts of technological development cannot be clearly forecasted. Therefore, beside purchase price, the Total Cost of Ownership (TCO) is also to be investigated. Our research objective is to elaborate a cost calculation method to facilitate spread of electromobility and aid users' decisions, as well as to develop a user-friendly information application.

LITERATURE REVIEW

Market of electric cars are influenced by both costs and incentives. We have summarized literature results accordingly.

Total cost of ownership

Literature pertaining to TCO deals mainly with calculation of costs and CO_2 emission. Besides, user preferences are investigated and forecasts regarding future vehicle market shares are provided in several research papers. Spatial validity and forecast time horizons are various in these papers. The most detailed research results are available for the USA, European Union, Germany, UK, France, the Netherlands, and Norway. In general, timespan 2030-2050 is applied in forecasts. Most of the studies focus on passenger cars; vans are mentioned only in some cases. Number (and size) of vehicle types varies between 1 and 6 (e.g., small, compact, medium, executive, SUV, minivan); while number of usage types is typically 3 according to rate of urban and long-distance travels. Generally, the following propulsion modes are involved in the investigations: Internal Combustion Engine Vehicle (ICEV), Hybrid Electric Vehicle (HEV), Plug-in Hybrid Electric Vehicle (PHEV), Battery Electric Vehicle (BEV) and Fuel Cell Electric Vehicle (FCEV). During emission calculation, the wider, so called Well-To-Wheel (WTW) approach is more common; but the narrower, so called Tank-To-Wheel (TTW) approaches are also often applied. In the case of emphasizing sustainability, external cost elements are also to be involved into the cost model. In consumer-oriented total cost of ownership (TCOC) calculations the latter ones are not considered. Cost models to support decisions of vehicle manufacturers are related to consumer models through purchase price.

Value of TCO is influenced by many (app. 30-40) factors either directly or indirectly, having impact with different strengths [1]. Besides, future values of cost elements may be calculated only with significant uncertainties. Therefore, scenarios are created in many cases and the total cost is derived from the parameters fixed in them. The scenarios are typically determined according to maturity of EV market; namely, rate of EVs within newly purchased vehicles. For instance, it has been stated that vehicle purchase promotions significantly facilitate market share increase of EVs according to market model based on the Germany, 2030 scenario [2].

Environmental and health impacts caused by shift from combustion engine powered vehicles to EVs were assessed as external costs using the ExternE method [3]. In this Europe-wide research, the different raw-materials and the technological features of energy generation were also considered, which vary country to country and change time by time.

Profit rate of car manufacturers is usually underestimated in the TCO-related literature, while they are aiming at payback of their investments. Consequently, TCO of EVs is expectedly not significantly lower than that of ICEVs. It also means that some measures should be applied to increase TCO of ICEVs (e.g., introduction of new taxes) [4]. Additionally, several prohibitions and restrictions with various spatial, temporal etc. extent can be applied for conventional vehicles to lessen their popularity.

One part of the applied models is based on so-called techno-economic approach. In these models, technological correspondences are validated using results coming from measurements performed under real driving conditions. The cost calculation uses these correspondences. In this way, more reliable values can be calculated than in the case of TCO models based on theoretical values provided by car manufacturers, as theoretical values differ from real ones, because they usually slightly tend towards combustion engine cars. Besides, it was also found that effect of economic variables on TCO is more significant than that of technical ones [5].

TCO calculations regarding vehicles with hydrogen fuel cells have several peculiarities, which is the consequence of the new and specific technology and its less matured characteristics. Further difficulty, that only little experience, as well as few operational and usage data are available. These TCO models also contain complex forecasting procedures to determine values of cost elements. It is one of the peculiarities that travel cost to the nearest charging facility is also considered, as the charging network is significantly rarer in the case of this new technology. Furthermore, calculation of maintenance and repair costs is more difficult (e.g., failure rates are considered), as well as specific costs of energy resources are to be forecasted only with uncertainties [6].

Cost calculations consider total life cycle of vehicles only in some cases. Therefore, in some studies, life cycle cost models were elaborated that include indirect costs (externalities), emission values (e.g., global, and local air pollution) etc. These models can be applied in the case of several vehicle technologies and fuels; both analyses and comparisons can be produced. These calculation results significantly contribute to the more efficient decisions and measures [7].

Incentives

Literature regarding incentives answer the questions that, which measures can facilitate and accelerate shift from conventional vehicles to EVs and related energy management solutions (e.g., vehicle to grid technology) and, which impacts are expected accordingly. Incentives can be categorized as monetary and non-monetary incentives. Several incentives facilitate higher EV market share through impact on TCO.

It was found in many studies, that high purchase price does not hold back growth of market share in the case of most hybrid vehicles, while significant subsidization is needed to increase competitiveness of plug-in hybrid and pure battery EVs [8].

Questionnaire surveys and deep interviews are widely used to identify incentives and estimate their impacts. For the latter case, transport, and energetics experts, as well as decision makers are involved usually. Analyses show that views and opinions regarding measures' advantages and disadvantages often significantly vary according to countries, regions, and cities, as well as maturity of EV market. It is stated that stabile and consistently managed target values and purchase discounts are needed in each country, which are to be combined with campaigns to enhance consciousness [9]. The national measures may be supplemented by regional or local incentives. Analyses of cities cover building regulations, facilities to connect to the energy network, issues related to social equity etc. in the context of EVs. It was found that significant differences can be observed regarding urban incentives from the lack of regulatory tools to very detailed and extended regulations. More emphasis is placed on incentives related to urban vehicle fleets, while less attention is paid to building regulations [10]. Not only the advantages and challenges of EVs were identified according to the respondents' answers in questionnaire survey, but the typical knowledge gaps and misbelieves were also revealed among the potential users. For example, users often do not know the exact environmental benefits because the lack of transparency due to varying energy-mix country by country.

STATE OF ELECTROMOBILITY

The most relevant indicators to characterize state of electromobility of certain countries (regions) are:

- number and rate of different EV types sold in the given period,
- size, composition, and attributes of EV fleet,
- extension and characteristics of charging facility network (spatial coverage,

quantity, power, capacity, tariff, standardization),

- characteristics of information system and services aiding electromobility,
- existence of political targets, governmental subsidies, and incentives.

Price of EVs decreased significantly in the last years, while the new models are getting to be more and more developed and equipped and the manufacturers provide longer and wider guarantee. Quick spread of electromobility is only possible if consumers accept the new technology and make rational monetary decisions.

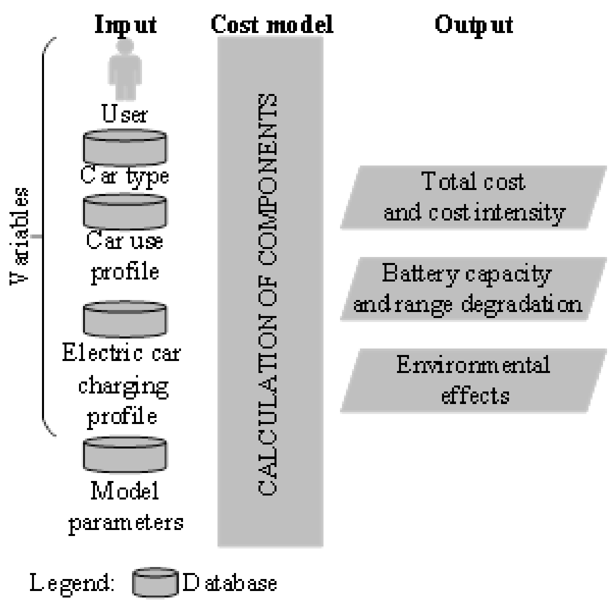
COST MODEL

The following model limitations were applied:

- The cost calculation may be performed for new vehicles for a maximum period of 15 years.
- The average fuel and electric energy prices over a period were considered.
- Car amortization is a function of time and mileage. Vehicle categories were not considered.
- Obligatory tax and fees were determined based on the Hungarian legislation.
- The car is sold at the end of the investigated period. The selling price is the original purchase price minus amortization.

The cost model is summarized in Figure 1.

Figure 1. Cost model



Input data were categorized into the following groups:

- Variables: the user may modify them.
- Model parameters: stable values that are may be modified by the operator. Model parameter values may be reviewed periodically.

Variables

To support manual data entry, some variable values are stored in databases. For instance, the attributes of an electric car may be stored in a database. The variables related to car purchase, maintenance and use are summarized in Table 1. The variables covering energy consumption, charging and pollution are given in Table 2.

Table 1. Model variables – purchase, maintenance, use

Cat.	Sign	Name
Purchase	B	Battery capacity
	C_v	Purchase price
	I	Highest own contribution, regardless of the purchase price
	P	Power
	$r_{\%}$	Interest
	APR	APR of a loan
	T_{APR}	Loan maturity
	T_0	Ownership period
Maintenance	C_{CASCO}	Annual fee of CASCO insurance
	C_{ITP}	Annual fee of third-party liability insurance
	C_{SE}	Cost of planned service
	C_{ST}	Cost of summer tyre set
	C_{WT}	Cost of winter tyre set
	C_{12V}	Cost of 12V car battery
	f_M	Frequency of planned service
	T_{ST}	Expected lifetime of a summer tyre set
	T_{WT}	Expected lifetime of a winter tyre set
	T_{12V}	Expected lifetime of a 12V car battery
Use	C_P	Parking cost
	C_R	Road toll
	M	Annual mileage
	$r_{E,L}$	Share of electric drivetrain on highways
	$r_{E,M}$	Share of electric drivetrain on main roads
	$r_{E,S}$	Share of electric drivetrain in urban areas
	$r_{T,L}$	Share of highway use based on mileage
	$r_{T,M}$	Share of main road use based on mileage
	$r_{T,S}$	Share of urban road use based on mileage

We considered road toll; however, drivetrain dependent road toll is not typical, but it may be introduced in the future. The following road categories were distinguished from the point of car use:

- highway,
- main road, and
- urban road.

The share of road use per category is based on the mileage. The share of electric drivetrain use (rE,x), electric energy and fuel consumption ($c_{E,x}$ and $c_{F,y}$), and pollution ($e_{E,x}$) may be different for each road category.

Table 2. Model variables – energy consumption, charging, pollution

Cat.	Sign	Name
Energy consumption	$c_{E,L}$	Electric energy consumption on highways
	$c_{F,M}$	Electric energy consumption on main roads
	$c_{E,S}$	Electric energy consumption on urban roads
	$c_{F,L}$	Fuel consumption on highways
	$c_{F,M}$	Fuel consumption on main roads
	$c_{F,S}$	Fuel consumption on urban roads
	$C_{CH,H}$	Cost of home charging
	$C_{CH,W}$	Cost of charging at workplace
	$C_{CH,AC}$	Cost of public charging at non-free normal chargers
	$C_{CH,DC}$	Cost of public charging at non-free superchargers
	$C_{CH,O}$	Cost of charging at other non-free locations
	C_{F}	Fuel cost
	$r_{CH,H}$	Share of home charging based on charged energy
	$r_{CH,W}$	Share of charging at workplace based on charged energy
	$r_{CH,AC}$	Share of public charging at non-free normal chargers based on charged energy
	$r_{CH,DC}$	Share of public charging at non-free superchargers based on charged energy
	$r_{CH,O}$	Share of charging at other non-free locations based on charged energy
	$r_{CH,FREE}$	Share of free charging based on charged energy
Pollution	$e_{CH,H}$	Emission intensity of home charging
	$e_{CH,W}$	Emission intensity of charging at workplace
	$e_{CH,O}$	Emission intensity of charging at other non-free locations
	$e_{CH,FREE}$	Emission intensity of free charging
	$e_{E,L}$	Emission intensity on highways
	$e_{F,M}$	Emission intensity on main roads
	$e_{E,S}$	Emission intensity on urban roads

The share of the electric drivetrain is 0 % for conventional cars, 100 % for pure electric cars and between 0 and 100 % for plug-in hybrid cars. The following charging station location types were distinguished:

- home,
- workplace,
- public non-free, normal charger,
- public non-free, supercharger,
- other non-free public,
- free charging.

The share of charging per location type is based on the charged energy. The cost of charging (CCH,x) and the emission intensity of electricity generation (eCH,x) may be different for each charging station location type.

The following databases support the manual data entry:

- Car type: the following variables may be given per car type: $B, C_V, P, F, r_E, i, c_{E,j}, c_{F,k}, e_{F,l}$.
- Car use profile: the following profiles may be given per car use profile: $M, r_{T,x}$.
- Electric car charging profile: the following variables may be given per charging profile: $r_{CH,y}$.

The set of variables were indicated using general indexes in subscript. For instance, $r_{E,i}$ indicates the share of electric drivetrain on highways ($r_{E,L}$), main roads ($r_{E,M}$) and urban roads ($r_{E,S}$). Based on the literature review and previous surveys, we determined car use (Table 3) and electric car charging profiles (Table 4). The car use profiles differ on the mileage and the share of road category use. We considered that the access to private charging and car use effect significantly the charging behavior. Therefore, the following electric car charging profiles were determined:

- charging at home is typical,
- short journeys, charging at the destination is typical,
- long journeys, charging interrupting journeys is typical.

Table 3. Car use profiles

Variable		Urban traveller	Commuter	Travelling salesman
M	[km]	13000	19000	25000
$r_{T,L}$	[%]	10	25	60
$r_{T,M}$		10	25	20
$r_{T,S}$		80	50	20

Table 4. Electric car charging profiles

Variable		Home	Destination	En-route
$r_{CH,H}$	[%]	70	0	0
$r_{CH,W}$		0	0	0
$r_{CH,AC}$		5	65	25
$r_{CH,DC}$		10	20	70
$r_{CH,O}$		0	0	0
$r_{CH,FREE}$		15	15	5

Furthermore, default values and the integration of existing calculators, such as loan and insurance cost calculators, may also support the manual data entry.

Model parameters

The amortisation was recorded as a time and mileage-dependent parameter (Table 5). Above-average mileage increases amortisation, and lower than average mileage decreases it. The amortisation rate and average mileage were based on conventional car use. The amortisation rate is the value loss compared to the original purchase price.

Obligatory tax, fee and cost elements regulated by legislation were recorded as parameters. Parameters related to battery degradation and pollution are summarized in Table 6.

Table 5. Amortization parameters

Parameter	Value
Value loss in the 1st year	30 %
Value loss in the 2nd year	15 %
Value loss in the 3rd year	10 %
Annual value loss between 4th and 6th year	4 %
Annual value loss between 7th and 10th year	3 %
Annual value loss between 11th and 15th year	2 %
Average mileage	15 000 km
Above-average mileage correction	0,5 %/5000 km
Lower than average mileage correction	0,3 %/5000 km

Table 6. Battery degradation and pollution parameters

Parameter	Value
Emission intensity of battery manufacturing	120 kgCO_2eq /kWh
Battery capacity degradation	3 %/100 charges
Average used battery capacity	60 %
Efficient battery capacity for range calculation	90 %
Emission intensity of electricity generation at public non-free normal and superchargers	200 gCO_2eq /kWh
Energy content of petrol	8,7 kWh/litre
Energy content of diesel	9,9 kWh/litre
CO_2 absorption of a tree	22 kg/year

Cost model

The cost model supports decision making through the following outputs:

- TCO calculation.
- Battery capacity and range calculation.
- Environmental effect calculation.

The cost elements are categorised into the following groups:

- Purchase: amortisation, loan, and losing capital income because of vehicle purchase.

- Maintenance: insurance, planned service, tax, and obligatory costs.
- Use: parking fee, road toll, and energy cost.

We assumed that the purchase price includes the cost of one summer tyre set. Planned service may depend on time and mileage. Thus, service is partly related to car use because above-average mileage may increase service costs. We applied a simplification and assigned the total service cost to the maintenance.

The TCO is the sum of purchase, maintenance and use related costs. We determined the TCO intensity based on time [€/month] and mileage [€/km] to support decision making. Namely, the TCO was divided by the number of months and mileage.

The remaining battery capacity is calculated according to eq. (1). We applied the battery capacity degradation (3 %/100 charging session) and the average used battery capacity (60 %) parameters.

$$B' = B \cdot (0.97)^{\frac{E'_E}{60B}} \quad (1)$$

Where B' is remaining battery capacity, and E'_E is total charged energy during the investigated period.

A range is calculated based on the remaining battery capacity and energy consumption, assuming a 90 % battery capacity utilisation.

The pollution was determined considering the emission of battery manufacturing, electricity generation and fuel consumption. Recycling and reuse (in static energy storage systems) of batteries were not considered because they may not increase the emission of battery manufacturing in the long term. Furthermore, we estimated the number of trees that may eliminate the environmental effects of vehicle use.

CASE STUDY

Theoretical conventional petrol, plug-in hybrid, and pure battery electric vehicles were compared based on the cost model. The vehicle characteristics are summarized in Table 7.

Table 7. Vehicle characteristics

Variable	Petrol	Plug-in hybrid	Electric
B	0	15	40
C_V	22 200	26 400	33 300
P	100	100	100
$r_{E,L}$	0	10	100
$r_{E,M}$	0	25	100
$r_{E,S}$	0	90	100
$c_{E,L}$	0	24	23
$c_{E,M}$	0	18	19
$c_{E,S}$	0	15	16
$c_{F,L}$	7	7	0
$c_{F,M}$	6	5,5	0
$c_{F,S}$	7	3	0
$e_{F,L}$	150	155	0
$e_{F,M}$	130	110	0
$e_{F,S}$	150	60	0
C_{SE}	275	250	165
f_M	1	1	1

The estimated annual planned service fee of a conventional petrol car was 275 €. The planned service fees of plug-in hybrid and pure electric battery cars were estimated based on our experiences. The commuter car use profile and home charging profile were selected. The cost of charging and emission intensity of electricity generation are summarised in Table 8. We assumed that local renewable power generation at home (e.g., solar panels) might reduce the cost of charging at home. We applied the typical Hungarian electricity prices and emission intensity (electricitymap.org).

The highest own contribution was 27 800 €. The APR and loan maturity were 5,75 % and 60 months, respectively. We assumed the customer does not invest the remaining own contribution after the purchase. The total annual insurance cost was 830€ for each car. The cost of summer and winter tyre set, and car battery were 235 €, 210 € and 95 €, respectively.

Table 8. Charging cost and emission intensity of electricity generation

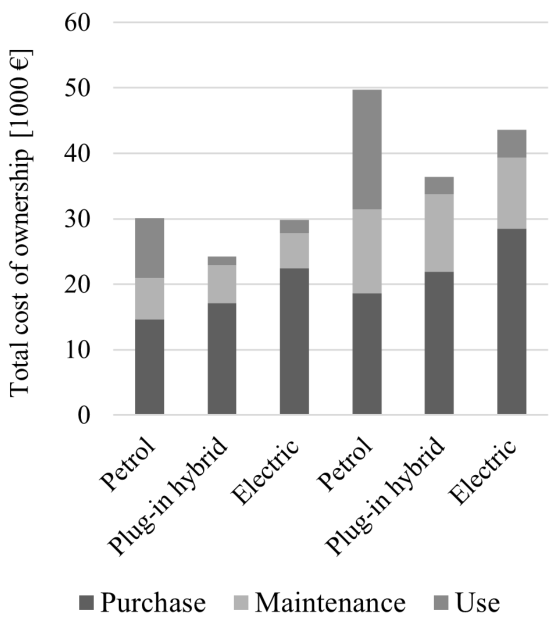
Location type	$C_{CH,x}$ [€/kWh]	$e_{CH,x}$ [gCO_2eq/kWh]
Home	0,028	45
Workplace	0	200
Public non-free, normal charger	0,375	200
Public non-free, supercharger	0,375	200
Other non-free	0,42	200
Free charging	0	200

The estimated lifetime of a tyre set, and car battery were 7 and 8 years. The monthly parking cost was 8 € for the petrol car, and 0 € for plug-in and pure electric cars. The annual road toll was 125 € for each car. The cost of petrol was 1,25 €. The TCO analysis was performed for 5- and 10-year long periods.

RESULTS AND DISCUSSION

The purchase, maintenance, and use related costs are given in Figure 2.

Figure 2. Total cost of ownership after 5 and 10 years



The purchase cost is different after 5 and 10 years because of the amortisation. It was noted that the plug-in hybrid car has the lowest TCO for both periods. However, the car use behaviour and access to the charging infrastructure may significantly influence the result. For a 5-year long period, the conventional petrol car is 25 % more expensive than the plug-in hybrid. Despite the significantly higher purchase cost of pure electric battery cars, there is no significant difference between petrol and pure electric battery cars. In the case of a petrol car, it was noted that only half of the TCO is the purchase cost. After 10 years, the TCO of the petrol car is 35 % and 15 % higher than the TCO of plug-in hybrid and pure electric battery cars. In other words, the higher purchase cost of electric cars may pay off after 5 years. The pure electric battery car is more expensive than the plug-in hybrid car because of the lower purchase and use related costs. The higher share of urban road use may decrease the TCO of pure electric battery cars. Accordingly, a pure electric battery car fits urban use, and a plug-in hybrid car is suitable for regular commuting. For long journeys, the conventional petrol car may be the most suitable. Further results are summarized in Table 9.

Table 9. Main results

	After 5 years			**After 10 years**		
	Petrol	**Plug-in hybrid**	**Electric**	**Petrol**	**Plug-in hybrid**	**Electric**
Amortization [1000 €]	14,45	17,2	21,7	18,45	21,9	27,7
Mileage based TCO intensity [€/km]	,32	,26	,31	,26	,19	,23
Remaining battery capacity [kWh]	0	11	31	0	8	23
Pollution [eqCO_2t]	14	8	6	28	14	8

The TCO intensity of cars is between 0,26-0,32 €/km after 5 years, and between 0,19-0,26 after 10 years. Namely, the extended operation of cars decreases the TCO intensity. It was noted that the remaining battery capacity is 77 % and 57 % after 5 and 10 years. The pollution of the conventional car was the greatest, and the pollution of the pure electric battery car was the lowest for both periods. Namely, the low pollution of electricity generation may eliminate the pollution of battery manufacturing after 5 years. After 10 years, the pollution of the petrol car is approximately three times higher than the pollution of the pure electric battery car and double of the plug-in hybrid car's pollution.

CONCLUSION

The developed cost model and cost comparison of drivetrains contribute to the literature in the field of electromobility and support decision making. Developing a future-proof cost model was the most significant challenge because of the rapid technology development and the complexity of electromobility systems.

According to our results, pure electric battery cars are the best fur urban roads, plug-in hybrid cars fit commuting, and conventional petrol cars are suitable for frequent long journeys from the TCO point of view. It was noted that the low emission intensity of electricity generation could outweigh the emission of battery manufacturing in 5 years. Since electric cars are not widespread yet, we lack information on the service and amortisation. Furthermore, the oil price significantly fluctuates and increases, which influences the pay-off of electric cars. Therefore, the reliability of the cost model may be improved by updating the parameters in the future.

We plan to extend the cost model to fleet cars and analyse the effect of charging infrastructure, electricity network and car use profile on the TCO. Additionally, we are going to involve alternative drivetrains (e.g., hydrogen) and vehicle types (e.g., bus, truck).

ACKNOWLEDGMENT

The article was financed in the cooperation of the National Bank of Hungary and Budapest University of Technology and Economics under the Green Finance Research Project.

The research was supported by the Ministry of Innovation and Technology NRDI Office within the framework of the Autonomous Systems National Laboratory Program.

REFERENCES

[1] Letmathe, P., Suares, M. (2020). Understanding the impact that potential driving bans on conventional vehicles and the total cost of ownership have on electric vehicle choice in Germany. Sustainable Futures 2: 100018. doi: 10.1016/j.sftr.2020.100018.

[2] Bühne, J-A., Gruschwitz, D., Hölscher, J., Klötzke, M., Kugler, U., Schimeczek, C. (2015). How to promote electromobility for European car drivers? Obstacles to overcome for a broad market penetration. European Transport Research Review, 7(3). doi: 10.1007/s12544-015-0178-0.

[3] Buekers, J., Holderbeke, M. V., Bierkens, J., Panis. L. I. (2014) Health and environmental benefits related to electric vehicle introduction in EU countries. Transportation Research Part D: Transport and Environment, 33: 26-38. doi: 10.1016/j.trd.2014.09.002.

[4] Velzen, A., Annema, J. A., Kaa, G., Wee, B. (2019). Proposing a more comprehensive future total cost of ownership estimation framework for electric vehicles. Energy Policy 129: 1034–1046. doi: 10.1016/j.enpol.2019.02.071.

[5] Desreveaux, A., Hittinger, E., Bouscayrol, A., Castex, E., Sirbu, G. M. (2020). Techno-Economic Comparison of Total Cost of Ownership of Electric and Diesel Vehicles. IEEE Access, 8: 195752-195762. doi: 10.1109/ACCESS.2020.3033500.

[6] Wróblewski, P.; Lewicki W.; Drożdż, W.; Dowejko, J. (2021). Total cost of ownership and its potential consequences for the development of the hydrogen fuel cell powered vehicle market in Poland. Energies 14(8), 2131; doi: 10.3390/en14082131.

[7] Mitropoulos L., K., Prevedouros, P. D., Kopelias P. (2017). Total cost of ownership and externalities of conventional, hybrid and electric vehicle. Transportation Research Procedia 24C: 267–274. doi: 10.1016/j.trpro.2017.05.117.

[8] Bubeck, S., Tomaschek, J., Fahl, U. (2016). Perspectives of electric mobility: Total cost of ownership of electric vehicles in Germany. Transport Policy 50: 63–77. doi: 10.1016/j.tranpol.2016.05.012.

[9] Kestera, J., Noel, L., De Rubens, G. Z., Sovacool, B. K. (2018). Policy mechanisms to accelerate electric vehicle adoption: A qualitative review from the Nordic region. Renewable and Sustainable Energy Reviews. 94: 719–731. doi: 10.1016/j.rser.2018.05.067.

[10] Wood, J., Jain, A. (2020). Raceways, rebates, and retrofits: an exploration of several American cities' policies to facilitate electric vehicle purchase and usage. International Journal of Urban Sustainable Development. doi: 10.1080/19463138.2020.1843467.

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Business Model for Mobility Services Based on Shared Autonomous Vehicles

DAHLEN SILVA, DÁVID FÖLDES, CSABA CSISZÁR

Abstract The use of autonomous vehicles (AVs) is likely to remodel urban mobility. The business model (BM) of shared mobility services is impacted by adopting this new technology. In order to forecast the changes caused by the implementation of AVs, a BM for mobility services based on shared autonomous vehicles (SAVs) using the Lean Canvas approach has been developed. The key findings are: the proposed service can replace all existing shared mobility services; AVs provide a high level of temporal and spatial flexibility; and a strong cooperation is to be established between service providers, vehicle operator, and vehicle owners. Our results support the establishment of future SAV-based services. Also, it increases awareness of all stakeholders about how transformations in shared mobility affect the interaction between them, implying policy measures.

Keywords: • Business Model • Shared Autonomous Vehicles • Shared Mobility. Stakeholders • Urban Mobility Service

---

CORRESPONDENCE ADDRESS: Dahlen Silva, PhD Candidate Dávid Földes, PhD, research associate Csaba Csiszár, PhD, habil associate professor, Budapest University of Technology and Economics, Faculty of Transportation Engineering and Vehicle Engineering, Department of Transport Technology and Economics, Műegyetem rkp. 3, Budapest, Hungary, e-mail: dahlen.silva@edu.bme.hu, e-mail: foldes.david@kjk.bme.hu, e-mail: csiszar.csaba@kjk.bme.hu

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

A business model (BM) is a framework in, which the necessary elements to deliver a product or service are identified, mainly the value proposition, customer, product, and resources. Additionally, elements that create value to the company itself, such as revenues and costs are also investigated. As it is more focused on the customer, it is a starting point to define the strategy, organizational structure, and business planning in order to overcome competitors [1]. They are used to attract investors and anticipate possible expenses, exploring viable opportunities for future business development.

The use of autonomous vehicles (AVs) has the potential to transform urban mobility. In 2040, AV-based mobility services are expected to travel about 55 % of total passenger-kilometers [2]. Despite this positive scenario, how BMs for shared mobility will perform in the long run is uncertain and the uncertainty is higher when assuming the insertion of a disruptive technology, such as AVs. In other words, studies investigating the impacts on BMs caused by the implementation of AVs are limited; for mobility service, a BM of autonomous taxis has been already analyzed using Lean Canvas [3].

Even though AVs can disrupt the definitions of shared mobility modes and current BMs [4][5], examining the changes in BMs of shared mobility service companies with the use of AVs is scarce. This research addresses this gap by proposing a BM for mobility services based on shared autonomous vehicles (SAVs) in order to forecast the changes and opportunities for the potential key stakeholders. It presents a definition and a qualitative description of the new service. Our research questions are: "How do BMs for shared mobility change with the implementation of AVs?" and "Is it possible to create a general BM for mobility services based on SAVs?".

The proposed mobility service based on SAVs operates in urban areas as a door-to-door service in, which vehicles, with highest automation level, and seats are shared among users. The service is provided by integrating the mobility service providers, vehicle and infrastructure operators. The vehicles, with a capacity of app. 4-9 persons, can be owned by vehicle operators or granted to the service by private owners. As a limitation public transport and micromobility are not considered as competing transport modes to the service proposed.

The paper is structured as follows: the literature is reviewed in is the next section; the service description of the mobility service based on SAVs and considerations during the elaboration of the BM are detailed in "Mobility Service based on Shared Autonomous Vehicles"; the proposed BM using the Lean Canvas approach is described and discussed in "The General Business Model for SAV services"; and conclusions are drawn in the last section.

LITERATURE REVIEW

Shared on-demand mobility services provide a travel experience that combines the advantages of private vehicles with those of the collective transport. For instance, the traveler can enjoy the privacy and comfort of a private trip without being concerned with parking costs [6].

The most common shared on-demand mobility services based on cars are: 1) car-sharing, a car is shared between people in different trips. The vehicle and drivers are charged for the usage time and the distance covered [7]; 2) taxi, providing short rides between origin and destination without sharing the vehicle. Drivers usually are the owner of the car, members of a cooperative or hired by a company; 3) ride-sourcing, similar as taxi service; lower fares and less regulated than taxi service; matching riders with the nearby drivers who are car owners, and [8]; 4) usually travelling long distances; drivers want to share trip costs. Drivers and passengers can directly interact with one another, arranging schedule, pick-up points and shared costs [9]; 5) car rental is similar to car-sharing, but offers daily car rentals with pre-determined locations for picking the cars up and limited by working hours.

Car-sharing and ride-sourcing services are usually based on smartphone application; the operational tasks are automatized; however, traditional taxi services are developing similar application to automatize their tasks.

BMs have been applied to shared and innovative mobility services, being classified into three categories. Business-to-consumer (B2C) BMs are commercially oriented and tend to operate internationally. The price is set by the mobility sharing platform (business), usually applying location-based and access-based price discrimination. Transaction fees, subscription fees, usage fees, and fines are the most dominant revenue streams. Despite the similarities, in peer-to-peer (P2P) mobility sharing platforms, a review system of users is presented and resource owners (peers) are the providers of products/services instead of a company. The price is set by the resource owner; there is a feature-based price discrimination, and a subscription fee is not common [10]. The business-to-business (B2B) is similar to B2C too, differing that the exchange of goods and services takes place between two or more businesses. Regarding shared mobility services, B2C BM can be applied to all the 5 services, P2P is typical for car-sharing and ride- sharing services, and B2B could occur in taxi, car rental and car-sharing services.

As shared on-demand mobility services usually offer flexible, convenient, accessible, and sustainable transport but only a single option of transport mode, it is predictable that Mobility as a Service (MaaS) will incorporate them in the future [11]. MaaS proposes a combination of all mobility service providers' offers in one digital platform, establishing multimodal and seamless transport services [12]. For this reason, BMs for MaaS have a wide range of key partners, customers and revenue streams, requiring an extensive development and provision of interoperable and integrated services. In the reseller BM, one interface combines multiple services from various transport service providers whereas in the integrator BM both traditional and additional transport services are offered via a mobile service provider, which grants mobile ticketing and a payment interface [13]. Consequently, the end-to-end customer experience is enhanced, and a customized mobility package based on data analysis can be suggested [6].

Mobility services based on AVs will be innovative due to the use of new technology. To introduce AV-based services, BMs should be formulated capitalizing novel and altering features; for instance, integrating AVs use with high-capacity transit systems, increasing vehicle occupancy levels, and encouraging multimodality [14].

Furthermore, the convergence of some BMs for shared mobility services is expected when the AVs becomes popular [5]. For example, car-sharing, taxi and ride- sourcing will be very similar services if using AVs. As AVs could pick users up, car-sharing services with AVs will be akin to the current ride-sourcing services [3]. Hence, it is foreseen that two BMs with AVs will shape the future of transportation: a private ownership model and a sharing model (i.e., SAVs) where car-sharing and taxi/ride-sharing companies offer on-demand mobility services [14].

In addition, due to the rapid development of AVs technology, fast obsolescence and growing cost are expected, which imply a significant reduction in private car ownership and high demand for AV-based mobility services [15]. The dismiss of a driver with AVs use encourages on-demand mobility services and allows for more novel BM possibilities [15][16]. Moreover, the owner and operator of the vehicles become the most important factors for BMs with SAVs [3].

As BMs are usually combined with a corporate strategy, the initial BM suffers modifications through continuous development [17]. To define the necessary modifications, the approaches align, adapt, and amplify can be used. Align refers to the ability of the BM aligns with the regime and not changing it. Adaptation occurs in order to re-align the value proposition with the regime, overcoming barriers to the business, which might result in a BM innovation. Companies amplify by seeking collaboration with key partners in the network, opening new business opportunities. As a consequence, adapting affects only the company while amplification may affect the whole niche [15]. Besides, BM diversifications aim to enhance competitiveness and performance by increasing the diversity and availability of the service; it can be used for creating a balance between demand and supply using various BMs altogether. As a result, business growth and profit are generated [12].

In conclusion, the main findings of the literature review are:

- Shared on-demand mobility services will be part of MaaS in the future.
- AVs will disrupt the definitions of the existing shared mobility services.

- Modifications in business models are necessary to accommodate changes in the regime and/or users' needs.

MOBILITY SERVICE BASED ON SHARED AUTONOMOUS VEHICLES

The mobility service based on SAVs is an alternative to private car usage; users can share vehicles and seats on urban trips. The key stakeholders are the travelers, mobility service providers, vehicle owners and operators, traffic control operator, and in-vehicle service providers; they can be either public or private companies or individuals. They distribute functions among each other through partnerships, whereas the legal and economic conditions are recorded in contracts (e.g., bonus-malus system, commission after travelled- kilometers). The operation is managed by integrated traffic control and operational centers.

The service is accessed via smartphone application, which offers high spatial and temporal flexibility (i.e., the user travels wherever and whenever s/he wants), personal and traffic safety, as well as reliability (e.g., more accurate expected time of arrival). Not only the traveler segments from the current shared mobility are attracted but also people without driving ability or license can use the service. Also, a complex and dynamic service fee is applied, where mainly the service, traveler attributes, the current demand and supply are considered besides many additional aspects (e.g., extra service elements – child seat).

The creation of the proposed BM was twofold. Firstly, the need for modifications in the BM of the current shared mobility services (e.g., taxi, ride-sourcing, car- sharing) caused by the implementation of AVs in the fleet has been investigated. After that, a general BM for SAV services has been developed using the Lean Canvas approach.

Current BMs for Shared Mobility Services

Existing literature describing the BMs of the current shared mobility services (e.g., [18][19][20][21]) use the BM Canvas developed by [22]. Alternatively, we have decided to use the Lean Canvas [23] because it focuses on understanding the problem that the business is trying to solve (i.e., problem), encourages simple ideas (i.e., solution), proposes key metrics to evaluate the business performance (i.e., key metrics), stimulates finding unique business characteristics (i.e., unique value proposition) that are extremely hard to replicate, hence, being more efficient for innovative solutions, such as AVs, and not yet well-established businesses [24]. The other items in the Lean Canvas are the same as in the BM Canvas: channels indicate the communication channels to target the audience; customer segments represent the possible customers to adhere to the service/product proposed; cost structure points out the variable and fix costs for the business; and revenue streams specify how revenues are achieved.

Based on the Lean Canvas items, similarities and differences between the current

BM for mobility service and the BM for the SAV services could be identified and analyzed.

Modifications with SAVs

The mobility service based on SAVs offers all benefits already provided by the current shared mobility services, keeping or combining them with others. As a result of the implementation of AVs in the BMs, some elements are excluded, and new ones are created. For instance, the key metrics "number of peers" and "number of rental days" attributed to P2P car-sharing and car rental are included into the key metrics "fleet per capita" and "daily trips" in SAV services, respectively. Elements related to drivers are disregarded, such as the number of drivers and costs with drivers. The customized fee is the main element created for the new mobility service, which could merge elements from the revenue streams according to users' requirements (e.g., extra services, subscription fee, travel fee).

The limitations of the model are: mixed fleet of conventional vehicles and AVs are disregarded; furthermore challenges in the transitional period, alteration in public transport and BMs of B2B car- sharing are not considered.

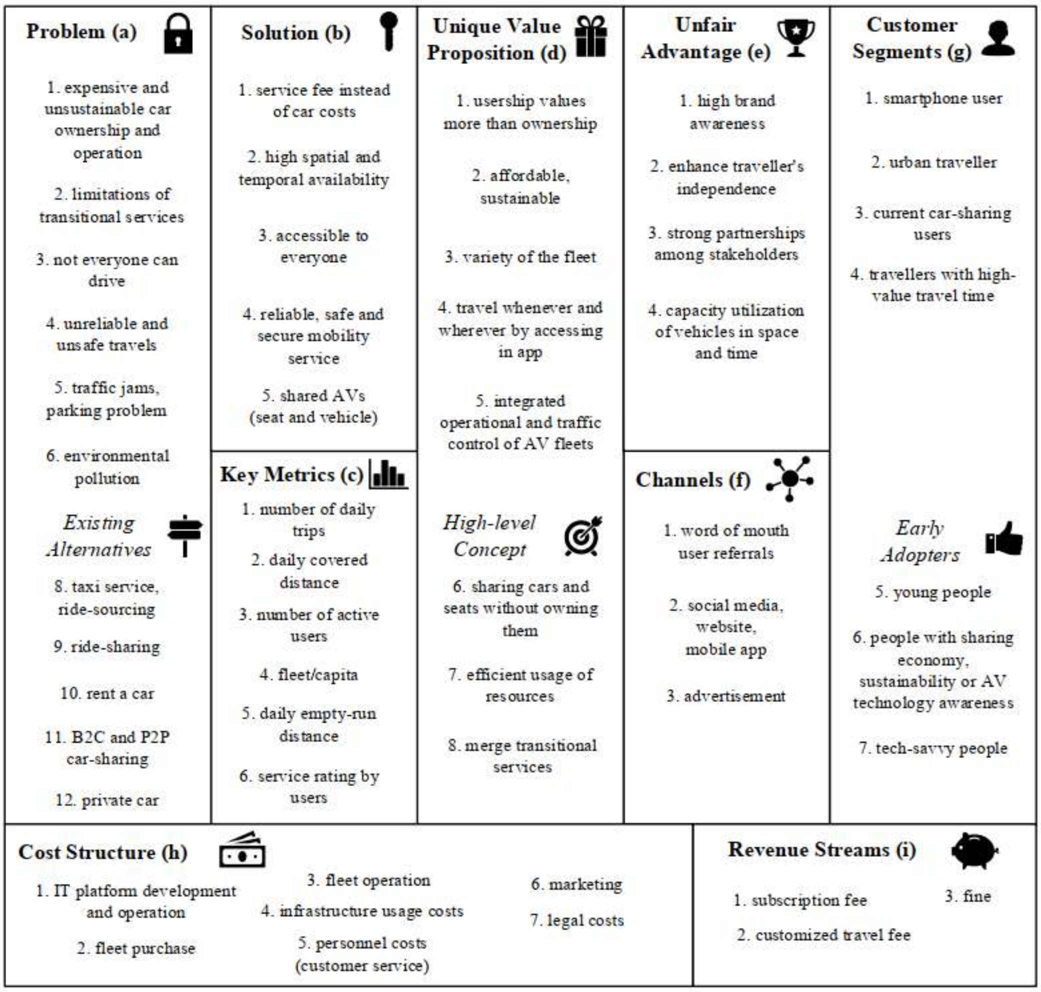
THE GENERAL BUSINESS MODEL FOR SAV SERVICES

The service providers coordinate the stakeholders involved in the service. There are strong partnerships between the fleet owners (company and individuals) due to mutual advantages; for instance, SAV service reduces fleet costs and private vehicle owners have an extra income. To provide a reliable and customized mobility service, more complex operational functions are required. However, customer independence and experience are enhanced. The SAV service can be incorporated into the MaaS concept, which establishes a bridge between the mobility service providers and the travelers, adding multimodality and ensuring the reliability, quality and affordability of the entire travel chain. The proposed BM for the mobility service based on SAVs is shown in Figure 1. A description of each item is followed.

Problem

Nowadays, car ownership (e.g., purchase, insurance, taxes) and operation (e.g., fuel, parking, maintenance, cleaning) are expensive. Besides, having a private vehicle is not efficient enough and not sustainable as its capacity is underutilized /a1/. On the other hand, travelers face some limitations of the transitional services /a2/, such as driving is exhausting, and commuting time is wasted. Besides that, individual car usage is not available for everyone /a3/, and many car accidents occur /a4/. Moreover, car usage causes increasing traffic jams and parking problem /a5/, as well as environmental pollution /a6/ in cities.

Figure 1. Lean Canvas of the mobility service based on SAVs



The existing alternatives of private car use are the more flexible transitional shared services (e.g., taxi, car- sharing) /a8-12/. However, they have several spatial, temporal, and usage limitations.

Solution

As an innovative solution for the previous issues, our proposed mobility service based on SAVs is operated by service providers. Vehicles can be owned by the company, as well as provided by private or public owners through partnerships. The operation is integrated with the traffic control of AV fleets. A service fee /b1/ is charged according to customized travel fees and hired additional services attending users' needs. The service offers high spatial and temporal availability /b2/ overcoming some limitations of the current mobility services: i) current taxi and ride- sourcing with pooling option are limited by the availability of a driver while the availability of the peer limits the P2P car-sharing service; ii) car rental has working hours as a limiting factor; iii) B2C car-sharing service is limited by coverage service area, parking and/or round-trip.

In the future, taxi service and ride-sourcing do not exist anymore as the driver will not be fundamental during vehicle operation. As a consequence, they migrate to ride-sharing, rent a car, P2P and B2C car-sharing services. Ride-sharing and P2P models are expected to exist with AVs if the ride is shared with the car owner, and the service negotiation is done with the peer, respectively. Otherwise, they become part of the service proposed. For the B2C car-sharing model, occupancy can be single or multiple; the latter includes the shared option. Thus, all existing shared mobility services can be replaced by the service proposed.

Moreover, it is accessible to everyone /b3/ because a driver and driving ability will not be a limiting factor anymore. Also, safety and reliability /b4/ are provided to travelers as it is expected that the technology and connectivity will improve traffic conditions, make travels predictable, mitigate human errors, and promote a safe environment in cities. The service is accessed via smartphone application, which offers the share of vehicles and seats to travelers /b5/. As the adoption of sharing with multiple occupancies increases, fewer traffic jams, parking problems, and environmental pollution are expected. Nevertheless, the use of electric or hybrid vehicles in the service fleet tends to transform transportation into more sustainable one.

Unique Value Proposition

In the mobility service based on SAVs, travelers use and may share cars without owning them /d6/, which makes usership to value more than ownership /d1/. An affordable and sustainable service /d2/ is foreseen; users pay only a service fee, and the same car is used for more people than in private ownership, enhancing the use of resources /d7/.

Some companies may opt for a uniform fleet type (i.e., the same car type, brand) to guarantee discounts when purchasing vehicles, but the variety of the fleet /d3/ may also increase attractiveness. Accordingly, users' various driving preferences and mobility needs might be tackled easily, broadening customer's segments.

The use of AVs facilitates merging the transitional services /d8/ and, consequently, travelling whenever and wherever the user prefers /d4/ is possible. It is foreseen that AVs will be able to communicate with each other and the mobility management center that includes both operational control and traffic control tasks /d5/. Accordingly, travel times and the mobility service itself are predictable and reliable.

Unfair Advantage

With the availability of technology and innovative BM understanding, the high brand awareness /e1/ is the unfair advantage of competitors; as the brand's recognition increases, so do the tendency of having more users and profitability. Additionally, the implementation of AVs enhances: i) traveler's independence /e2/, mainly for the ones without driving license (e.g., elderly, disabled people) as they will not depend on someone to drive them; ii) traveler's privacy as the service is available through a platform, avoiding the contact with AV owners from the partnerships.

Strong partnerships /e3/ among stakeholders imply a competitive advantage in the mobility market. Creating partnerships with AV owners allows to attend the demand without purchasing new vehicles and to boost the capacity utilization of vehicles both in space and time /e4/, benefitting all parties.

Customer Segments

Depending on the benefits (e.g., usage fee) provided and the limitations (e.g., travelled distance, coverage area, round-trip and parking) imposed by the BM, many customer groups can be interested on the service; especially, the smartphone users /g1/ and urban travelers /g2/. For instance, without round-trip limitation, one-way travelers are benefitted; customers leasing a car or from car rental companies due to the availability of the last-minute booking option; individuals who cannot afford car ownership and current car-sharing users /g3/. Furthermore, young people, people with sharing economy, sustainability and technology awareness /g5-g7/ are the early adopters of the service. Younger and graduated travelers are more likely to shift from private vehicles to a SAV service [25][26]. Alternatively, non-drivers and elderly people, who would be the most likely group to benefit from SAVs, hold in general low levels of AVs acceptability [25]. That is why the service proposed is simple and reliable, being able to increase acceptability levels.

Moreover, private vehicle owners who want to earn money make their vehicles available for public use via the proposed mobility service. The SAV services may invite all current shared mobility service users, especially travelers without the driving ability, and with high-value travel time /g4/ due to the service reliability. Even though the mobility service based on SAVs does not focus on attracting public transport users, it can happen.

Key Metrics

The success of the business will be measured through the number of daily trips, daily distance covered, the number of active users, fleet per capita, daily empty-run distance, and service rating by users /c1-c6/. The number of partner's vehicles provided to the service affects the fleet per capita, highlights the strength of partnerships and the probability of service expansion; thus, whether the service provided attends the variations in demand and purchasing new vehicles is necessary provides an important indicator of performance. Due to the flexibility of the service, the daily empty-run distance /c5/ should be monitored regarding impacts on operational costs and environment (e.g., energy wasting). The service rating by users /c6/ will show the service quality enhancement provided by AVs implementation.

Channels

It is not expected that the means with, which SAV service companies communicate with possible customers change significantly from the current ones /f1-f3/. Though, the intensity of use of each channel may vary in the future, tending to an even more internet- or app-based approach than the current one.

Cost Structure

Costs with platform development and operation /h1/ will remain and an increase in costs generated by the development of info-communication system and its operation is foreseen. In order to provide a high quality of service, more intensive cooperation of operational and traffic control centers is required, demanding more complex operational functions. Alternatively, costs with personnel for customer service /h5/ and marketing /h6/ may be reduced with automation and high brand awareness.

Fleet purchase /h2/ and operation /h3/ are fundamental costs for the future service as they influence the service quality and demand attended. Infrastructure usage costs /h4/ (e.g., parking) vary according to the fleet usage and the incentives provided by the local government, such as free parking, subsidies on vehicle charging, tax exemptions and favorable policies. The support from the government is decisive to the BM of disruptive innovations; besides cost reductions, policies or incentives can make customers perceive a higher value of adopting new mobility services or technologies [6], as well as defining potential customer groups to reach profitability in the business model [27].

In the mobility service based on SAVs, personnel costs with reallocation are disregarded. Costs with cleaning and maintenance are minimized by automating the process. Although the establishment of partnerships brings a new cost, which can be called a service fee paid to the partner, reductions in the costs with parking and electric charging could be achieved as these activities will be paid by the car owner. A rise in legal costs /h7/ is expected to cope with regulations and establish a fruitful partnership with vehicle owners.

Revenue Streams

Current shared mobility service companies already diversify service fees (e.g., dynamic fees), applying subscription fees and usage fees or only charging the usage fees. Besides that, it is common to apply fines, which becomes another source of revenue. As high flexibility of the service is achieved with AVs use, a customized travel fee /i2/ is applied as the main element to increase revenue and attractiveness at the same time. In order to attend to users' needs, the customized travel fee can be a combination of service options, such as temporal flexibility and on-board entertainment. Furthermore, a subscription fee /i1/ and fines /i3/ are kept.

CONCLUSION

Adopting a new technology, such as AVs brings high level of uncertainty to shared mobility service providers. Therefore, prediction of impacts to the business caused by the implementation of AVs is necessary. In this way, the main contribution of this study is the development of a general business model for mobility services based on SAVs using the Lean Canvas approach. We considered the following key stakeholders: travelers, mobility service providers, vehicle owners and operators, traffic control operator, and in-vehicle service providers.

The key findings are:

- All existing shared mobility services can be replaced by the SAV-based service proposed.
- AVs provide a high level of temporal and spatial flexibility.
- Strong cooperation is to be established between service provider, vehicle operator and private vehicle owners.

Although forecasting the impacts in BMs was challenging as technology is not fully developed yet, we filled an essential research niche. Our results support the establishment of future mobility services based on SAVs and increase awareness of all stakeholders about future impacts on them.

In the future research, we focus on a detailed investigation of the alterations regarding each type of shared mobility service and investigate new ones, such as door-to-door or feeder with or without seat sharing.

ACKNOWLEDGMENT

The research was supported by the Ministry of Innovation and Technology NRDI Office within the framework of the Autonomous Systems National Laboratory Program. EFOP-3.6.3-VEKOP-16-2017- 00001: Talent management in autonomous vehicle control technologies. The Project is supported by the Hungarian Government and co-financed by the European Social Fund.

REFERENCES

[1] Peric, M., Durkin, J., & Vitezic, V. (2017). The constructs of a BM redefined: A half-century journey. SAGE Open. doi: 2158244017733516.

[2] Möller, T., Padhi, A., Pinner, D., & Tschiesner, A. (2019, December 19). The future of mobility is at our doorstep. Retrieved June 09, 2021, from https://www.mckinsey.com/industries/automotive- and-assembly/our-insights/the-future-of-mobility- is-at-our-doorstep.

[3] Raudaschl, A. H. (2020, February 9). The Business Model of Autonomous

Tesla Taxis. The Lean Canvas. Retrieved June 10, 2021, f r o m https://medium.com/lean-canvas-takedown/the- short-term-gains-of-level-4-autonomy-on- personal-income-d51653d5310.

[4] Stocker, A., & Shaheen, S. (2017, July 20). Shared Automated Vehicles: Review of Business Models (Discussion Paper). Retrieved June 11, 2021, from International Transport Forum website: https://www.itf-oecd.org/shared-automated- vehicles-review-business-models.

[5] Münzel, K., Boon, W., Frenken, K., Vaskelainen, T. (2018) Car-sharing BMs in Germany: characteristics, success and future prospects. Information Systems and e-Business Management, 16, 271–291. doi:10.1007/s10257-017-0355-x.

[6] Kao, P., Busquet, C., Lubello, V., Meta, M., & Van den Heuvel, C. (2019, December 11). Review of business models for new mobility services. Retrieved June 15, 2021, from http://h2020- gecko.eu/fileadmin/user_upload/publications/GECKO_D1.2_Review_of_business_models_for_new_ mobility_services.pdf.

[7] Cohen, B., Kietzmann, J. (2014). Ride On! Mobility BMs for the Sharing Economy. Organization & Environment, 27(3), 279–296. doi:10.1177/1086026614546199.

[8] Sagar, P. (2021, March 17). Lyft business Model: Knowing the inside out of Ride-hailing giant. Retrieved June 20, 2021, from https://www.apurple.co/lyft-business-model/.

[9] ZOO (2021, April 07). Bla Bla Car – business model exemplar. From https://www.businessmodelzoo.com/exemplars/bla-bla-car/.

[10] Curtis, S. K. (2021). Business model patterns in the sharing economy. Sustainable Production and Consumption, 27, 1650-1671, doi:10.1016/j.spc.2021.04.009.

[11] Polydoropoulou, A., Pagoni, I., Tsirimpa, A., Roumboutsos, A., Kamargianni, M., Tsouros, I. (2021). Prototype business models for Mobility-as- a-Service. Transportation Research Part A: Policy and Practice, 131, 149-162, doi:10.1016/j.tra.2019.09.035.

[12] Kamargianni, M., Matyas, M. (2017). The business ecosystem of mobility-as-a-service. 96th Transportation Research Board (TRB) Annual Meeting. Washington, DC, USA: National Academy of Sciences.

[13] Eckhardt, J., Aapaoja, A., Nykänen, L., Sochor, J. (2017). Mobility as a Service business and operator models. 12th European congress on intelligent transportation systems, (pp. 19-22).

[14] Harb, M., Stathopoulos, A., Shiftan, Y., Walker, J. L. (2021). What do we (Not) know about our future with automated vehicles? Transportation Research Part C: Emerging Technologies, 123, 102948, doi:10.1016/j.trc.2020.102948.

[15] Meijer, L. L. J., Schipper, F., Huijben, J. C. C. M. (2019). Align, adapt or amplify: Upscaling strategies for car sharing BMs in Sydney, Australia. Environmental Innovation and Societal Transitions, 33, 215-230, doi:10.1016/j.eist.2019.06.003.

[16] Attias D. (2017) The Autonomous Car, a Disruptive BM? (pp. 99-113). In: Attias D. (eds) The Automobile Revolution. Springer, Cham. doi:10.1007/978-3-319-45838-0_7.

[17] Yun, J. J., Won, D., Park, K., Jeong, E., Zhao, X. (2019). The role of a BM in market growth: The difference between the converted industry and the emerging industry. Technological Forecasting and Social Change, 146, 534-562, doi:10.1016/j.techfore.2019.04.024.

[18] Tart, S., Wells, P., Beccaria, S., & Sanvicente, E. (2018, April 06). Analysis of business models for car sharing - Deliverable D3.1 (Report). Retrieved June 13, 2021, from LGI Consulting website: http://www.lgi-consulting.com/wp-content/uploads/2019/10/STARS-D3.1.pdf.

[19] Vaskelainen, T. (2014). Sustainable BMs - The Case of Car Sharing. In Resilence - The New Research Frontier : Proceedings of the 20th Annual International Sustainable Development Research Conference (pp. 615-627). Norwegian University of Science and Technology; International Sustainable Development Research Society.

[20] Uenlue, D. (2020, September 01). Business Model Canvas Uber [2020 update]. Retrieved June 12, 2021, from https://innovationtactics.com/business-model-canvas-uber/.

[21] The emerging business model canvas of conventional taxi services embracing mobile apps. (2019, August 16). Retrieved June 17, 2021, from https://www.spotnrides.com/blog/the-emerging- business-model-canvas-of-conventional-taxi- services-embracing-mobile-apps/.

[22] Osterwalder, A. , Pigneur, Y. (2010). BM Generation: A Handbook for Visionaries, Game Changers, and Challengers. John Wiley & Sons.

[23] Maurya, A. (2015, March 23). Why lean canvas vs business Model Canvas? Retrieved June 09, 2021, from https://www.linkedin.com/pulse/why-lean-canvas-vs-business-model-ash-maurya.

[24] Skowron, M. (2020, April 15). Lean canvas vs business Model Canvas: Which should you choose? Retrieved June 12, 2021, from https://uigstudio.com/insights/lean-canvas-vs- business-model-canvas-which-should-you-choose#:~:text=The%20lean%20and%20business%20model,around%20selling%20a%20specific%20product.

[25] Zhou, F., Zuduo Zheng, Z., Whitehead, J., Washington, S., Perrons, R. K., Page, L. (2020). Preference heterogeneity in mode choice for car- sharing and shared automated vehicles. Transportation Research Part A: Policy and Practice, 132, 633-650, doi:10.1016/j.tra.2019.12.004.

[26] Haboucha, C. J., Ishaq, R., Shiftan, Y. (2017). User preferences regarding autonomous vehicles. Transportation Research Part C: Emerging Technologies, 78, 37–49. doi:10.1016/j.trc.2017.01.010.

[27] Vokony, I., Hartmann, B., Kiss, J., Sőrés, P., Farkas, C. (2020). Business Models to Exploit Possibilities of E-mobility: An Electricity Distribution System Operator

Perspective. Periodica Polytechnica Transportation Engineering, 48(1), 1-10. doi:10.3311/PPtr.13471.

Influence of COVID-19 On PM_{10} Concentrations in Maribor

DAVID JESENKO, DOMEN MONGUS, UROŠ LEŠNIK

Abstract The pandemic caused by the coronavirus COVID-19 is having a worldwide impact that affects health, the economy and affects the air pollution in cities indirectly. In Slovenia, as well as in all other countries, the number of cases increased continually in 2020, which has affected the health system and caused movement restrictions, which, in turn, affects the air pollution in the country. This article analyses the indirect effect produced by this pandemic on air pollution in Maribor, Slovenia, by comparison of data from a period of movement restriction of the citizens by the government – the COVID lockdown periods in 2020 with data from baseline conditions, starting in 2013. Traffic and air quality data, in particular PM_{10} daily concentrations from the monitoring station in Maribor, were used to perform this evaluation. By processing, observing, and analysing detailed traffic data and PM_{10} concentrations acquired in the Maribor (Slovenia) city centre before and during pandemic times, we show the influence of COVID-19 on PM_{10} concentrations in that part of the town. Results show slightly lower PM_{10} concentrations and significantly lower traffic volume values in lockdown months.

Keywords: • PM_{10} • COVID-19 • Traffic • Particulate Matter

CORRESPONDENCE ADDRESS: asist. dr. David Jesenko, mag. inž. rač. in inf. tehnol., izr. prof. dr. Domen Mongus, univ. dipl. inž. rač. in inf.University of Maribor, Faculty of Electrical Engineering and Computer Science, Koroška cesta 46, SI-2000 Maribor, Slovenia, e-mail: david.jesenko, e-mail: domen.mongus@um.si, Uroš Lešnik , univ. dipl. ing. prom., National Laboratory of Health, Environment and Food, Prvomajska ulica 1, SI-2000 Maribor, Slovenia, e-mail: uros.lesnik@nlzoh.si

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

Air pollution has become a critical threat to the environment, as well as a cause of serious threats to humans' health. About 80 % of people in urban areas are exposed to air pollution exceeding the air quality standard value set by the World Health Organization (WHO), and even 98 % of cities in low-middle income countries and 56 % in high income countries do not meet the WHO guidelines [1]. Particulate matter with a diameter less than 10 µm (PM_{10}) can cause serious health problems due to their small size. Particles of this type can penetrate deep into the lungs, and impose significant risks to the respiratory and cardiovascular systems [2]. Although the sensitivity of individuals may vary with their general health and age, high concentrations of PM_{10} affect the whole population. According to the EU legislation [3], the concentration of PM_{10} particles should not exceed 50 µg/m3 more than 35 times in a year, while guidelines for protecting human health are even stricter, by recommending an annual mean value of 20 µg/m3 [4]. However, despite the successful legislation, a large part of Europe's and the World's population is unfortunately still breathing air with pollution levels that exceed the Air Quality Guidelines as defined by the WHO [5].

Coronaviruses are a diverse group of viruses infecting many different animals, and they can cause mild to severe respiratory infections in humans. In 2002 and 2012, respectively, two highly pathogenic coronaviruses with zoonotic origin, Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV) and Middle East Respiratory Syndrome Coronavirus (MERS-CoV), emerged in humans and caused fatal respiratory illness, making emerging coronaviruses a new public health concern in the twenty-first century [6]. At the end of 2019 and at the beginning of 2020 the world was hit by the novel coronavirus designated as Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) [7, 8]. SARS-CoV-2 emerged in the city of Wuhan, China, and caused an outbreak of unusual viral pneumonia. Being a highly pathogenic, transmittable and invasive pneumococcal disease, this novel coronavirus disease 2019 (COVID-19), has spread fast all over the world [9, 10].

COVID-19 was first reported in Slovenia on March 4, 2020. Since then, to prevent its propagation, the Slovenian government declared a state of health emergency [11]. A set of rapid and strict countermeasures were taken, including locking down cities, limiting the population's mobility, and prohibiting almost all avoidable activities. Also, in March 2020, a world pandemic was declared by the WHO [12]. In that time, all Slovenian cities were locked down, and the majority of industrial and commercial activities were forced to stop their activities until further notice. The same restrictions were made for citizens; the authorities requested them to stay at home and not to leave it except for very specific reasons.

Due to all the mentioned restrictions, it was expected that the COVID-19 outbreak would play a significant role in air pollution, PM_{10} concentrations, in general, have influence on air quality. Bad air quality, especially PM_{10} particles, impose significant risks to human health and the well-being of individuals in general [13]. In this paper, by processing, observing, and analysing traffic and air quality data acquired in the Maribor city centre before and during pandemic times, we show the influence of COVID-19 on PM_{10} concentrations in that part of the town. The acquired data were analysed using the visualisation and analytics tool for multi-dimensional data presented in [14]. From the obtained results we can suggest various adjustments and modifications in that part of town to reduce PM_{10} concentrations, and, thereby, improvement of health for the residents [15].

The remaining part of the paper is organised as follows. In Section 2, the related work is presented, while Section 3 contains a description of data capturing, data, and used methods. Section 4 presents the obtained results. The paper's conclusion is given in the Section 5.

RELATED WORK

In recent months the interrelationship between COVID-19 and the environment has been an emerging research topic. There has been a flood of papers on the topic of COVID-19 in connection with environmental degradation, air pollution, climate/meteorological factors and temperature [16]. Wang and Su reported significant reduction of air pollution due to full or partial lockdown in the short run, but the study does not support the reduction of greenhouse gas emissions (GHG) in the long run [17]. In [18] the authors present improvement of air quality, beaches, and reduced noise levels because of COVID-19, and GHG reduction in a shorter time period. Saadat et al. reported improvement of air and water quality worldwide, but, on the other hand, generation of a big amount of medical waste [19].

The authors in [20, 21] presented the significant influence of average and minimum temperatures, as well as the air quality on COVID-19 transmissions. Sahin presented a positive correlation between wind and COVID-19 cases in Turkey [22]. Qi et al. and Gupta et al. showed the notable negative influence of temperature and humidity on daily cases of COVID-19, while in the US, the prediction of COVID-19 transmissions by temperature and humidity is possible [23, 24]. Sobral et al. presented that those countries that have higher rainfall experienced an increase in COVID-19 transmissions [25].

Abdullah et al. found a significant influence of the movement control order in Malaysia on the reduction of particulate matters, especially $PM_{2.5}$ [26]. Authors from Rio de Janeiro, Brazil, and Barcelona, Spain, reported CO reduction during the lockdown period, in parallel with the mentioned reduction, an NO_2 and PM_{10} decrease also happened [27]. While CO, NO_2, and PM_{10} has been decreased, O3 has been increased by more than 50 % during lockdown [28]. An air pollution reduction by 30 % and mobility reduction by 90 % during COVID-19 lockdowns has been reported by Muhammad et al. [29]. In the major cities of central China, the source of the new SARS-CoV-2, the concentrations of $PM_{2.5}$, PM_{10}, SO_2, CO, and NO_2 reduced by 30,1 %, 40,5 %, 33,4 %, 27,9 % and 61,4 %, respectively, during the COVID-19 lockdown [30]. Moreover, Jain and Sharma stated that maximum reduction happened in the case of PM2,5 in most regions in India. The concentrations of $PM_{2.5}$, PM_{10}, and NO_2 declined by 41 %, 52 % and 28 %, respectively, in six megacities in India [31].

METHODOLOGY

Data capturing

Data used in the presented study were acquired using a monitoring system that was established in 2013 as part of the PMinter project. The monitoring station was located in a street canyon in the Maribor, Slovenia, city centre (direction west-east, as shown in Fig. 1, around 6 m from the centre of the road (two lane road, one way street) [15].

Figure 1. Location of monitoring system in Maribor

Automatic monitoring accounted for PM_{10} concentrations, measured using laser aerosol spectrometry, a laser with a 660 nm wavelength, according to the EN 12341 Standard. The device delivered particle counts in 31 size channels, and was able to conduct measurements in the range from 0,1 to 10 000 µg/m3. The data were gathered continuously from 01.01.2013, with the exception of short intervals (maximum 2-3 weeks per year) due to the maintenance and calibration work conducted on the sensory system. Temporal resolution of the system was 1 minute on average [15].

Data

In addition to particulate matter (PM_1, $PM_{2.5}$, and PM_{10}), the sensory system measured traffic data volume simultaneously using an induction loop installed within the roadway. The presence of a vehicle and its speed was measured using inductance footprints obtained with the inductive loop, and data were aggregated with 15 min temporal resolution (i.e., by counting the number of vehicles and estimating their average speed). Finally, the acquired data were combined with weather data using a 1 hour temporal resolution. Weather data include measurements of wind direction, atmospheric pressure, wind speed, rainfall, ambient temperature and relative humidity [15].

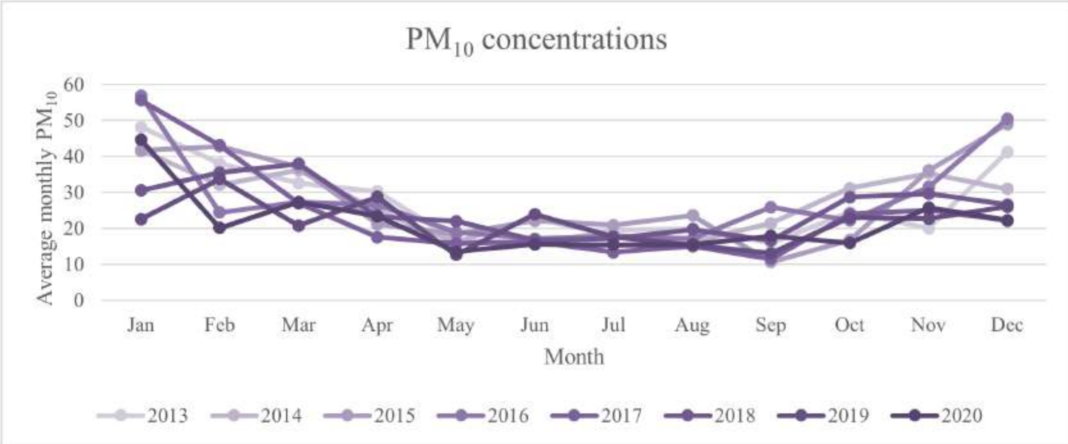
Analytics tool

Every empirical study requires proper data preparation for further examination and knowledge discovery. In the presented case, the data were structured in a spreadsheet, where each row represents an individual entry, which is treated as a multi-dimensional point, while the number of columns represents the dimension of a point. In that way, each measured value (from PM_1 to relative humidity) serves as a separate dimension. In some cases, it is possible that data has too many dimensions. Dimensionality reduction using principal component analysis is performed in that case. To get only a small number of important dimensions, data were mapped to the new space, where we arranged the dimensions according to the maximal dispersion of data, from those with the largest to the smallest ones [32]. In the next, the final step of data preparation, the mapped data was clustered hierarchically into clusters on different levels [33]. Data prepared in just the described way is ready for visualisation and further analysis. In our case, more important than visualisation is the analytic tool, which includes a great number of statistics and metrics, filtering data by individual variables or their values, and calculation of their probability density function [14]. The results presented in the next section were obtained and extracted using just the described tool.

RESULTS

The results in the continuation have been produced on an AMD Ryzen 5 4500U with 32 GB of main memory on Windows 10. The results shown in Fig. 2 represent the average monthly values from the beginning of 2013 till the end of 2020. We can see that there are no big deviations in PM_{10} concentrations in 2020, where two lockdown periods occurred in Maribor, and, in general, in Slovenia. The first lockdown period was from 12.03.2020 to 14.05.2020, and the second one started on 18.10.2020 and continued into 2021. In general, we can also see higher PM_{10} concentrations in the colder months, which is the result of more frequent use of heating systems (especially those powered by wood), and also a consequence of temperature inversions. They are one of the main reasons for the pollutions in Maribor [15]. From Fig. 2 we can also observe the descending trend in concentrations in the city of Maribor across the years. One of the reasons is global warming (higher winter temperatures), another one is more frequent use of electric cars and cars with lower exhaust emissions, bit there are also more and more houses with new-better thermal insulation and more efficient heating systems (also minor use due to better insulation).

Figure 2. Average monthly PM_{10} concentrations (01.01.2013 – 31.12.2020)



In Fig. 3 we can observe average monthly traffic volumes from the beginning of collecting data till the end of 2020. Unlike PM_{10} concentrations, Fig. 3 shows some deviations in 2020 in comparison to other years. There are two main reasons for such behaviour. On the one hand it is a consequence of COVID-19, and with it, connected lockdowns in the whole country. We can see lower values in April, March and also May, as an after effect of the first lockdown, and decreased values in October, November, and December due to the second lockdown. On the other hand, we have some months in 2020 with increased traffic volume, such as February and the whole time between both lockdowns. The reason behind those higher traffic volume values is the closure of Koroška cesta in the city centre of Maribor. Due to this closure the traffic was rearranged in the city of Maribor, and part of it was led past the PM_{10} concentrations measuring station. By taking this fact into account, closure of the road also means more traffic in lockdowns near the measuring station and, consequently, higher PM_{10} values than they were without the road closure. As mentioned before, there are no outstanding average monthly values in PM_{10} concentrations in Fig. 2, but we observed lower traffic volumes in the lockdown months (Fig. 3). The difference comes because that, in the lockdown months, people stayed at home and produced more PM_{10} with heating systems (notably in the winter months).

Figure 3. Average monthly traffic volume (01.01.2013 – 31.12.2020)

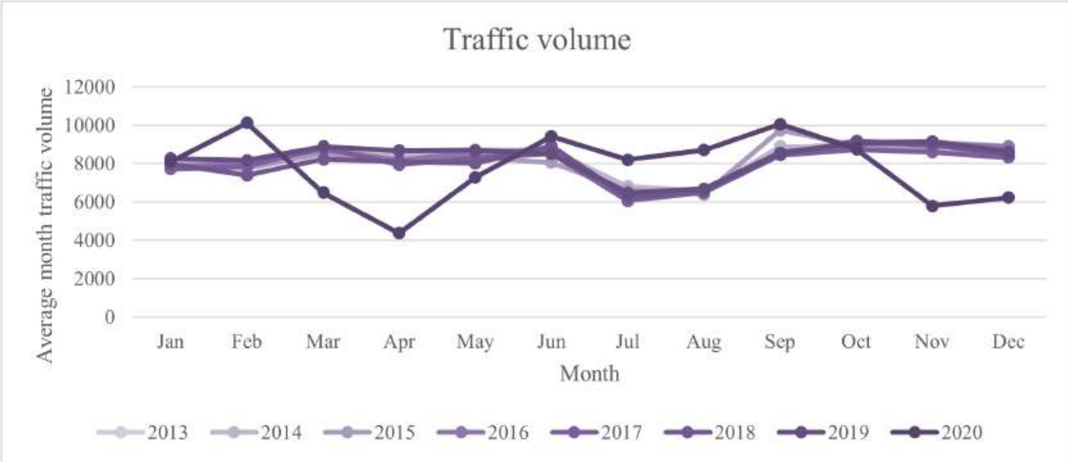
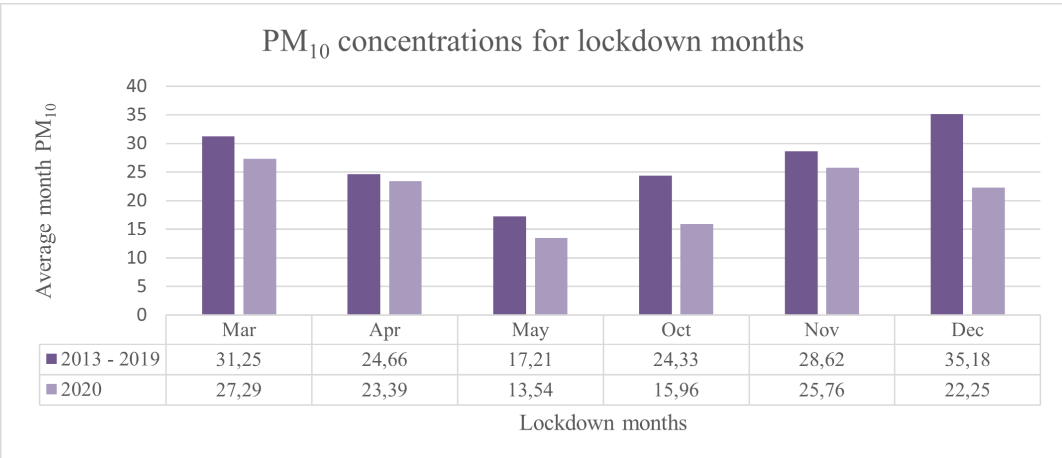


Fig. 4 shows the PM_{10} concentrations only in the lockdown months. For the period from 2013 to 2019 the average value of average monthly concentrations was used, while, for the year 2020, the monthly average values were used. In all the observed lockdown months, the PM_{10} concentrations were lower than the seven-year average, but that does not mean that 2020 PM_{10} concentrations values are the lowest in the history of measurements in Maribor (this happened only for two months, February and October). The graph in Fig. 4 also confirms the already mentioned finding from Fig. 2, that there was a descending trend in PM_{10} concentrations in the city of Maribor.

Figure 4. Average monthly PM_{10} concentrations during lockdown months in comparison to average monthly concentrations for the period from 2013 to 2019



CONCLUSION

The influence of COVID-19 on air quality, especially particulate matter, in the city of Maribor, Slovenia, is presented in this paper. By processing, analysing and investigating the data captured from the beginning of 2013 till the end of 2020, we came to some conclusions in general, and, most important, in the last year of used data we found out the influence of COVID-19 on PM_{10} concentrations in the observed city:

- the trend of decreasing PM_{10} concentrations since the beginning of the measurements,
- warmer weather and mild winters in recent years means lower concentrations of PM_{10},
- the closure of Koroška cesta had a significant impact on the increased traffic past the measuring station,
- decreased PM_{10} concentrations during COVID-19 lockdowns.

According to the results the used visualisation and analytics tool are suitable for new in-depth research and knowledge discovery. Future directions of this work are aimed at extending of the measurements used in this research with additional data, and then repeating the used approach to discover new knowledge.

ACKNOWLEDGEMENTS

The authors acknowledge the financial support from the Slovenian Research Agency (Research Core Funding No. P2-0041, Projects No. L2-1826, L7-2633, and N2-0181).

REFERENCES

[1] WHO, "WHO global urban ambient air pollution database," World Health Organization, 2016.

[2] Loomis D., Grosse Y., Lauby-Secretan B., El Ghissassi F., Bouvard V., Benbrahim-Tallaa L., Guha N., Baan R., Mattock H., and Straif K., "The carcinogenicity of outdoor air pollution," Lancet Oncology, vol. 14, no. 13, pp. 1262-1263, 2013.

[3] Marco G. and Bo X., "Air quality legislation and standards in the European union: Background, status and public participation," Advances in Climate Change Research, vol. 4, no. 1, pp. 50-59, 2013.

[4] WHO, "Air quality guidelines: Global update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide," World Health Organization, 2006.

[5] Guerreiro C. B. B., Foltescu V. and De Leeuw F., "Air quality status and trends in Europe," Atmospheric environment, vol. 98, no. 1, pp. 376-384, 2014.

[6] Cui J., Li F. and Shi Z. L., "Origin and evolution of pathogenic coronaviruses," Nature Reviews Microbiology, vol. 17, no. 3, pp. 181-192, 2019.

[7] Gama C., Relvas H., Lopes M., and Monteiro, A., "The impact of COVID-19 on air quality levels in Portugal: A way to assess traffic contribution," Environmental Research, vol. 193, no. 1, pp. 193-200, 2021.

[8] Hu B., Guo H., Zhou P., and Shi Z. L., "Characteristics of SARS-CoV-2 and

COVID-19," Nature Reviews Microbiology, vol. 19, no. 3, pp. 141-154, 20221.

[9] Wu J. T., Leung K., and Leung G. M., "Nowcasting and forecasting the potential domestic and international spread of the 2019-nCoV outbreak originating in Wuhan, China: A modelling study," The Lancet, vol. 395, no. 10225, pp. 689-697, 2020.

[10] Hui D. S., Azhar E. I., Madani T. A., Ntoumi F., Kock R., Dar O., Ippolito G., Mchugh T. D., Memish Z. A., and Drosten C., "The continuing 2019-nCoV epidemic threat of novel coronaviruses to global health - The latest 2019 novel coronavirus outbreak in Wuhan, China," International journal of infectious diseases, vol. 91, no. 1, pp. 264-266, 2020.

[11] Vodičar P. M., Valenčak A. O., Zupan B., Županc T. A., Kurdija S., Korva M., Petrovec M., Demšar J., Knap N., Štrumbelj E., Vehovar V., and Poljak M., "Low prevalence of active COVID-19 in Slovenia: a nationwide population study of a probability-based sample," Clinical Microbiology and Infection, vol. 26, no. 11, pp. 1514-1519, 2020.

[12] WHO, "Coronavirus disease 2019 (COVID-19): situation report, 73," World Health Organization, 2020.

[13] Fajersztajn L. , Veras M., Barrozo L. V., and Saldiva P., "Air pollution: A potentially modifiable risk factor for lung cancer," Nature Reviews Cancer, vol. 13, no. 9, pp. 674-678, 2013.

[14] Jesenko D., Brumen M., Lukač N., Žalik B., and Mongus D., "Visualization and analytics tool for multi-dimensional data," in Proceedings of the 2018 International Conference on Big Data and Education, Honolulu, Hawaii, 2018.

[15] Lešnik, U., Mongus D. and Jesenko D., "Predictive analytics of PM10 concentration levels using detailed traffic data," Transportation research part D: Transport and rnvironment, vol. 67, no. 1, pp. 131-141, 2019.

[16] Shakil M. H., Munim Z. H., Tasnia M., and Sarowar S., "COVID-19 and the environment: A critical review and research agenda," Science of the Total Environment, vol. 745, no. 1, p. 141022, 2020.

[17] Wang Q. and Su M., "A preliminary assessment of the impact of COVID-19 on environment - A case study of China," Science of the total environment, vol. 728, no. 1, p. 138915, 2020.

[18] Zambrano-Monserrate M. A., Ruano M. A., and Sanchez-Alcalde L., "Indirect effects of COVID-19 on the environment," Science of the total environment, vol. 728, no. 1, p. 138813, 2020.

[19] Saadat S., Rawtani D., and Hussain C. M., "Environmental perspective of COVID-19," Science of the total environment, vol. 728, no. 1, p. 138870, 2020.

[20] Bashir M. F., Ma B., Komal B., Bashir M. A., Tan D., and Bashir M., "Correlation between climate indicators and COVID-19 pandemic in New York, USA," Science of the total environment, vol. 728, no. 1, p. 138835, 2020.

[21] Tosepu R., Gunawan J., Effendy D. S., Lestari H., Bahar H., and Asfian P., "Correlation between weather and Covid-19 pandemic in Jakarta, Indonesia,"

Science of the total environment, vol. 725, no. 1, p. 138436, 2020.

[22] Sahin M., "Impact of weather on COVID-19 pandemic in Turkey," Science of the total environment, vol. 728, no. 1, p. 138810, 2020.

[23] Qi H., Xiao S., Shi R., Ward M. P., Chen Y., Tu W., Su Q., Wang W., Wang X., and Zhang Z., "COVID-19 transmission in Mainland China is associated with temperature and humidity: a time-series analysis," Science of the total environment, vol. 728, no. 1, p. 138778, 2020.

[24] Gupta S., Raghuwanshi G. S., and Chanda A., "Effect of weather on COVID-19 spread in the US: A prediction model for India in 2020," Science of the total environment, vol. 728, no. 1, p. 138860, 2020.

[25] Sobral M. F. F., Duarte G. B., da Penha Sobral A. I. G., Marinho M. L. M., and de Souza Melo A., "Association between climate variables and global transmission oF SARS-CoV-2," Science of the total environment, vol. 729, no. 1, p. 138997, 2020.

[26] Abdullah S., Mansor A. A., Napi N. N. L. M., Mansor W. N. W., Ahmed A. N., Ismail M., and Ramly Z. T. A., "Air quality status during 2020 Malaysia Movement Control Order (MCO) due to 2019 novel coronavirus (2019-nCoV) pandemic," Science of the total environment, vol. 729, no. 1, p. 139022, 2020.

[27] Dantas G., Siciliano B., Franca B. B., and da Silva C. M., and Arbilla G., "The impact of COVID-19 partial lockdown on the air quality of the city of Rio de Janeiro, Brazil," Science of the total environment, vol. 729, no. 1, p. 139085, 2020.

[28] Tobias A., Carnerero C., Reche C., Massague J., Via M., Minguillon M. C., Alastuey A., and Querol X., "Changes in air quality during the lockdown in Barcelona (Spain) one month into the SARS-CoV-2 epidemic," Science of the total environment, vol. 726, no. 1, p. 138540, 2020.

[29] Muhammad S., Long X., and Salman M., "COVID-19 pandemic and environmental pollution: a blessing in disguise?," Science of the total environment, vol. 728, no. 1, p. 138820, 2020.

[30] Xu K., Cui K., Young L. H., Hsieh Y. K., Wang Y. F., Zhang J., and Wan S., "Impact of the COVID-19 Event on Air Quality in Central China," Aerosol and air quality research, vol. 20, no. 5, pp. 915-929, 2020.

[31] Jain S., and Sharma T., "Social and travel lockdown impact considering coronavirus disease (COVID-19) on air quality in megacities of India: Present benefits, future challenges and way forward," Aerosol and Air Quality Research, vol. 20, no. 6, pp. 1222-1236, 2020.

[32] Abdi H. and Williams L. J., "Principal component analysis," Wiley Interdisciplinary Reviews: Computational Statistics, vol. 2, no. 4, pp. 433-459, 2010.

[33] Lukač N. and Žalik B., "Fast approximate k-nearest neighbours search using GPGPU," GPU Computing and Applications, vol. 2, no. 1, pp. 221-234, 2015.

Cross-Border Regional Railway Connections with Hybrid Powered Vehicles

MARCELL FETTER, BÁLINT CSONKA

Abstract Nowadays, because of the decreasing available amount of fossil fuels and increasing environmental requirements, transportation systems need to transform to the use of new energy sources. Among the inland transport systems, rail transport is the most energy-efficient but still uses many diesel-fueled vehicles in regional railway lines where the construction of catenary systems is not profitable. Due to historical events, many railway lines were cut due to border changes in the central European region. Many of these railway lines still operate today, but the connection between these neighboring counties is still missing. In these regions, the re-connection of railway lines improves the access to opportunities for the local population. In this research, we highlight the cross-border importance of eco-friendly rail transportation and propose a solution to these abandoned border connections. A multi-criteria evaluation method was used to harmonize various parameters related to hybrid vehicles and evaluate railway lines based on the attributes of hybrid-powered locomotives in the tri-border region of Croatia, Hungary, and Slovenia. We were aimed to answer the following questions with our research: "Which railway lines should be operated with hybrid, battery electric railcars between Slovenia, Croatia, and Hungary?", "What type of hybrid vehicle would be optimal to use in these railway lines?", and "What benefits would it cause to reopen border connections to passengers and railway operators?"

Keywords: • Hybrid Railway Vehicles • Multi-Criteria Evaluation Method • Battery-Electric Railcars • Cross-Border Railway Connections

CORRESPONDENCE ADDRESS: Marcell Fetter, BSc student, Bálint Csonka, PhD research associate Budapest University of Technology and Economics, Faculty of Transportation Engineering and Vehicle Engineering, Department of Transport Technology and Economics, Műegyetem rkp. 3, Budapest, Hungary, e-mail: marcell.fetter@edu.bme.hu, e-mail: csonka.balint@kjk.bme.hu

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

Internal land border regions in the European Union are less developed because infrastructure investments were determined with a centralized state in mind on a national level. Therefore, the periphery regions of countries are less developed, which lead to a migration toward the core regions causing a vicious cycle of further reduced investments. Furthermore, border regions have limited connection to neighboring regions because of historical, cultural, and linguistic barriers [1]. Consequently, the population has less opportunity in these areas. Despite considerable achievements, the border effect is still remarkable in Europe [2]. Currently, the permeability of borders and increasing cross-border traffic are considered as an opportunity for regional development [3].

After the Brexit, the European Union has 38 internal land border regions, which represent 40 % of the Union's territory and close to 30 % of the EU population [4]. To address the difficulties that these regions face, the European Commission adopted its Communication 'Boosting Growth and Cohesion in EU Border Regions' in 2017[4]. It was found that transport has a key role in exchanges between regions across national borders. Especially public transport because it provides a sustainable connection. Therefore, the organization and implementation of cross-border public transportation are high priorities.

Cross-border commuting is mostly guaranteed by private cars, which cause several negative environmental impacts. Since the railway sector has a significantly lower emission intensity and is safer than road transport the focus was put on rail transportation. The development of a trans-European rail network has been largely successful, but relatively little has been done for short cross-border travel [5]. Namely, smaller scale railway infrastructure is missing or inoperative in many cases along EU borders. However, the transport demand may be missing that could justify such an investment [6]. Accordingly, the efficient establishment of cross-border railway connection is one of the main challenges regarding integration in the European Union. Consequently, it is important to identify key regions, and evaluate the potential and effect of new and high-quality railway connections. In this paper, various small railway lines in the tri-border area of Croatia, Hungary and Slovenia were evaluated from the operation of hybrid railcars point of view. The aim was to identify new railway connections that boost economics, tourism and re-establish former connections.

The structure of the paper is the following: after a brief literature review, an overview of the cities in the tri-border region can be found, and the proposed railway lines are presented. The evaluation method is briefly presented and applied for the proposed railway lines. Finally, conclusion has been drawn, and future research trends are discussed.

LITERATURE REVIEW

Several papers investigated the effect of infrastructure developments on cross-border interactions, regional, urban, and local developments. It is expected that cross-border transport infrastructure developments improve foreign market access and reduce border effects [7]. Recent evidence shows that EU measures improved the accessibility in lagging regions [8] but the effect on market integration is debatable. The accessibility and population growth were analyzed in Western Europe between 1961 and 2011 [9]. It was found that domestic interaction opportunities provided by highway infrastructure clearly affected population growth and the population effects of cross-border transport infrastructure is limited, which indicates the lack of market integration across borders. It confirms the expectation that other factors, such as institutional quality [10], cultural and linguistic differences [11], [12] establish barriers. It is observable in Belgium, where the cultural and linguistic differences have effect on the interregional commuting [13].

The overall current panorama of cross-border transportation in the EU was examined and a cross-border transport permeability index was introduced [14]. According to a public consultation on border obstacles, the current state of physical accessibility is still regarded as one of the most important barriers after legal-administrative and linguistic barriers. In Central Europe, the rapid and partially unbalanced development after 1989 played a core role, especially for the high car dependency that affects cross-border flows [15]. After the independence of the Soviet Bloc the rail infrastructure investments significantly decreased that further increased car dependency. In line with that, public transport demand models show some weaknesses at the cross-border scale [16], [17]. The state of the public transport service in the Alps was examined from the tourist mobility point of view [18]. It was found that public transport may increase accessibility of points of interest and help to preserve the environment. Close to our aims, the connection was analyzed at the Hungary–Austria border [19]. It was found that the cross-border railway services provided by GYSEV represent a milestone in cross-border integration and public transport services should be further harmonized because long travel times, complex multimodal chains, and unappealing fares are still huge barriers.

In summary, the presence of cross-border public transport service is a key element in reducing the border effect and increasing regional integration. However, other aspects, such as cultural differences, should be also considered to successfully connect regional markets in border regions.

TRI-BORDER REGION

The relationship between Croatia, Hungary and Slovenia is unique because they belonged to the Austro-Hungarian Monarchy until 1918. Therefore, the cultural and linguistic differences are smaller and ethnicities from these countries can be found in each country. Furthermore, after 1918, several cross-border connections were closed, and previously integrated regions become separated. Hungary and Slovenia joined the European Union in 2004, Croatia joined in 2013. Since the EU supports the cross-border connections, the re-establishment of former connections is high priority.

Based on the current state of the rail network, the following settlements were considered:

- Croatia: Beli Manastir, Čakovec, Koprivnica, Mursko Središće, Osijek, Varaždin, Zagreb.
- Hungary: Dombóvár, Kaposvár, Lenti, Nagykanizsa, Őriszentpéter, Pécs, Villány, Zalaegerszeg.
- Slovenia: Lendava, Maribor, Ormož.

The population and the relative GDP per inhabitant are summarized in Table 1.

Table 1. Characteristics of the settlements in the tri-border region

Settlements	Population	GDP per inhabitant in PPS (% of EU27 avg.)	Settlements	Population	GDP per inhabitant in PPS (% of EU27 avg.)
Croatia	2M	65 %	Lenti	7755	54 %
Beli Manastir	8034	45 %	Nagykanizsa	45682	54 %
Čakovec	15185	54 %	Őriszentpéter	1168	66 %
Koprivnica	23896	46 %	Pécs	145468	48 %
Mursko Središće	3465	54 %	Villány	2237	48 %
Osijek	83496	45 %	Zalaegerszeg	56177	54 %
Varaždin	38746	57 %	Slovenia	4M	89 %
Zagreb	792875	118 %	Lendava	2947	59 %
Hungary	9,7 M	73 %	Maribor	97019	71 %
Dombóvár	18275	55 %	Murska Sobota	11025	73 %
Kaposvár	61948	47 %	Ormož	1862	71 %

Source: Croatian Bureau of Statistics, Ministry of Interior (Hungary), Statistical Office (Slovenia), https://ec.europa.eu/eurostat/

It is noted that the NUT3 regions of the investigated settlements (except Zagreb) are underdeveloped in comparison with the country average. Therefore, there is a huge potential in cross-border market integration. The new connections may boost economics in the regional centers, such as Osijek, Kaposvár, Zalaegerszeg, Pécs and Maribor, and improve the access to opportunities at small settlements, such as Beli Manastir, Lenti and Lendava.

Since the countries are members of the European Union, efforts were made to improve cross-border connection with a focus on road transport. New border crossing points were opened, such as Rédics– Genterovci (2014), and new connection on highway between Croatia and Hungary is in development. On the other hand, the high-quality rail service, like GYSEV between Austria and Hungary, is missing.

RAILWAY LINES AND NEW RAILWAY CONNECTIONS

In this chapter, new rail connections between the settlements in the examined tri-border region are proposed.

Several different types of railway connections were examined. There are railway lines with long-distance passenger traffic still run today between Budapest and Ljubljana via Hodos border station and between Budapest and Zagreb via Gyékényes border station. There are railway connections where passenger transport services were cancelled years ago, but the railroad is still used today for freight transport for example in Murakeresztúr border station. Finally, there are railway lines that had been cut by new state borders, and a few kilometers of railroad tracks are missing between the two countries for example between Lendava and Rédics.

The following aspects were taken into account during the development of new railway connections:

- population,
- distance,
- economic development,
- track condition,
- characteristics of electrification along the railway lines.

According to the aspects, the following routes were examined in this paper:

1. Pécs – Villány – Beli Monastir – Osijek

The Pécs - Osijek railway line is approximately 80 km long with an average maximum allowed speed of 80 km/h. It has only a small, 6 km long electrified section. Along the railway line the biggest cities are Pécs with 145 thousand inhabitants and Osijek with 83 thousand inhabitants. Also, there are about 12 smaller cities and villages.

2. Dombóvár – Kaposvár – Gyékényes – Koprivnica – Zagreb

The Dombóvár - Zagreb railway line is approximately 203 km long with an average maximum allowed speed of 100 km/h. The whole railway line is electrified with 25kV 50Hz AC. Along the railway line the biggest cities are Zagreb with 792 thousand inhabitants, Kaposvár with 62 thousand inhabitants and Koprivnica with 24 thousand inhabitants. At Dombóvár station, there is hourly InterCity connection towards Budapest and Pécs.

3. Nagykanizsa – Čakovec – Ormož – Maribor

The Nagykanizsa - Maribor railway line is approximately 126 km long with an average maximum allowed speed of 100 km/h. The two ends of the railway line are electrified. In Hungary, there are 15 km of 25kV 50Hz AC while in Slovenia there are 69 km of 3kV DC. Along the railway line, the biggest cities are Maribor with 97 thousand inhabitants, Nagykanizsa with 46 thousand inhabitants, and Čakovec with 15 thousand inhabitants. Also, there are about 25 smaller cities and villages.

4. Zalaegerszeg – Lenti – Lendava – Mursko Središće – Čakovec – Varaždin

The Zalaegerszeg - Varaždin railway line is approximately 90 km long with an average maximum allowed speed of 60 km/h. On the whole railway line, only Zalaegerszeg station is electrified with 25kV 50Hz AC. Many years ago, the passenger trains between Rédics, Hungary and Lendava, Slovenia were cancelled Therefore, 7 km of the railway line would need to be rebuilt. Along the railway line, the biggest cities are Zalaegerszeg with 56 thousand, Varaždin with 39 thousand and Čakovec with 15 thousand inhabitants. Trains running on this route would connect to the Maribor - Nagykanizsa trains at Čakovec station.

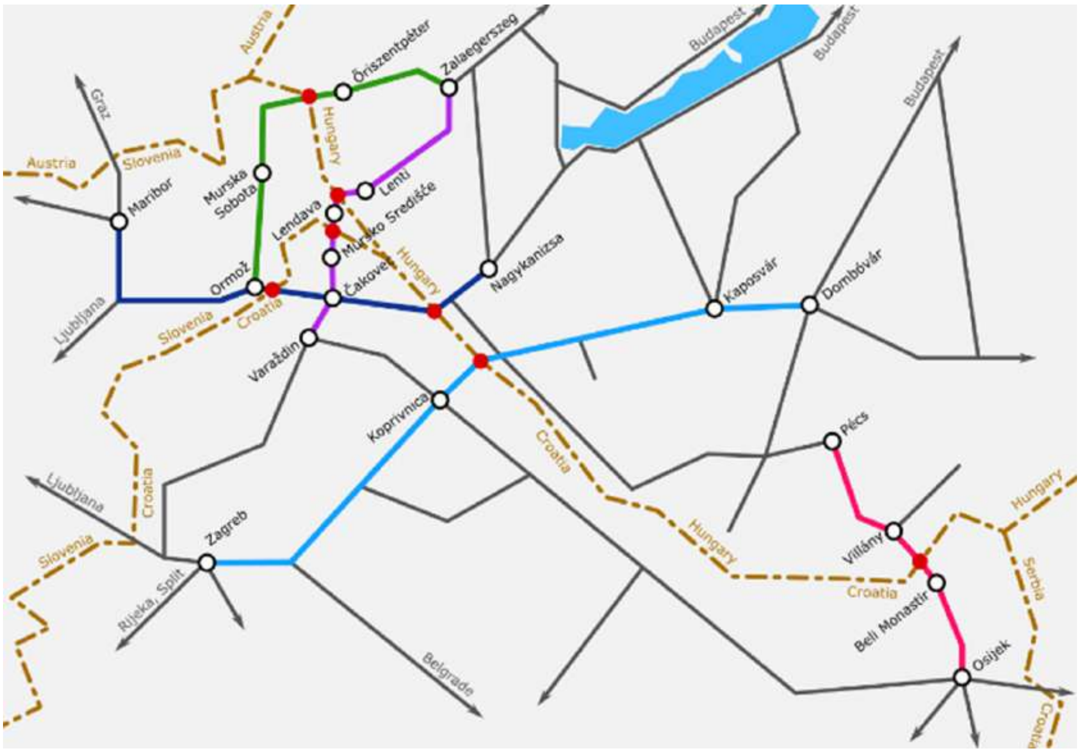
5. Zalaegerszeg – Őriszentpéter – Murska Sobota – Ormož

The Zalaegerszeg - Ormož railway line is approximately 112 km long with an average maximum allowed speed of 100 km/h. The Hungarian part of the railway line with a length of 43 km is electrified with 25kV 50Hz AC, while the 69 km long Slovenian section is electrified with 3kV DC. The railway line is an important route for freight trains connecting the Mediterrian sea with Central Europe. Also, it passes through

National Parks that may be important tourist destinations. Along the railway line, the biggest cities are Zalaegerszeg with 56 thousand inhabitants, and Murska Sobota with 11 thousand inhabitants. Trains running on this route would connect to the Maribor - Nagykanizsa trains at Ormož station.

The railway lines are given in Figure 1.

Figure 1. Rail network in the tri-border area



OVERVIEW OF THE EVALUATION METHOD

In a previous research [20], a weighted multi-criteria evaluation method was elaborated to determine the applicability of a battery electric railway car on a railway line, based on the characteristics of the line, vehicle, and passenger traffic. The evaluation aspects are as follows:

- railway line electrification,
- battery capacity utilization,
- railway track conditions,

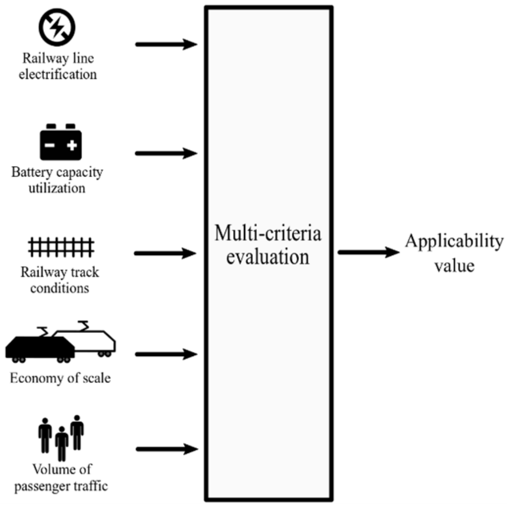
- economy of scale,
- volume of passenger traffic.

Each aspect is evaluated on a scale from 1 to 5. 1 point means low applicability, and 5 points mean high applicability. The weighted average of the evaluation points for each aspect is the aggregated evaluation value of the railway line. Based on the aggregated evaluation value:

- railway lines can be ranked,
- the effect of charging infrastructure development on the application of battery electric railcars can be evaluated, and
- the appropriate type of battery electric railcars can be selected.

The evaluation process is summarized in Figure 2.

Figure 2. Evaluation process



In this paper, this multi-criteria evaluation method is used to rank the examined railway lines between Croatia, Hungary, and Slovenia.

In order to use the evaluation method, the types of railcars that are planned to be used on the railway lines are also needed, Therefore, the characteristics of battery electric railcars were also analyzed in previous research to reveal their effects on operation and passenger comfort. The analyzed hybrid railcars were the Siemens Mireo Plus B railcar, the Bombardier Talent 3 railcar, the Stadler Flirt Akku railcar, and the Alstom Coradia Continental railcar.

The parameters of the examined vehicles are summarized in Table 2.

Table 2. Characteristics of hybrid railcars

Vehicle type	Range [km] (R)	Seats (C)	Max. speed [km/h]
Alstom Coradia Contin [21]	120	150	160
Bombardier Talent 3 [22]	100	169	140
Siemens Mireo Plus B [23]	80	120	140
Stadler Flirt Akku [24]	150	154	140

EVALUATION OF THE RAILWAY LINES

Using the multi-criteria evaluation method, the following, railway connections are evaluated and ranked:

1. Pécs – Villány – Beli Monastir – Osijek

2. Dombóvár – Kaposvár – Gyékényes – Koprivnica – Zagreb

3. Nagykanizsa – Čakovec – Ormož – Maribor

4. Zalaegerszeg – Lenti – Lendava – Mursko Središće – Čakovec – Varaždin

5. Zalaegerszeg – Őriszentpéter – Murska Sobota – Ormož

In order to use the evaluation method, there are different parameters that need to be known. The vehicle parameters can be found in table 1. Variable M, which is the minimum number of railcars that can be operated economically, is determined to be 20 vehicles, and variable V, that stands for the acceptable permitted maximum average speed is determined to be 80 km/h. Furthermore, the parameters of the evaluated railway lines are summarized in table 3, where:

- L_{NE} is the longest non-electrified section of the railway line,
- $\bar{u}$ is the average number of passengers per train for the whole journey,
- v_{avg} is the distance-weighted average maximum permitted speed of the railway line.

Table 3. Railway line parameters

Line	L_{NE}	$\bar{u}$	v_{avg}
1	74 km	~20	80 km/h
2	0 km	~50	100 km/h
3	42 km	~40	100 km/h
4	89 km	~40	60 km/h
5	0 km	~30	100 km/h

Railway track conditions and economy of scale aspects were decided to be the most important, while the volume of passenger traffic got the lowest weight. The focus of this research was to find new passenger train connections between the three countries, Therefore, the hybrid aspects got lower weights, because there are railway lines that are fully electrified. Also, on many relations, the passenger trains were cancelled many years ago, so it is difficult to predict the volume of passenger traffic in the future, and with a higher weight, these predictions could give false results. The exact weight numbers used in the research are summarized in table 4.

Table 4. Weight numbers

Aspect	Weight (si)
Railway line electrification	0,2
Battery capacity utilization	0,2
Railway track conditions	0,3
Economy of scale	0,25
Volume of passenger traffic	0,05

The results provided by the multi-criteria evaluation method for each railway line and vehicle combination are summarized in table 5.

Table 5. Evaluation results

Rail-way line	Siemens Mireo Plus B	Bombardier Talent 3	Stadler Flirt Akku	Alstom Coradia Continental
1	2,4	2,6	3,4	2,6
2	3,6	3,55	3,55	3,6
3	4,1	4,45	4,65	4,65
4	2,7	2,85	3,25	3,05
5	4,05	4	4	4,05

As the results show, the most suitable railway line for hybrid railcars is railway line number 3 between Maribor and Nagykanizsa. The main reason that it turned out to be the best is because it has the best ratio of electrified and non-electrified sections, the railway track conditions are acceptable and the length of the railway lines in the region is long enough to operate a larger number of vehicles.

CONCLUSION

In this article, in order to support the sustainable cross-border railway connections and market integration, several settlements affected by railway lines in Croatia, Hungary and Slovenia were examined.

After comparing the population and economic development of the settlements, the establishment of new railway connections were recommended taking into account the population, distances, economic development, railway track conditions and the electrification of railway tracks in the tri-border region.

The 5 recommended railway routes were evaluated using a weighted multicriteria evaluation method developed in our previous research, which helps to rank railway lines where it is worthwhile to operate hybrid-powered railcars and helps to select the appropriate type of railcars. After the evaluation it turned out that the best connection would be the Nagykanizsa – Čakovec – Ormož – Maribor railway line because its inner non-electrified section has a suitable length. Because of the differences between the lines, the best railcar highly depends on the railway line.

In the future, we plan to include other aspects in the evaluation method, such as the population and economic development of the settlements along the examined railway lines. Also, in a future research, we would like to develop a method that helps to reliably estimate the future number of passengers in presently not existing railway connections.

ACKNOWLEDGEMENT

The research was supported by the Hungarian Government and cofinanced by the European Social Fund through the project "Talent management in autonomous vehicle control technologies" (EFOP-3.6.3-VEKOP-16-2017-00001).

REFERENCES

[1] Christodoulou A., & Christidis P. (2018). Cross-border transport infrastructure in the EU. Luxembourg: Publications Office of the European Union.

[2] Rietveld, P. (2012). Barrier Effects of Borders: Implications for Border-Crossing Infrastructures. European Journal of Transport and Infrastructure Research (Vol. 12, pp. 150-166).

[3] Sohn, C. (2014). Modelling cross-border integration: the role of borders as a resource. Geopolitics (Vol. 9, pp. 587-608).

[4] European Commision (2017). Boosting growth and cohesion in EU border regions.Brussels.

[5] European Commision (2017). Overcoming obstacles in border regions. Luxembourg: Publications Office of the European Union.

[6] Condeço-Melhorado, A., & Christidis, P. (2017). Road Accessibility in Border Regions: a Joint Approach. Networks and Spatial Economics (Vol. 18, pp. 363-383).

[7] Brülhart, M. (2011). The spatial effects of trade openness: a survey. Review of World Economics (Vol. 147, pp. 59-83).

[8] Ferrara, A.R., McCann, P., Pellegrini, G., Stelder, D., & Terribile, F. (2016). Assessing the impacts of Cohesion Policy on EU regions: A non-parametric analysis on interventions promoting research and innovation and transport accessibility. Papers in Regional Science (Vol. 96, pp. 817-841).

[9] Jacobs-Crisioni, C., & Koomen, E. (2017). Population growth, accessibility spillovers and persistent borders: Historical growth in West-European municipalities. Journal of Transport Geography (Vol. 62, pp. 80-91).

[10] De Groot, H.L.F., Linders, G.-J., Rietveld, P., & Subramanian, U. (2004). The Institutional Determinants of Bilateral Trade Patterns. Kyklos (Vol. 57, pp. 103-123).

[11] Nitsch, V. (2000). National borders and international trade: evidence from the European Union. Canadian Journal of Economics (Vol. 33, pp. 1091-1105).

[12] Chen, N. (2004). Intra-national versus international trade in the European Union: why do national borders matter? Journal of International Economics (Vol. 63, pp. 93-118).

[13] Persyn, D., & Torfs, W. (2015). A gravity equation for commuting with an application to estimating regional border effects in Belgium. Jourenal of Economic Geography (Vol. 16, pp. 155-175).

[14] Medeiros, E. (2019). Case Studies on Transport Policy (Vol. 7, pp. 1-12).

[15] Cavallaro, F., & Dianin, A. (2019). Cross-border commuting in Central Europe: features, trends and policies. Transport Policy (Vol. 78, pp. 86-104).

[16] Emberger, G., Schumich, M, Leth, U., & Bezak, B. (2013). Central European Cross Border Transport Model (CECBTM) (pp. 1-19). Rio de Janeiro, Brazil: World Conference on Transport Research Society.

[17] Martí-Henneberg, J. (2013). European integration and national models for railway networks (1840–2010). Journal of Transport Geography (Vol. 26, pp. 126-138).

[18] Cavallaro, F., & Dianin, A. (2019). Cross-border public transport as a driver for tourism in the Alps (pp. 2446-2461). Mumbai, India: World Conference on Transport Research Society.

[19] Dianin, A., & Cavallaro, F. (2020). Efficiency of public transport for cross-border commuting: An accessibility-based analysis in Central Europe. Journal of Transport Geography (Vol. 89, 102876).

[20] Fetter, M., & Csonka, B. (2021). Multi-criteria evaluation method for operating battery electric railcars (pp. 1-6). Prague, Czech Republic: 2021 Smart City Symposium Prague.

[21] Alstom S.A. (2020). Alstom signs first contract for battery-electric regional trains in Germany. [Online] Available: https://www.alstom.com/.

[22] Siemens Mobility Gmbh. Mireo Plus B Mireo Plus H hybrid multiple units. [Online] Available: https://www.mobility.siemens.com/.

[23] Alstom S.A. Commuter trains. [Online] Available: https://rail.bombardier.com/.

[24] Glickenstein, H. (2019). March 2019 Land Transportation News. IEEE Vehicular Technology Magazine (Vol. 14, pp. 18-26).

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Towards Zero-Emission Bus Fleets in Poland: The Perspective of the Organisers of Transport

KRZYSZTOF KRAWIEC, ADRIAN BARCHAŃSKI

Abstract The public transport sector in Poland is legally bound to replace the bus fleets under the provisions of the Act on Electromobility and Alternative Fuels. This act enforces urban areas to achieve the levels of so-called zero-emission buses (these include, among others, battery electric buses). In the article, we present the results of the questionnaire addressed to authorities responsible for the organization of public bus systems in urban areas in Poland. The purpose of the research was to find out the opinions of the organizers of public transport involving the issue of bus fleet modernization. The study has been divided into the following sections: general information, routes and traffic control, infrastructure, strategy, and economic issues. This is the first scientific study of this kind in Poland and its results may be of interest for the discussion on the battery electric bus deployment.

Keywords: • Battery Electric Bus • Electromobility • Organisers of Transport

CORRESPONDENCE ADDRESS: Krzysztof Krawiec, PhD, Silesian University of Technology, Faculty of Transport and Aviation Engineering, Department of Railway Transport, ul. Krasinskiego 8, 40-019 Katowice, Poland, e-mail: krzysztof.krawiec@polsl.pl, Adrian Barchański, MSc, Silesian University of Technology, Faculty of Transport and Aviation Engineering, Department of Transport Systems, Traffic Engineering and Logistics, ul. Krasińskiego 8, 40-019 Katowice, Poland, e-mail: adrian.barchanski@polsl.pl

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

Agglomeration processes are progressing across the world, causing some negative environmental effects. In this context, in the ranking of general social, axiological values of the XXI century, the previously undervalued good – fresh air – plays an increasingly important role [1]. High pollution levels negatively influence the quality of life of large social groups, especially in densely populated areas. This impact is egalitarian as it affects regardless of the material and social status of the population. To counteract these negative effects, actions are taken at different political levels and in different areas; transport is among them [2], [3].

The vision of sustainable transportation requires actions involving the adjustment of public transport systems to contemporary requirements. These include further integration of various transport sub-systems and modernization of the public fleet [4]. The latter includes the challenge of bus fleet transition towards a lower-carbon one, which we address in this paper [5]–[7]. One option, among others, is to replace the existing fleet with the fleet completely or at least partially, composed of battery electric buses (BEBs). This type of vehicle have included economic (higher purchase costs) and technical constraints (limited range and the associated long charging time and the currently insufficient number of charging points in the city area), However, there are also benefits arising from their operation, such as the lack of tailpipe emissions, and the reduction in noise pollution [8], [9].

Transport policy at the European level has long advocated for low-carbon vehicle deployment in cities and agglomerations. For several years, Polish legislation has also been active in this area. Importantly, the Polish Act on Electromobility and Alternative Fuels defines the specific timeframe for achieving the following levels of so-called zero-emission vehicles (including BEBs and trolleybuses; but not trams) [10]:

- 5 % on January 1, 2021,
- 10 % on January 1, 2023,
- 20 % on January 1, 2025,
- 30 % on January 1, 2028.

Such provisions create significant challenges for the local authorities and transit agencies in technical, organizational, and economic terms.

The process of bus fleet transition itself is adaptive, usually long-term, and complex [5], [11]. It is even more difficult when considering electrification of the entire functional area of the city. The challenges include e.g., bus route selection to be

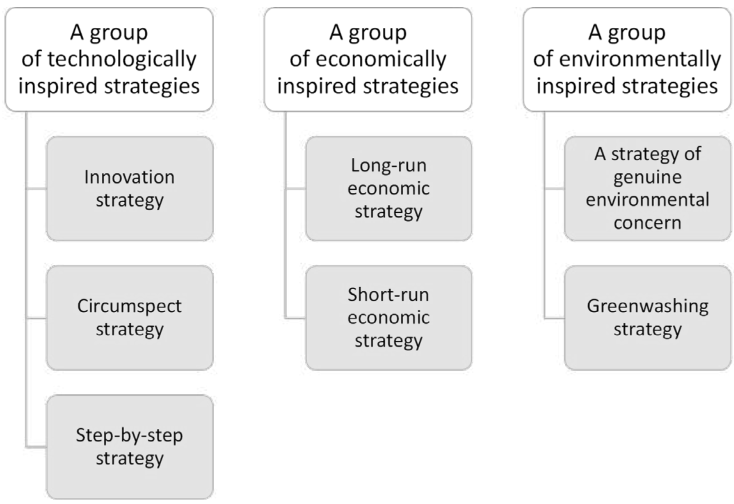
BEB-operated, choosing a proper charging technology strategy, ensuring the supply of electricity to various points in the transportation network (among many others). The consequences of the decisions to implement or abandon the transition will be will have an impact for many years to come [12].

This paper aims to present selected aspects of this issue from the point of view of their perception by organizers of public transport. The Public Transport Act of 16 December 2010 defines them as the competent local government units ensuring public transport operations on a given area (e.g., a city or agglomeration). We attempt to examine, which factors are significant to improve and popularize the process of bus fleet transition in this group. Previous studies have little addressed this problem, focusing more on technological issues or passenger and inhabitant perspectives of public transport electrification.

STRATEGIES OF ORGANISERS OF TRANSPORT

The deployment process may look different depending on where it takes place: the BEB deployment process looks different in a small city and a multi-million agglomeration. There are places where 100 % of the electric fleet has already been achieved, e.g., the Chinese city of Shenzhen [13]. There are many times more cities worldwide that will not even have public transport for a long time to come, not to mention the electric fleet. Among cities with reasonable public transportation quality, however, there are several patterns in the perception of the conversion process. For the purposes of this article, we have grouped them into the groups of technological, economic and environmental inspiration, respectively.

Figure 1. Strategies to address the fleet conversion problem



The first of a group of technologically inspired strategies is inspired by innovation. The innovation strategy is that the operator is trying to replace as much of the bus fleet as soon as possible. To this end, it began testing different models of tech buses fairly quickly, then deciding to purchase one batch of electric buses as large as possible. After that, often using donations for innovative or green measures, it aims for the largest possible share of electric buses in its fleet. Often, entities pursuing this strategy are open to research and testing new technologies, such as inductive charging or battery replacement. Motivation for such action may be i.a. will to improve the city's image as an innovative place that cares about the natural environment. A modification of this strategy is the cautious strategy, in, which the first batch of buses purchased (often smaller) is followed by a time-out while waiting for the technology to evolve and match the needs. A step-by-step strategy is between them. It means successive purchases of buses depending on the operator's needs, available technical solutions and financing possibilities.

Entities following a short-run economic strategy have as their main aim the minimization of the costs of operating the communication lines (e.g., in the price per vehicle kilometer). As long as the price of conventional bus service is lower, they will choose it. The conversion will take place when in the current cost calculation the electric bus is cheaper. Although this approach seems to be reasonable, e.g., in terms of annual settlements with the transport operator (city), in the long run, it may be more expensive, not to mention the environmental losses associated with such an approach. The long-term economic strategy emphasizes the total cost of ownership of buses, regardless of the technology. While this is a rational action, it does not consider the local environmental benefits of using electric vehicles earlier.

The strategy of genuine environmental concern stems from a sincere desire to improve the emissions performance of public transport throughout the city. The key is to maximize the environmental effect either for public transportation or in synergy with other sources of pollution. It is to this strategy of minimizing environmental pollution that the other elements of the transport system served by electric buses are matched (choice of vehicles, technical issues of charging and its strategy, choice of routes, etc.). Another strategy for large-scale implementation of buses is one that has its origin in the city's image as part of a broader policy. The policy of introducing buses on successive lines of communication is here their routing through the city centre, especially its representative areas. The cost of such an action may not be the lowest, but they assumed that the image gains are worth it. Obviously, also in this strategy, there is an ecological effect (no local emissions "from the tailpipe"), but we distinguish this strategy because of different motivations. A modification of this strategy is the strategy of false concern for the natural environment (greenwashing) with no genuine efforts to protect it in other areas, focused solely on image.

METHODOLOGY

The preparation of the questionnaire began after the Act on Electromobility and Alternative Fuels came into force. This created a completely new situation in, which a vivid discussion arose about how to achieve the objectives. Since the transit agencies often depend on the policy of the organisers of transport (thus, from the local authorities), it is their views that matter to the other actors.

Aiming to identify all the organizers of transport in Poland, the official websites of cities with at least 20 000 inhabitants were searched for information on, which department of the municipality or external institution acts as the organiser of public transport in their area. We have identified 48 organizers and sent to all of them a hard copy of the questionnaire by regular mail with an acknowledgement of receipt, along with a cover letter informing them of the purpose and scope of the study and instructions. The completed questionnaire had to be sent back to the organiser's address; we received 16 answers (33 %).

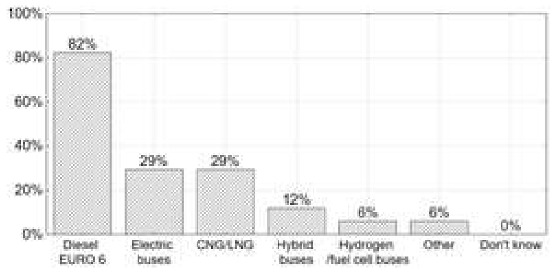
The Polish territory comprises 7 macro-regions according to the NUTS (Nomenclature des unités territoriales statistiques) level 1 classification developed by the European Statistical Office. Our questionnaire involved 4 organizers from the Northern macro-region, 4 from the Southern macro-region, 3 from the South-Western macro-region, 2 from the North-Western macro-region, 2 from the Central macro-region, 1 from the Mazovia macro-region, and 1 from the Eastern macro-region. They represent cities with the following characteristics: 53 % of the cities have a population below 200 000, 18 % between 400 000 and 600 000, 12 % between 200 000 and 400 000 and between 600 000 and 800 000 respectively. 35 % of the organizers operate in cities with an area of 50-100 km^2, 24 % with an area of 250-300 km^2, 12 % of the operators in cities with an area of up to 50 km^2 and between 100 and 150 km^2 respectively, 6 % of the operators in cities with an area of 150-200 km^2, 300-350 km^2 and 500-550 km^2, respectively. 29 % of cities have a population density between 1 500-2 000 people per km^2, 24 % each have a population density of 1000-1500 people per km^2 , and 2 000-2 500 people per km^2, 12 % 500-1 000 people per km^2 and 6 % each in cities with densities up to 500 people/km^2 and between 3 000 and 3 500 people per km^2. 41 % of the organisers operate in an area with over 40 % of public transport trips, 41 % of the organisers operate in an area with between 30-39 % and 18 % in an area with between 20-29 %. We are aware of the statistical imperfection of this sample, however, the study is heavily qualitative. Moreover, the participation in the study was voluntary and participants did not receive any benefit from completing the questionnaire. In this context and given the novelty of the subject and the probable absence of an opinion or fear of expressing one, we consider the results are worth analysing: the responses came mainly from institutions actively working in the field of public transport, with extensive knowledge, experience and practice in the issues covered by the survey. Based on basic city characteristics (population, density, etc.) there is no reason to reject the hypothesis that the structure of organisers who responded differs from the structure of organisers to whom we sent the questionnaire.

The questionnaire for local authorities responsible for organising public transport systems in cities or large conurbations consisted of 9 parts. The first one was about the organisational chart and included questions on how public transport is organised, the role of the local authority in it, the types of support for the transition to clean transport in the city/region, and the views on the future adoption of electric buses. The second part was about the availability of geographical data on public transport. The third part of the survey contained questions about routes and traffic control in the context of electric buses. Specifically, the questions addressed the potential for organizational and spatial changes resulting from the implementation of electric buses in a managed area. The fourth part of the survey for transportation organizers included questions about the existing technical infrastructure in terms of its support for electrification of the bus fleet. The key part of the survey included questions about preferences for the type of propulsion of the bus fleet (part 5). It included questions about views and ways to achieve zero-emission transport with different technical options, along with time horizons. Further parts of the questionnaire contained questions about IT support for the fleet conversion process (section 6), regional public transport popularity data (section 7) and economic issues (section 8). The latter included questions about the preferred type and level of support for purchasing and operating electric buses. The survey ends with a question about contact/identification data (section 9).

RESULTS

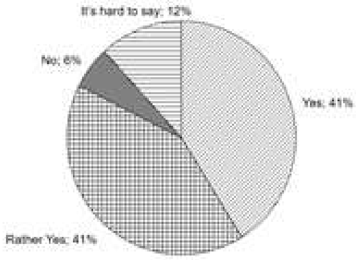
The vast majority of respondents in a multiple-choice question about their preferred power systems indicated Diesel EURO 6 (82 %). Electric buses share second place with gas-powered buses (both 29 %), getting ahead of hybrid buses and fuel cells ones.

Figure 2. Preferred drive systems



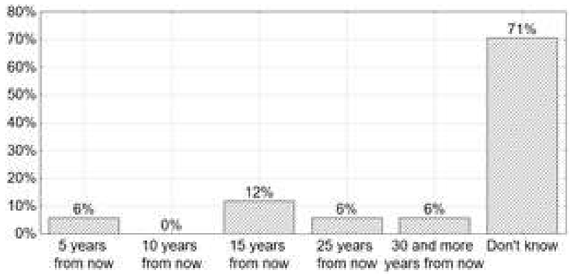
Most of the organizers we interviewed expect BEB numbers to increase in their area (82 %). Only 6 % foresees otherwise, and 12 % is uncertain (Fig. 3).

Figure 3. Answers to the question 'Do you foresee an increase in the number of BEBs?'



None of the operators surveyed had a 100 % electric fleet at the time of our research, and only 18 % of respondents see the electrification of the fleet happening soon (within 15 years). The vast majority of respondents (above 70 %) express the uncertainty of the total bus fleet electrification – see Fig. 4. This shows a strong backlash against ambitious transportation policy plans.

Figure 4. Time perspective to achieve a 100 % electric bus fleet



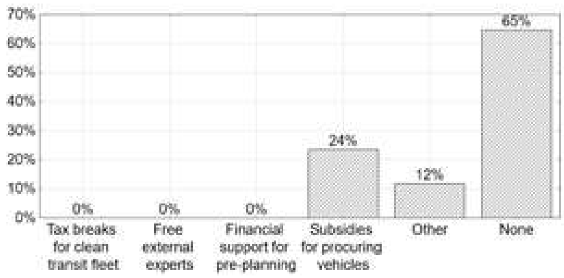
Organizers expect an increase in BEB usage 43 % yes, 43 % rather yes. However, only 12 % of the organizers back conversion to 100 % electric fleet. (It is worth noting that there is more support among respondents for extending tram coverage in cities where it already exists as 59 % of organizers have trams or trolleybuses in their area.) Organizers with more public transport stops per km^2 and operating trams more clearly expect an increase in BEB use. They also feel greater, stronger pressure to deploy this technology.

The organizers of transport show the following major barriers to the adoption of electric buses: high purchase cost (96 % of respondents marked this option in the multiple-choice question) and insufficient range (52 % of answers in the same question); of less importance in their opinion are higher operational costs (43 %), lack of existing charging infrastructure (30 % of answers). (Experts interviewed are less likely to point to the high cost of purchasing buses; however, they suggest a lack of experience, uncertainty about battery life, energy prices, lack of a coherent strategy, and technical and administrative problems associated with the need to build infrastructure and restrictions on its location).

A large share of organisers cannot identify the best charging strategy: 47 % of them have no opinion either on giving up charging at bus stops or on the possibility of using these stations to charge other vehicles. Those who can express a preference are unlikely to want to give up charging at bus stops while there are no extremes in terms of sharing charging stations, an equal share of rather yes and rather no opinions. Organizers who cannot identify the best strategy most often point to Euro VI and gas propulsion, while virtually no other options are selected.

To convince transport operators to invest in clean technologies, various economic tools encourage them to do so. These are, e.g., tax incentives, non-refundable grants, loans with subsidised rates or delayed repayment. While, of course, the most desirable option among the incentives listed above is the non-refundable grant, this is not always possible because of the limited financial resources of the grantor.

Figure 5. Perception of individual incentives to encourage BEB deployment problem



In Fig. 2. we depict the answers to the question of how the conversion process is supported, what forms of support are used in the area of transport organization. Most respondents indicated a lack of support for clean transportation within their area. Among other responses were subsidies for procuring vehicles (24 %).

UTILIZATION OF RESEARCH RESULTS

The survey results were used to define the bus fleet conversion planning process. This process is IT-supported through a set of components that support fleet conversion stakeholders what is of importance from the point of view of the practical impact. We also discuss how these components can be used by the organisers of transport to support them in achieving the goals set out by the transport policy. Based on the scheme, one may use the following components supporting electric bus deployment:

- BusVehicleSimulation - Simulation of the electric bus performance on the route
- CellParameters - Determining the value of traction battery elements
- DataProc – Generation of vehicle cycles
- CollectApp - Gathering real-time data on the potential route envisioned to be served by electric buses
- ECBus+ - Energy consumption calculations
- NMEA simulator - Calculation of the energy balance for the operating models
- OptimSched - Solve optimization problems related to fleet conversion process planning
- SyntheticalTrips - Simulation model for automatic generation of typical dynamic bus vehicle movement sequences in urban public transport
- TCOModel - A study of the total user cost of ownership of electric buses over their life cycle
- VisualGrids - Searching and editing bus routes to study their possible electrification
- ReportGenerator - for procurement decision support.

The above components can be toolkits for public transport organisers and other actors involved in the fleet conversion process.

SUMMARY

The research carried out revealed a wide variety of attitudes among the organizers of public transport towards the fleet conversion process. These attitudes result from different personal and institutional experiences - resulting in the selection of the most diverse strategies discussed in this article. These strategies differ in their sensitivity to environmental issues and in their confidence in the new technology. The time horizons of perspective from, which investment is evaluated economically also vary. An important factor is also the law, which forces certain actions and will force more and more. In each European country, the environment for decision-making in this area is different. As a result, operators have a lot of options to choose from, often taking into account other stakeholders in the process.

REFERENCES

[1] W. B. Pietsch, Agglomeration processes: phenomena, technologies, equipment. John Wiley \& Sons, 2008.

[2] European Commision, WHITE PAPER Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system. European Commision, 2011.

[3] European Commision, The European Green Deal. European Commision, 2019.

[4] United Nations, A Handbook on Sustainable Urban Mobility and Spatial Planning Promoting Active Mobility. Geneva: United Nations Publications, 2020.

[5] G. Santos, H. Behrendt, and A. Teytelboym, "Part II: Policy instruments for sustainable road transport," Research in Transportation Economics, vol. 28, no. 1. pp. 46–91, 2010, doi: 10.1016/j.retrec.2010.03.002.

[6] M. Dzikuć, R. Miśko, and S. Szufa, "Modernization of the Public Transport Bus Fleet in the Context of Low-Carbon Development in Poland," Energies 2021, Vol. 14, Page 3295, vol. 14, no. 11, p. 3295, Jun. 2021, doi: 10.3390/EN14113295.

[7] J. Patalas-Maliszewska and H. Łosyk, "Analysis of the Development and Parameters of a Public Transport System Which Uses Low-Carbon Energy: The Evidence from Poland," Energies, vol. 13, no. 21, p. 5779, Nov. 2020, doi: 10.3390/en13215779.

[8] M. Hamurcu and T. Eren, "Electric Bus Selection with Multicriteria Decision Analysis for Green Transportation," Sustainability, vol. 12, no. 7, p. 2777, Apr. 2020, doi: 10.3390/su12072777.

[9] H. Basma, C. Mansour, M. Haddad, M. Nemer, and P. Stabat, "Comprehensive energy modeling methodology for battery electric buses," Energy, vol. 207, Sep. 2020, doi: 10.1016/j.energy.2020.118241.

[10] Journal of Laws of the Republic of Poland, Act on Electromobility and Alternative Fuels (Polish: Ustawa z dnia 11 stycznia 2018 r. o elektromobilności i paliwach alternatywnych). 2018.

[11] K. Krawiec et al., "PLATON - Planning Process and Tool for Step-by-Step Conversion of the Conventional or Mixed Bus Fleet to a 100 % Electric Bus Fleet. Deliverable 5.4: User's manual.," 2020.

[12] A. Grauers, S. Borén, and O. Enerbäck, "Total Cost of Ownership Model and Significant Cost Parameters for the Design of Electric Bus Systems," Energies, vol. 13, no. 12, p. 3262, Jun. 2020, doi: 10.3390/en13123262.

[13] M. Li, H. Ye, X. Liao, J. Ji, and X. Ma, "How Shenzhen, China pioneered the widespread adoption of electric vehicles in a major city: Implications for global implementation," Wiley Interdisciplinary Reviews: Energy and Environment, vol. 9, no. 4. John Wiley and Sons Ltd, p. e373, Jul. 01, 2020, doi: 10.1002/wene.373.

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

The Use of Machine Learning to Predict Diesel Fuel Consumption in Road Vehicles

ARTUR BUDZYŃSKI, ALEKSANDER SŁADKOWSKI

Abstract The article is devoted to the issues of using machine learning methods with the scikit-learn library to predict diesel fuel consumption for trucks. Its main goal was to find a solution that allows predicting the fuel consumption of a truck with the least error. The data for the study was collected using the GPS tracking system of a small transport company from Poland. The problem of data adaptation for analysis was presented. 13 different forecasting models were evaluated on three success indicators. Finally, the models became available on the git-hub platform, which each user can use to predict fuel consumption in their fleet.

Keywords: • Machine Learning • Fuel Consumption Prediction • Scikit-Learn

CORRESPONDENCE ADDRESS: Artur Budzyński, MSc, Aleksander Sładkowski, Prof., DSc, Silesian University of Technology, Krasiński 8, 40-019 Katowice, Poland, e-mail: artur.budzynski@polsl.pl, e-mail: aleksander.sladkowski@polsl.pl

 ISBN 978-961-95633-0-4

INTRODUCTION

Fuel consumption is one of the main cost items in the operation of road transport. For every transport company, actions to optimize fuel consumption are essential. This is dictated by both environmental and economic factors.

For example, in the article [1], models for predicting fuel consumption based on data from a smartphone and an onboard diagnostic (OBD) system in a taxi were proposed. Models of neural networks, backpropagation errors, carrier vector regression, and random forests were used. The inputs were: average speed, average acceleration, average deceleration, percentage of acceleration time, percentage of deceleration time. The random forest model turned out to be the best.

Artificial neural networks are used relatively often to predict fuel consumption in vehicles of energy companies, for example, [2]. At the same time, the following is analyzed: maintenance that excludes downtime, periodic service and installation supervision. For the analysis in the network, the following data are entered, among other things: the number of cylinders of the car engine, engine displacement, number of valves, vehicle model and weight.

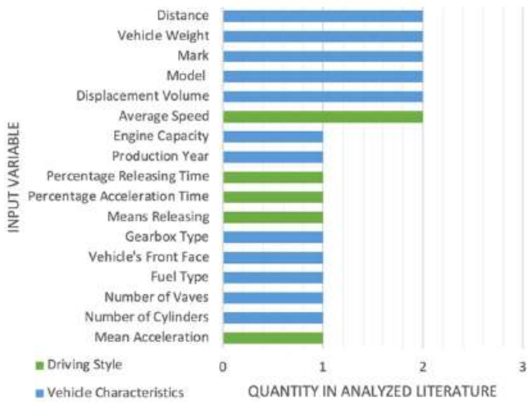
Scientists from Turkey have built 3 models to predict instantaneous and total fuel consumption. To do this, they used multiple linear regression, an artificial neural network, and a support vector machine. The type of fuel, the working volume of the cylinder, the frontal surface of the car, the mass of the car, the distance, and the average speed were used as the initial data. Support vector machine turned out to be the best forecasting tool [3].

Canadian scientists decided to build prediction models based on large data sets. The input data included: car segment, model, year, gearbox type, engine volume, driving time and distance. They used a carrier vector regression model and artificial neural networks, which proved to be better [4].

After analyzing the literature, we can conclude that individual projects are focused either on the vehicle and its characteristics, or on the driver and his driving style. Information about how often each of the variables from the projects from the above literature appeared is shown in Fig. 1. In the article, both types of data were taken into account in the modeling. The data for the analysis comes from a small transport company in southern Poland that uses the Lontex system to monitor its vehicles. The data is uploaded in the form of daily vehicle mileage reports. The surveyed vehicle fleet consists of 8 trucks (set: a tractor with a semitrailer). The analyzed data refers to the period from the beginning of May 2019 to the end of May 2020. This includes

1797 cases where the daily mileage for a given vehicle was non-zero. The aim of this article is to investigate whether the models from the scikit-learn libraries are useful for predicting the fuel consumption of trucks.

Figure 1. Input variables in the analyzed literature



When analyzing the literature, no example of shared knowledge was found on how to build a machine learning model step by step so that you can repeat the experiment and implement it in the company. In this work, it was decided to make available the code written during the analyzes. It is assumed that this is a phenomenon beneficial for entrepreneurs, especially small ones. The argument is that keeping an analyst full-time for such a company is too much of an expense. An analyst who is a machine learning specialist is especially expensive.

A Jupyter Notebook [5] was used to perform the tests. This is a tool that allows you to write code and comment on it in your browser. It is convenient for managing ongoing projects and documents. It also allows you to freely share the code referred to in the publication. The Python programming language was used during the calculations. It is a language used successfully for scientific calculations and reflection. It is attractive for exploratory data analysis and for the development of algorithms. There are many useful libraries for Python [6]. One of them is Scikit-Learn, which allows the implementation of many machine learning algorithms [7]. The Pandas library was also used for analyzes, which facilitates working with data sets [8]. The NumPy library was also used, which allows many numerical calculations in Python and is an open access software [9]. The survey data is collected by the GPS vehicle tracking system. A comprehensive library for creating static, animated, and interactive visualizations in Python named Matplotlib was used for data visualization [10].

PREPARATION OF DATA FOR RESEARCH

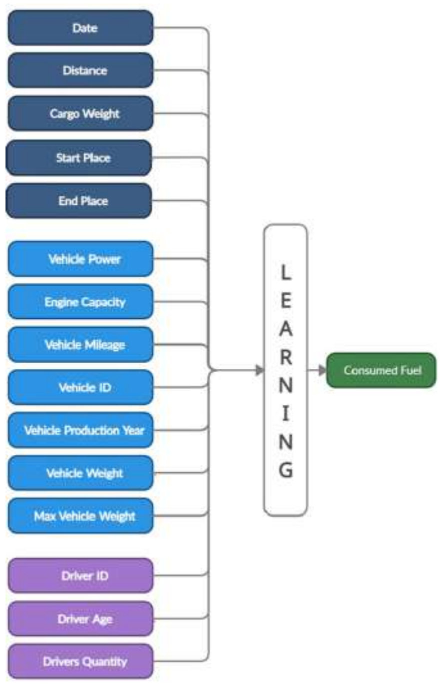
The data for the study is taken from the Lontex monitoring fleet management system. The lines with zero kilometers have been deleted. Based on the date, new features were created by specifying separately: year, month, day of the week. Vehicle mileage data in the Lontex system is stored intermittently. It is visually convenient when a person is looking at the table. However, it is not good for the machine and it needs to be changed. Using the code, the gaps were removed and the variable type changed to be useful for the model. The model diagram is shown in Fig. 2.

Missing data was supplemented with the mean value of a given feature based on existing data; it is common practice. In this case, it was considered better than filling the gaps with a value of 0 or -1. Data for the test for the period from the beginning of May 2020 to the end of May 2021. The training data is 70 %, the test data is 30 %, which corresponds to 1257 training and 540 test cases.

SUCCESS METRICS

3 success metrics were selected to assess the quality of the models. Calculating them will allow you to compare individual models with each other. The first is MSE (mean square error), this is the difference of sums of squares. The lower the value, the better the model performs. The pattern is shown below.

Figure 2. Variables for prediction model



$$MSE = \frac{1}{n}\sum_{t=1}^{n}(\hat{y}_t - y_t)^2 \ , \tag{1}$$

where: $\hat{y}_t$ – predicted value of the dependent variable; y_t – actual value of the dependent variable.

The second metric is RMSE (root mean square error), i.e., the root of MSE, and R^2, i.e., the coefficient of determination. It illustrates errors better than MSE. The lower the value, the better the model performs. The pattern is shown below.

$$RMSE = \sqrt{MSE}. \tag{2}$$

The last metric is the coefficient of determination R^2. It ranges from 0 to 1. The formula is presented below.

$$R^2 = \frac{SS_M}{SS_T} = \frac{\sum_{t=1}^{n}(\hat{y}_t - \bar{y})^2}{\sum_{t=1}^{n}(y_t - \bar{y})^2} \ , \tag{3}$$

where $\bar{y}$ – mean value of the dependent variable.

PREDICTIONS USING VARIOUS MODELS

13 regression models were selected: 2 classical linear regression, 7 regression with the selection of variables, 2 Bayess regressors, 1 outlier regressor, 1 generalized regression. The formula for the generalized linear model is shown below:

$$\hat{y}(w, x) = w_0 + w_1 x_1 + \cdots + w_p x_p \ , \tag{4}$$

where: $\hat{y}$ – forecasted value; w_0 – regression coefficient for an absolute term; w_1, ...,w_p – regression coefficients; x_1, ... , x_p – variables.

LinearRegression

LinearRegression is a linear regression model. A linear model with coefficients adapts to minimize the residual sum of squares between the observed target values in the data set and the target values predicted by the linear approximation. The problem is described mathematically by the pattern:

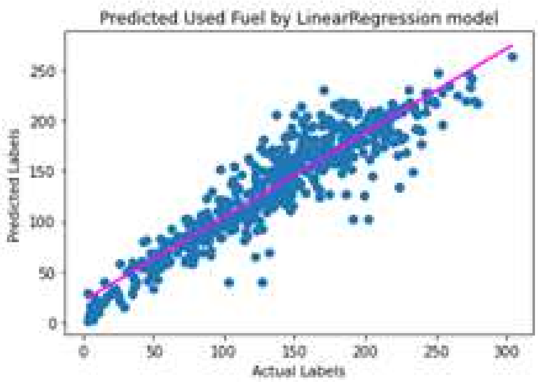
$$\min_{w} ||Xw - y||_2^2, \tag{5}$$

where: w – $(w_1, \dots, w_p)$ – coefficient; y – output variable.

The calculated metrics during training are shown below, and the model predictions during testing are shown in Fig. 3.

MSE: 560,67; $RMSE$: 23,68; R_2: 0,85

Figure 3. Predictions with model LinearRegression



Similar figures could be presented for each calculation method (each model).

RidgeRegression

RidgeRegression is also a linear regression model. It solves some of the problems of ordinary least squares by imposing a penalty on the size of the coefficients. The formula below describes the problem to be solved and the calculated metrics. Model predictions when testing in Fig. 4.

$$\min_{w} ||Xw - y||_2^2 + \alpha ||w||_2^2 \ , \qquad (6)$$

where α - complexity parameter.

MSE: 560,68; $RMSE$: 23,68; R^2: 0,85

ElasticNet

It is a linear regression model with two regulations of the norms of coefficients. This allows you to learn a rare model in, which few weights are non-zero as in the case of the Lasso. The formula below describes the problem to be solved and the calculated metrics. The model predictions during testing are shown in Fig. 5.

$$\min_{w} \frac{1}{2n_{\text{samples}}} ||Xw - y||_2^2 + \alpha\rho ||w||_1 + \frac{\alpha(1-\rho)}{2} ||w||_2^2 \ , \qquad (7)$$

where ρ - $l1\_ratio$.

MSE: 580,56; $RMSE$: 24,09; R^2: 0,85

Lars

Least-angle regression is a regression algorithm for high-dimensional data. At each step, the algorithm finds the function that most correlates with the goal. If there is a situation where there are many features with equal correlation, it does not continue along the same feature but runs in an equilateral direction between these features. The calculated metrics are shown below. The model predictions during testing are shown in Fig. 6.

MSE: 563,33; $RMSE$: 23,73; R^2: 0,85

Lasso

Lasso is a linear model that estimates rare coefficients. This is useful in some contexts because it tends to prefer solutions with fewer non-zero coefficients, effectively reducing the number of features on, which a given solution depends. The calculated metrics are shown below. The model predictions during testing are shown in Fig. 7.

MSE: 578,64; $RMSE$: 24,06; R^2: 0,85

LassoLars

It is a Lasso model with an implemented Lars algorithm. The calculated metrics are shown below. The model predictions during testing are shown in Fig. 8.

MSE: 2062,24; $RMSE$: 45,41; R^2: 0,46

LassoLarsIC

It is a Lasso model with an implemented Lars algorithm. It uses BIC and AIC for this. BIC is a Bayessian evaluation criterion. AIC is the Akaike evaluation criterion. The calculated metrics are shown below. The model predictions during testing are shown in Fig. 9.

MSE: 567,87; $RMSE$: 23,83; R^2: 0,85

OrthogonalMatchingPursuit (OMP)

Orthogonal Matching Pursuit (OMP) implements the OMP algorithm to approximate the fits of a linear model with a limited number of non-zero elements. If this number is not specified then the default value of 10 % of the features is used.

$$\underset{w}{argmin}||y - Xw||_2^2 \; subject\ to \; ||w||_0 \leq n_{nonzero\backslash\_coefs} , \tag{8}$$

where $n_{nonzero\backslash\_coefs}$ – restriction of non-zero elements.

This model predictions during testing are shown in Fig. 10.

MSE: 716,03; $RMSE$: 26,76; R^2: 0,81

OrthogonalMatchingPursuitCV

It is an OMP algorithm with cross validation. The calculated metrics are shown below. The model predictions during testing are shown in Fig. 11.

MSE: 605,12; $RMSE$: 24,60; R^2: 0,84

BayesianRidge

Bayesian techniques can be used to include regularization parameters in the estimation procedure. The regularization parameter shall be fine-tuned to the available data. BayesianRidge estimates the probabilistic model of the regression problem. The predictions during testing are shown in Fig. 12.

$$p(w|\lambda) = \mathcal{N}(w|0, \lambda^{-1}I_p) , \tag{9}$$

where: p – predictive distribution; λ – regularization parameter; I_p – identity matrix $M \times M$.

MSE: 585,76; $RMSE$: 24,20; R^2: 0,85

ARDRegression

ADR (Automatic Relevance Determination) is very similar to BayesianRidge but can lead to rarer ratios.

$$p(w|\lambda) = \mathcal{N}(w|0, A^{-1}) , \tag{10}$$

where $A = \lambda = \{\lambda_1, \dots , \lambda_p\}$ – diagonal matrix.

MSE: 716,05; $RMSE$: 26,76; R^2: 0,81

RANSACRegressor

The RANSAC model (RANdom Sample Consensus) is an iterative algorithm for the reliable estimation of parameters from a subset of intermediate data from a complete dataset. The calculated metrics are shown below.

MSE: 704,72; $RMSE$: 26,55; R^2: 0,81

TweedieRegressor

This model is used for analyzing various GLM (Generalized Linear Regression) models. The calculated metrics are shown below.

MSE: 936,21; $RMSE$: 30,60; R^2: 0,75

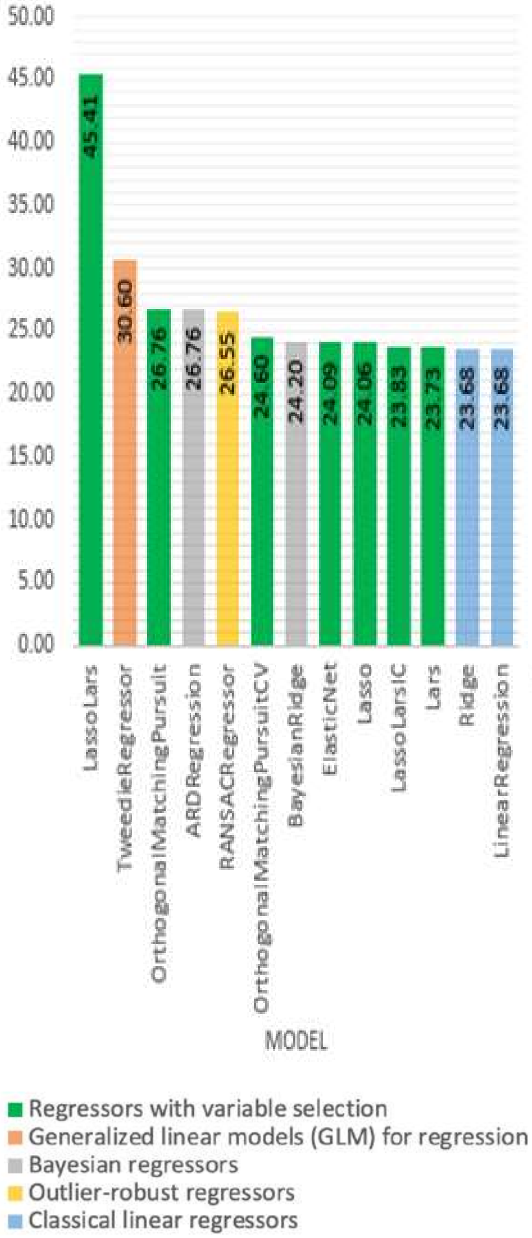
Summary of training and testing

Thirteen models were trained and tested in the work. 3 success metrics were calculated for each: MSE, $RMSE$, and R^2. A breakdown of the models according to the $RMSE$ metric is shown in Fig. 4. The MSE metrics are not plotted as they are simply squared $RMSE$ values. The $RMSE$ metric was found to better visualize the results than the MSE. The summary of the R^2 metric is shown in Fig. 5.

VALIDATION

For the validation process, data was collected from the Lontex vehicle tracking system. The data comes from the same company. The time range covers the entire month of June 2021. In summary, the conditions are the same as for testing.

Figure 4. Testing with metric RMSE



The new thing is that the data on new data reflects the conditions in, which the model is to be implemented and operated, i.e., predict fuel consumption in the future. Figs. 6 and 7 show the $RMSE$ and R^2 metrics of all tested models. The $RMSE$ metric is simply the root of the MSE metric. It was considered sufficient to plot one of them, i.e., $RMSE$, as the one that better visually presents the results. The LARS was the best performing model. The LassoLars model was the weakest. There are also visible differences between the values obtained during testing and validation. This is an argument for validating after testing is complete. This is valuable and answers the question of how the model deals with completely new data under real conditions when deployed.

Figure 5. Testing with metric R² (hereinafter column colors match the description in the previous figure)

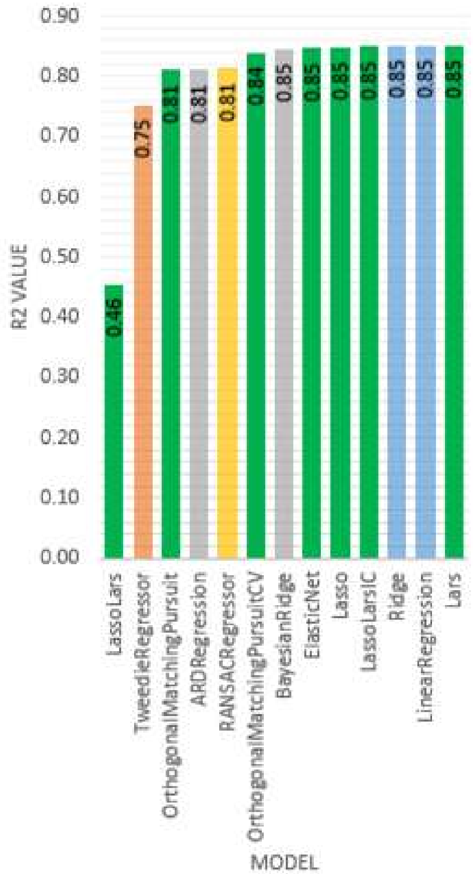


Figure 6. Validation with metric RMSE

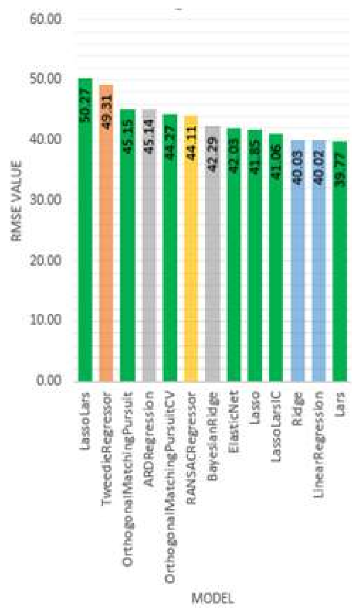
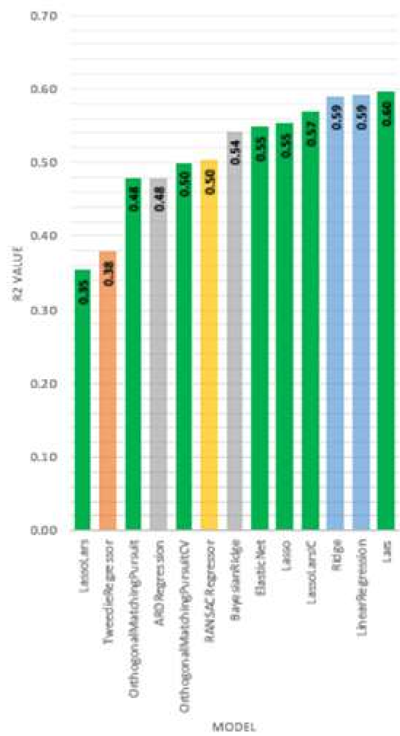


Figure 7. Validation with metric R²



IMPLEMENTATION

At the beginning of the article, the subject of the software language, tool and software was discussed. Creating the right environment to do such a project on your own is quite a complicated process. The solution to this problem is to use the ready-made Anaconda package [12].

It should be downloaded from the manufacturer's website. The software is available for the most popular operating systems: Windows, Linux and MacOs. After downloading, we have access to Jupyter Notebook, which is a very convenient tool for programming in Python. All necessary libraries are also configured: Scikit-Learn, Pandas and NumPy.

The next step is to create your own "csv" file that will be used to train the models.

Then download the ready code from the project website [14] and run it on your computer in Jupyter Notebook. In case of problems with implementation, you can use the "Step by Step" guide also available on the project website [14]. There, each of the steps above is presented with a detailed description of each click and a visualization of what it looks like in Windows. The tutorial is adapted to a person who had no contact with programming before.

CONCLUSIONS

Machine learning can be used to predict fuel consumption in heavy goods vehicles. Many variables affect fuel consumption. These are the variables related to the driver, his driving style, the vehicle and its properties, and the connection route with the specification of the goods transported. One of the goals of this article is to increase machine learning deployment possibilities for the road haulage business. This is in line with the strategies of research and government units aimed at the widest possible use of artificial intelligence in the economy by generating positive value. The Lars was the model that performed best during the research. LassoLars was the weakest.

GitHub allows you to make your code available to a wide audience. This is beneficial for improving collaboration and learning [13]. The code from testing, validation and all saved models were made available on the GitHub platform to enable implementations [14]. Using the information contained in this publication and the provided code, you can make a prediction or build your own machine learning model. Using the provided code, it can be done by a person who does not have much experience with machine learning and programming in Python. It is assumed that the use of machine learning will allow fleet managers to increase awareness of the dependencies affecting fuel consumption. This knowledge can help you make better fuel-saving decisions. This effect is beneficial for economic and environmental reasons, both for the enterprise and for the state economy as a whole.

REFERENCES

[1] Yao, Y., Zhao, X., Liu, C., Rong, J., Zhang, Y., Dong, Z., Su, Y. & Chen, F. (2020). Vehicle Fuel Consumption Prediction Method Based on Driving Behavior Data Collected from Smartphones. Journal of Advanced Transportation, 2020 (9263605), 1-11.

[2] Zargarnezhad, S., Dashti, R. & Ahmadi, R. (2019). Predicting vehicle fuel consumption in energy distribution companies using ANNs. Transportation Research Part D: Transport and Environment. 74, 174-188.

[3] Çapraz, A.G., Özel, P., Şevkli, M. & Beyca, Ö.F. (2016). Fuel Consumption Models Applied to Automobiles Using Real-time Data: A Comparison of Statistical Models, Procedia Computer Science. 83, 774-781.

[4] Moradi, E. & Miranda-Moreno, L. (2020). Vehicular Fuel Consumption Estimation Using Real-World Measures Through Cascaded Machine Learning Modeling. Transportation Research Part D: Transport and Environment. 88(102576), 1-17.

[5] Kluyver, T., Ragan-Kelley, B., Pérez, F., Granger, B., Bussonnier, M., Frederic, J., Kelley, K., Hamrick, J., Grout, J., Corlay, S., Ivanov, P., Avila, D., Abdalla, S. & Willing, C. (2016). Jupyter Notebooks—a Publishing Format for Reproducible Computational Workflows. Positioning and Power in Academic Publishing: Players, Agents and Agendas - Proceedings of the 20th International Conference on Electronic Publishing, ELPUB 2016 (pp. 87-90).

[6] Pérez, F. & Granger, B.E. (2007). IPython: A System for Interactive Scientific Computing. Computing in Science and Engineering. 9(3), 21-29.

[7] Pedregosa, F., Varoquaux, G., Gramfort, A., Michel, V., Thirion, B., Grisel, O., Blondel, M., Prettenhofer, P., Weiss, R., Dubourg, V., Vanderplas, J., Passos, A., Cournapeau, D., Brucher, M., Perrot, M. & Duchesnay, É. (2011). Scikit-learn: Machine learning in Python. Journal of Machine Learning Research. 12, 2825-2830.

[8] McKinney, W. (2010). Data Structures for Statistical Computing in Python. Proceedings of the 9th Python in Science Conference, SCIPY 2010 (pp. 56-61).

[9] Van Der Walt, S., Colbert, S.C. & Varoquaux, G. (2011). The NumPy Array: A Structure for Efficient Numerical Computation. Computing in Science and Engineering. 13(2), 22-30.

[10] Hunter, J.D. (2007). Matplotlib: A 2D Graphics Environment. Computing in Science and Engineering. 9(3), 90-95.

[11] Dabbish, L.A., Stuart, H.C., Jason, T. & Herbsleb, J.D. (2012). Social Coding in GitHub: Transparency and Collaboration in an Open Software Repository. Proceedings of the ACM Conference on Computer Supported Cooperative Work, CSCW (pp. 1-11).

[12] Budzyński, A. (2021). FCPS – Fuel Consumption Predicting System. URL: https://github.com/BudzynskiA/FCPS.

SECTION 3:

INNOVATIONS IN URBAN / REGIONAL MOBILITY AND FREIGHT

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Role of Railway Transport in Green Deal 2050 Challenge – Situation in Czechia

VÁCLAV LAUDA, VOJTĚCH NOVOTNÝ

Abstract Motivating people to change the mode of transport to public transport instead of using their own car is one of the most important parts of the way to accomplish the Green Deal 2050 challenge. On the example of Czech Republic where the number of passengers was rapidly rising in the pre-pandemic time, in most of the long-distance relations individual car transport still offers much more travel benefits than railway lines. How to strategically develop the railway infrastructure? Will the planned high-speed railways really be the appropriate solution to this problem in time? Will it satisfy all the different requirements of the passengers who are potentially able to move from car to train?

Keywords: • Green Deal • Modal-Split • Railway Transport • Sustainable Mobility

---

CORRESPONDENCE ADDRESS: Václav Lauda, Ing., Vojtěch Novotný, Ing., PhD, Czech technical university in Prague, Faculty of Transportation Sciences, Horská 3, Prague, Czech Republic, e-mail: int-office@fd.cvut.cz

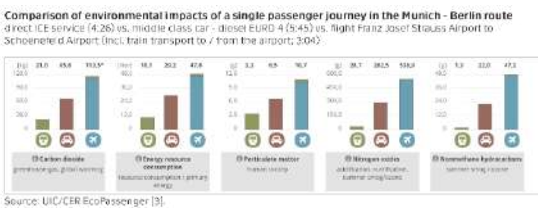
Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

THE ROLE OF RAILWAYS IN SUSTAINABLE MOBILITY

Europe has decided to become a climate-neutral region by 2050 [1]. And because transport makes a very significant contribution to the current carbon footprint, ways to meet population mobility and freight transport will be a key aspect of meeting the goals set by the Green Agreement for Europe.

The transport of both freight and passengers using motorised means of transport always places a burden on the environment. Ultimately, energy can be saved, and pollutants can be avoided through the choice of transport mode. Whoever travels by train travels in an energy-efficient and environmentally friendly manner, even more so for modern electric railways. In terms of environmental impact, the railway system performs significantly better than cars, heavy good vehicle, or aircrafts. Rail transport reveals a particularly favourable energy input to transport capacity ratio. In comparison with cars, the railway only requires around half as much energy for the same transport volume in passenger transport. It is mainly because of low rolling resistance (steel wheel on steel rail instead of rubber tyres on asphalt). And finally, travel in long distance train is almost three times more energy efficient than air traffic [2].

Figure 1. Comparison of environmental impact of a single passenger journey in the Munich – Berlin route [3]



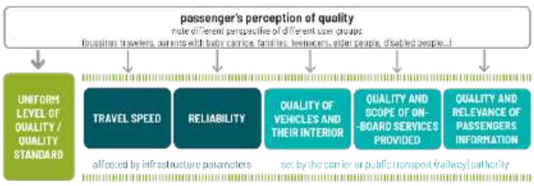
In addition, in some cases the railway may be even better than today, and the standard energy consumption of railways can be further reduced, for example by electrifying lines not yet electrified, expanding the option of braking energy recovery, etc.

For the environmental objectives to be achieved at all, the railways need to significantly increase their share of the modal-split. However, passengers will not start using the railway because it is environmentally friendly. They will start using it if it is modern and high-quality mobility product. To reduce the environmental impact of transport, it is necessary to offer the railways in the form of an attractive and customer-oriented part of mobility as a service concept [4].

QUALITY MODERN RAILWAY TRANSPORT ATTRACTS THE PASSENGERS

For rail to be attractive to passengers and motivate them to make journeys by public transport rather than the private car, rail must meet and exceed the expectations not of passengers who already use rail but of those who currently use the private car. This article is primarily concerned with long-distance and interregional transport. The perception of the quality of rail transport from the passenger's perspective is of course somewhat subjective, but several areas can be defined that play a role in deciding whether a passenger chooses to travel by train or by car (see Figure 2).

Figure 2. Passenger's perception of quality of railway services



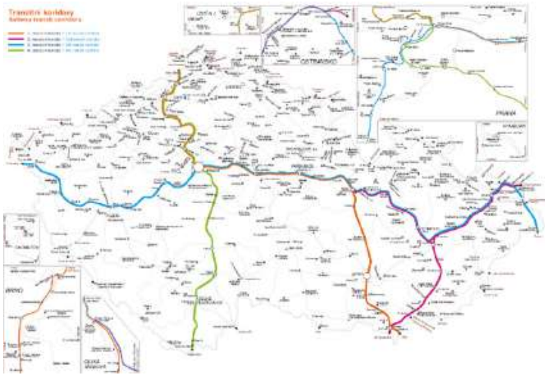
Good practice experience (French TGV, German ICE, Austrian and Czech Railjet, also Czech "Pendolino" service) shows that a successful long-distance rail service has the character of a line (regular interval, same trainsets, same level of quality and service provided on board of each train).

However, travel speed plays a very important role in decision making, whether the passenger will use a long-distance train or a car ride [5], [6]. And It is mainly influenced by infrastructure parameters. Therefore, in this sense, the railway network should be developed by building high-speed lines, as well as conventional lines to achieve competitive and systemic travel times between cities.

SITUATION IN CZECHIA

Although the Czech Republic has one of the densest railway networks in the world, most of the lines do not meet the requirements of contemporary fast and modern railway transport due to their parameters, especially line speed and state of technology. As a result, more than 70 % of rail transport (passenger and freight) is carried out on approximately 30 % of the rail network. These are mainly lines that have been upgraded over the past thirty years as part of the so-called rail transit corridors modernisation programme. This usually included renewal of the railway substructure and superstructure, modernisation of stations, increase in line capacity, basic modernisation of signalling equipment and increase in line speed.

Figure 3. Map of the railway network of the Czechia with marking of rail transit corridors



Generally speaking, the realization of rail transit corridors modernisation programme (the programme is still ongoing, some sections and key nodes are not yet complete) created conditions for the development of modern passenger and freight railway transport in Czechia.

The popularity of passenger rail transport is growing in Czechia. Two segments of passenger rail transport are particularly successful – suburban rail transport as part of regional integrated public transport and long-distance (interregional or interstate) rail transport. Over the last 10 years, the number of passengers has increased by 16 %.

Figure 4. Trend in number of routes in Czechia [7]

The medium distance travelled is also on an upward trend, suggesting that long-distance transport is the main driver of rail's success. This positive development is due to several aspects:

- The liberalisation of the rail market and the related emergence of competition have led to an increase in the range and quality of the transport offer.

- Modernised infrastructure has created the conditions for a better and more reliable offer.
- Generally higher perception of environmental aspects and sustainability in society.

However, this development is happening almost exclusively on modernized lines. There is Therefore, a large disparity in the quality and transport offer across the network.

Before the pandemic, in 2019, the modal-split of passenger transport in Czechia achieved 9,9 %. It is not that bad compared to Austria (12,9 %) or Netherlands (11,3 %), but the Green Deal challenge requires far better values [8].

Capacity problems and missing links

Due to the development of passenger railway transport concentrated on corridor lines, the capacity of these lines is practically exhausted, especially in the vicinity of large railway junctions (Prague, Brno). It has become clear that the corridor modernisation programme significantly underestimated the issue of line capacity around these nodes. For example, nowhere was it planned to increase the number of tracks around these nodes in order to segregate intensive suburban and long-distance rail traffic. Unfortunately, Správa železnic, Czech railway infrastructure manager, does not publish information on the level of capacity utilization of the railway infrastructure. However, it is clear that line capacity is or will very soon become a limit to the development of passenger rail transport.

A chronic feature of the development of the railway network and, to a significant extent, of transport policy, is the neglect of the development of the Prague - Munich and Prague - Linz routes. Bavaria is the Czech Republic's largest trading partner. Although the D5 motorway linking Prague with Nuremberg and Munich was quickly built in the 1990s, there is still no fast, high-capacity railway line of equivalent importance between the Czech Republic and Bavaria. The situation between Prague and Linz is largely similar. However, it should be noted that even Germany and Austria do not give this connection much priority in their infrastructure planning.

Inconsistent level of quality

The offer of modern railway long-distance passenger transport in the Czech Republic is limited almost exclusively to corridor lines. However, the level of quality varies considerably. It is logical that the level of quality varies between the different open-access long-distance rail products (e.g., SC Pendolino, Regiojet, LeoExpress). However, the level of quality is significantly different in a number of aspects also for express services operated under a public service obligation, i.e., ordered by the public administration (in the Czechia, long-distance transport is ordered by the Ministry of Transport of the Czech Republic). The highest standard of services offered in express trains includes for example first and second seat class, air conditioning, free unlimited Wi-Fi connection, train restaurant, cinema for children. However, in some line, for example, there is a systematic lack of a dining car and related service. There is also an enormous difference in the quality of train sets. The carriages of most of the trains consist of restored vehicles dating back to the last century.

Figure 5. Express (EC) Berliner (Prague-Berlin) consists of rolling stock built in the 1990s and reconstructed after 2010

There is no uniform level of quality across the express network. Moreover, the express network basically follows only the corridor lines and does not even serve some major cities (Hradec Králové, Jihlava, Karlovy Vary).

Travel speed as a key parameter

Travel speed is a key parameter for the competitiveness of passenger rail transport. Achieving a certain travel speed is also a crucial parameter for the design of infrastructure and its line speed.

Czechia today

In order to accurately describe the current situation in the Czech Republic, we have selected the 22 largest Czech cities, where 32 % of the country's total population live, and analysed all interconnections between them using rail transport and individual car transport. This selection, included all cities that are administrative centers of

Czech regions, is show in the following table:

Table 1. List of 22 largest Czech cities

No.	City/town	Population	Region	Corridor line
1	Praha	1 324 277	Praha	yes (1, 3, 4)
2	Brno	381 346	Jihomoravský	yes (1)
3	Ostrava	287 968	Moravskoslezský	yes (3, 4)
4	Plzeň	174 842	Plzeňský	yes (3)
5	Liberec	104 802	Liberecký	no
6	Olomouc	100 663	Olomoucký	yes (2, 3)
7	České Budějovice	94 463	Jihočeský	yes (4)
8	Hradec Králové	92 939	Královéhradecký	no
9	Ústí nad Labem	92 716	Ústecký	yes (1, 4)
10	Pardubice	91 727	Pardubický	yes (1, 3)
11	Zlín	74 935	Zlínský	no
12	Havířov	71 200	Moravskoslezský	no
13	Kladno	69 337	Středočeský	no
14	Most	66 034	Ústecký	no
15	Opava	56 450	Moravskoslezský	no
16	Frýdek-Místek	55 557	Moravskoslezský	no
17	Karviná	52 128	Moravskoslezský	yes (3)
18	Jihlava	51 216	Vysočina	no
19	Teplice	49 731	Ústecký	no
20	Chomutov	48 635	Ústecký	no
21	Děčín	48 594	Ústecký	yes (1, 4)
22	Karlovy Vary	48 479	Karlovarský	no

Note that most of these cities are not connected by lines that were parts of the rail corridor modernization programme.

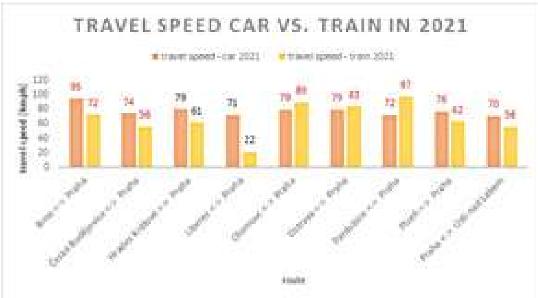
A total of 232 routes were analysed. With the help of the digital road map and railway timetables all intercity distances, travel times, travel speeds and operating intervals of railway lines were obtained and every pair of connections was compared (car vs. train).

Currently (i.e., in 2021), the travel speed of rail transport is higher than the travel speed of individual car transport one in only 20 of 231 analysed routes (8,7 %). Average travel speed of trains is only 47 kmph but cars achieve 67 kmph. The summary statistics of this comparison are following:

- ratio of routes realized faster by train 8,7 %
- average travel speed of trains 47 kmph
- average travel speed of cars 67 kmph
- average air distance 184 km
- average train operation interval 86 min
- average number of train transfers 0,93

The connections between Prague (the capital city and the largest passenger rail hub in the country) and other major cities is shown in following chart.

Figure 6. Comparison of travel speed in 2021



Routes marked with a black number are parts of corridor lines. It is evident that even on the reconstructed corridor lines, higher travel speeds are not achieved than for road transport.

Czechia – projected 2050

The Czech Republic is currently preparing to implement a programme for the construction of high-speed lines with an expected completion in 2045. The programme promises three new complexes of high-speed tracks dimensioned for speed 200 – 350 kmph. Many of conventional lines should be modernized too, for example line Praha – Liberec or Plzeň – Domažlice – Germany (Munich). In order to see how this programme will change the competitiveness of railway services (in terms of travel speed), we have carried out the same analysis for the 2050 model. The year 2050 was chosen because it is the year in, which the goals of the Green Deal are to be accomplished.

Figure 7. Map of railway lines in 2050

The model includes the completion of all planned high-speed lines and planned upgrades to conventional lines. At the same time, the planned development of the motorway network is also included in the model calculation.

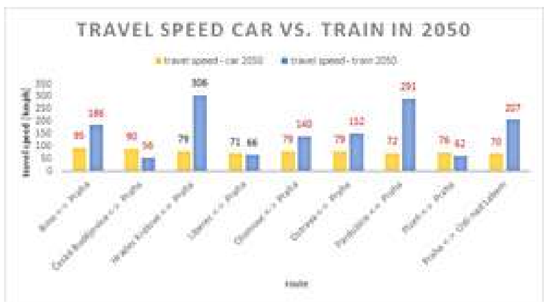
In 2050, the travel speed of rail transport is higher than the travel speed of individual car transport one in 119 of 231 analysed routes (51,5 %). Average travel speed of trains is only 47 kmph but cars achieve 67 kmph. The summary statistics of this comparison are following.

Table 2. Comparison in years

Size	2021	2050
Ratio of routes realized faster by train [%]	9	52
Average travel speed of trains [kmph]	47	84
Average travel speed of cars [kmph]	67	74
Average train operation interval [min]	86	61
Average number of train transfers [-]	0,93	0,79

The connections between Prague (the capital city and the largest passenger rail hub in the country) and other major cities is shown in the following figure.

Figure 8. Comparison of travel speed in 2050



The biggest improvement will be perceptible in routes coming from Prague. Unfortunately, situation in cities, that do not lie in the corridors or new high-speed tracks, will be almost the same.

We can look forward to some extreme improvements. For example, there are some routes where the train will be three or four times faster than car and the operation interval will be great too:

Table 3. List of very fast train routes

Route	**Travel time [min]**		**Travel speed [kmph]**		**Air distance [km]**	**Ratio [-]**	**Operation interval [min]**
	car	train	car	train	together	train/ car	train
Pardubice – Praha	81	20	72	291	97	0,25	12
Hradec Králové – Praha	77	20	79	306	102	0,26	30
Brno – Jihlava	56	15	83	308	77	0,27	60
Olomouc – Ostrava	62	20	75	231	77	0,32	60
Praha – Ústí n/L.	59	20	70	207	69	0,34	20

For comparison, see the table with data for the three biggest cities:

Table 4. List of routes among three biggest cities

Route	**Travel time [min]**		**Travel speed [kmph]**		**Air distance [km]**	**Ratio [-]**	**Operation interval [min]**
	car	train	car	train	together	train/ car	train
Brno – Ostrava	102	40	81	207	138	0,39	30
Brno – Praha	118	60	95	186	186	0,51	10
Ostrava – Praha	211	110	79	152	278	0,52	30
Olomouc – Ostrava	62	20	75	231	77	0,32	60

On the other side, there are some routes where the state of railway transport beside the individual one will be the same or even worse. Unpleasant situation threatens for example in Kladno or Zlín.

Table 5. List of the worst train routes

Route	Travel time [min]		Travel speed [kmph]		Air distance [km]	Ratio [-]	Operation interval [min]
	car	train	car	train	together	train/ car	train
Karlovy Vary – Kladno	57	158	94	34	89	0,36	60
Hradec Králové – Liberec	57	149	87	33	83	0,38	120
Frýdek-Místek – Zlín	80	208	53	20	71	0,38	120
Chomutov – Kladno	40	97	90	37	60	0,41	60
Frýdek-Místek – Karviná	31	75	46	19	24	0,41	60
Kladno – Plzeň	64	138	64	30	68	0,46	60
Děčín – Kladno	79	168	54	25	71	0,47	60
České Budějovice – Kladno	103	213	77	37	133	0,48	60

Planned high-speed rail and modernisations will definitely improve the situation but there will still be many routes in unsatisfactory condition, and this deficiency may subvert the whole system.

CONCLUSION

After a very long stagnation (practically from the 1960s until the first decade of the 21st century), the railway in the Czech Republic has revived and it can be seen that, if the conditions are right, it can offer a competitive modern service that passengers like to use. This is an important conclusion as it confirms that if the public administration creates the conditions for the development of passenger rail transport in a strategically correct and sufficiently generous way, there is a great potential for increasing the share of rail transport in the modal-split. And that is absolutely essential to meet the Green Deal goals.

Currently, the development of railway transport in Czechia is limited by wrong strategic decisions made in the relatively recent past:

- The development of railway infrastructure was limited to railway corridors instead of being systematically oriented towards connecting the largest and most important cities in the country.

- The scope of modernisation was too small. There have been no significant upgrades in terms of capacity or signalling.
- Instead of setting the line speed based on the competitive travel speed in each route a fixed limit of 160 kmph was chosen. However, even this limit is not reached on a significant part of the corridor lines even after reconstruction.

These poor strategic decisions could have been avoided. Both the principles of the integral timetable and the good practice examples of the network approach to rail transport were well known in the 1990s when these strategic decisions were made.

Rail transport and increasing its share of modal share will play a crucial role in meeting the targets set by the Green Deal. Czechia must Therefore, systematically develop fast, modern, and high-quality railways.

"Transport accounts for a quarter of the EU's greenhouse gases and its share is still growing. To achieve the climate neutrality, transport emissions need to be reduced by 90 % by 2050. Both road, air, rail and waterborne transport must contribute to this reduction. Achieving sustainable transport means prioritizing users and obtaining them more affordable, accessible, healthier and cleaner alternatives to the means of transport to, which they are currently accustomed" [1].

Our analysis confirmed that the planned construction of high-speed lines and modernisation of existing lines will make rail transport in the Czech Republic significantly more competitive with road transport than at present. However, rail transport will still be speed-competitive on only about half of the selected routes. Little consolation can be taken from the fact that this half includes all the largest cities except Pilsen, which is senselessly excluded from the high-speed system. Equally alarming, however, is the long-unresolved connection with European cities, such as Munich, Nuremberg or Linz in Austria. These three cities with several million inhabitants represent a huge potential for connection to the high-speed system. But the Czech plans so far completely ignore these traditional trading partners and tourist destinations.

Overall, the 2050 route plan, however ambitious and developmental, is still quite inadequate. The railway transport simply needs to offer even better-quality connections between at least all our selected settlements, so that the incentive for the passenger hesitating between individual and public transport is clearly on the side of the public transport.

The Green Deal is an opportunity to catch up with these internal debts of the Czech infrastructure in relation to its European neighbours, but this opportunity must be grasped well. In this particular case, this means not relying entirely on the 2050 plan, but developing rail lines on a much larger scale and building the railway system in the Czechia in a conceptual and systematic way.

REFERENCES

[1] EUR-Lex (2019, December 11). Green Deal for Europe. Retrieved from https://eur-lex.europa.eu/legal-content/CS/TXT/?qid=1596443911913&uri=CELEX:52019DC0640#document2.

[2] EcoTransIT (2014, December 4). Ecological Transport Information Tool, Environmental Methodology and Data. Retrieved from http://www.ecotransit.org/download/EcoTransIT_World_Methodology_Report_2014-12- 04.pdf.

[3] Knörr, W., Hüttermann R.: EcoPassenger (2016, November 17). Environmental Methodology and Data. Retrieved from http://ecopassenger.hafas.de/hafas-res/download/Ecopassenger_Methodology_Data.pdf.

[4] Hensher, D. A., Ho, C. Q., Mulley, C., Nelson, J. D., Smith, G., Wong, Y. Z. (2020). Understanding Mobility as a Service. ISBN 9780128200445.

[5] Gärling, T., Axhausen, K. W. (2003). Introduction: Habitual travel choice: Transportation, 30 (1), 1-11.

[6] Graham-Rowe, E., Skippon, S., Gardner, B., Abraham, Ch. (2011). Can we reduce car use and, if so, how? A review of available evidence, Transporatation Research Part A, 45 (5), 401-418.

[7] Sydos (2020). Ročenky dopravy. Retrieved from https://www.sydos.cz/cs/rocenky.htm.

[8] eurostat (2021, July 7). Modal split of passenger transport. Retrieved from https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=tran_hv_psmod&lang=en.

The New Franco - Genevan Rail Passenger Service "Léman Express": The Challenge of Sustainable Mobility in the Cross-Border Metropolis of Greater Geneva?

LAURENT GUIHÉRY

Abstract The Léman Express is the achievement of an old project of connecting Geneva with the French hinterland of Annemasse and the North East part of the Region Auvergne Rhône-Alpes. 16 km of new tracks have been build (2 km in France and 14 km in Geneva with 5 new underground stations). This Swiss – French rail service is opened to cross-border commuters mainly since Mid-December 2019 on 230 km of tracks from Coppet to Annecy, Thonon, Bellegarde and Evian. 50 000 passengers are targeted for this service: now around 40 000 passengers are travelling every day in March 2021. 500 000 commuters cross the French – Swiss boundaries every day, which means a huge impact in terms of congestion and greenhouse effects and this new service will speed up modal transfer towards rail. Mid-2021, reliability of the system and quality passenger information have to be improved. The key issue is to improve the French – Swiss interoperability of rail system.

Keywords: • France • Switzerland • Geneva • Rail Passenger Transport

---

CORRESPONDENCE ADDRESS: Laurent Guihéry, CY Cergy Paris Université, 33 boulevard du Port, 95011 Cergy-Pontoise cedex, e-mail: Laurent.guihery@cyu.fr

 ISBN 978-961-95633-0-4

This article aims to evaluate, in mid-2021, the first eighteen months of operation of the new rail passengers service Léman Express connecting Geneva[2] and the French hinterland, which is likely to reverse the trends of growing congestion and the associated environmental nuisances in the cross-border metropolis of Greater Geneva.

Every day, 630 000 trips take place, mainly commuting, around Geneva , between France and Switzerland (65 %), but also between the Canton of Vaud and the Canton of Geneva (35 %). The overall modal share of public transport on the cantonal borders was close to 14 % in 2018. For working people living in France and working in the canton of Geneva, 80 % of trips are made by car, 13 % by public transport and 7 % by two-wheelers (2014; see Table 1).

Table 1. Modal share of public transport for cross-border flows to Geneva

France	
Annemasse side	15 %
Ain side	8 %
Saint-Julien-en-Genevois side	3 %
Chablais side	2 %
Switzerland	
Canton of Vaud	33 %

Source: [3].

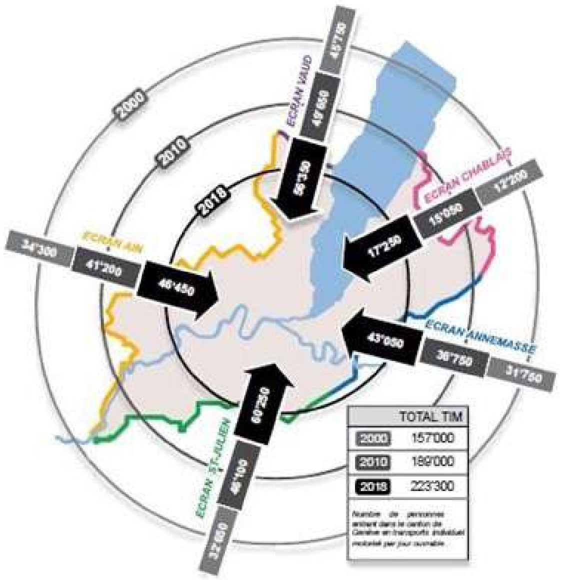
Mobility by private car – 223 300 crossings of the cantonal border by motorized transport every day, mainly characterized by single driver's vehicles - is very impressive in a city that has long been devoted to the car: it is no coincidence that Geneva hosts, on an annual basis, the major international motor show that celebrated its centenary in 2005! The city has very heavy congestion in its various accesses, particularly for border crossings, which causes environmental nuisances and makes Geneva one of the cities most affected by automobile pollution. In addition to the problems of congestion and nuisance (pollution, noise, road insecurity), there are also parking problems in a highly constrained public space.

A CROSS-BORDER REGION WITH STRONG CONTRASTS

This new Franco-Genevan, cross-border, high-frequency rail service appears in a region - Haute-Savoie, Annemasse and Geneva - with very strong contrasts.

2 This compares with 550 000 inhabitants in Geneva.

Figure 1. Entry into the canton of Geneva per day by motorized individual transport: 2000 – 2010 – 2018



Source: [3].

On the one hand, the quality of life is one of the best in Europe: beyond the presence of Lake Geneva and the mountains, the proximity of Geneva makes this region, for some, an Eldorado. Geneva occupies a special position on the West side of Lake Geneva: 110 km of border with France (Ain and Haute-Savoie), which surrounds it, but only 4 km with the canton of Vaud, which links it to the Swiss Confederation. The high salaries in Switzerland attract many workers who want to obtain the status of cross-border commuter. It must be said that Geneva's place in Europe remains central: After being the historic headquarters of the League of Nations (SDN), it remains today a place of diplomatic exchanges and conventions and still hosts many international organizations: WTO, ILO, CERN, UNHCR, etc. The weight of these international organizations is estimated at nearly 11 % of GDP, i.e., approximately 1 job in 10. The department of Haute-Savoie has a median standard of living of almost 23 700 euros[3], the highest among the French departments outside the Ile-de-France region.

On the other hand, as a former railway and working class town, Annemasse has a poverty rate of 22 %, 3 points higher than the national average [10]. Inequalities are among the highest in France, with Annemasse ranking 4th in France for the highest

3 https://www.insee.fr/fr/statistiques/1285869

inter-decile inequalities[4]. The Swiss Eldorado does not work for everyone[5].

A city of contrasts, Haute-Savoie, and Annemasse, is also a city of contrasts because of the dynamism of jobs in Geneva and jobs on the French side, which have difficulty in finding human resources[6]. In 2021, 26 % of jobs in the Canton of Geneva will be occupied by cross-border workers, compared with 15 % in 2005. Roughly speaking, 50 % of the active population of Annemasse work in Geneva. The health sector is the leading recruiter of cross-border workers: more than 50 % of employees in Geneva's public hospitals (12 000 in all) live in France.

Finally, this region also has a strong contrast in mobility! Geneva's strong attractiveness generates considerable mobility that the current infrastructure, especially roads, cannot support. The flow of commuters is growing rapidly and threatens the ecological balance of the region – air quality, global warming, road water runoff, pollutant emissions, road safety, road noise. Congestion, which is omnipresent at peak times, causes misunderstandings and tensions in Swiss companies, where compliance with schedules is essential, along with delays by border workers. 140 000 cross-border commuters go to work in Switzerland every day, generating 8 billion euros in wages per year. Part of this money goes to the French local authorities (3,5 % of the wage bill) but this is too little to meet the management costs of the authorities in the face of this influx of people, in particular to manage transport.

AN INITIAL SOLUTION: THE CROSS-BORDER METROPOLIS OF GREATER GENEVA

The urgent need to find a framework to improve the sustainable mobility in Geneva comes first from the Swiss Confederation: in fact, there is a strong imbalance between the Lake Geneva area (1,5 million inhabitants with a modal share of public transport of 16 %) and the Zurich area (1,9 million inhabitants and a modal share of public transport of 35 %), which led the Confederation to support and finance the Léman express project in the name of a certain homogeneity of living conditions on Swiss territory.

Then came the construction of the Greater Geneva area, a local grouping for cross-border cooperation (GLCT) bringing together 209 municipalities between France and

4 Behind Neuilly, Paris and Boulogne-Billancourt (Hauts-de-Seine). In Annemasse, the poorest 10 % of households earn less than 800 euros per month (barely 10 000 euros per year), while the richest 10 % earn 5,3 times as much, an average of 4,200 euros per month (50 400 euros per year [10]).

5 Annemasse offers a very high rate of social housing (27 %) and manages a priority district of the city policy [10]. 577 homeless people took up residence in Annemasse in 2020 compared to 492 in 2019 [10]. In Haute-Savoie, the number of recipients of the minimum active solidarity income remained high: + 22 % between 2019 and 2020.

6 Strengthened thanks to the exchange rate with the Swiss franc, which has gone from 1,60 Swiss francs (CHF) for 1 euro in 1999 to almost parity today [10].

Switzerland. It takes the form of a Franco-Swiss discussion and decision-making area, corresponding to a European cross-border metropolis: this cross-border conurbation bringing together the Canton of Geneva, the district of Nyon and the French Genevan metropolitan area, in detail:

- Canton of Geneva
- Community of communes of the Pays Bellegardien
- Pays de Gex agglomeration community
- Annemasse Agglomeration Community
- Thonon Community of communes Arve et Salève Agglomeration Community
- Community of communes of the Genevois
- Community of municipalities Faucigny-Glières
- Community of communes Pays Rochois
- District of Nyon

A forward-looking agglomeration plan has provided a framework for development shared by all the territories. At the heart of this plan is the question of commuting between France and Geneva. The employment area covers approximately one million inhabitants over more than 2 000 km^2: 50 % of the French population in this territory works in Geneva.

In a logic of catching up, a strong response from Greater Geneva to deal with road congestion was the launch of the Léman Express project. It aims to put Geneva and its French hinterland on a new trajectory to reverse the trend of strong and congested growth in road traffic and pollutant emissions. Indeed, this RER-type rail service offers a modal alternative that is finally credible in order to meet the very high demand for commuting by French people working in Geneva and the resulting environmental damages that it implies (CO_2 emissions, noise and local pollution). Could this new Léman Express service meet the challenge of strong growth in mobility? Will it help reposition Geneva as a major European metropolis?

A RESPONSE TO THESE CHALLENGES THROUGH A CROSS-BORDER RAIL PROJECT OF METROPOLITAN SCOPE: THE LÉMAN EXPRESS

A response to the challenges of mobility in Greater Geneva took started 15 December 2019 with the launch of a major metropolitan rail network, the Léman Express[7]. On

7 At the same time, the Annemasse-Geneva cross-border tramway was inaugurated in 2019, which is obviously much slower. The Léman express has led to an increase in the range of soft and low-carbon mobility services in Greater Geneva: 200 km of cycle paths have been made permanent (a greenway links Annemasse to Geneva, using the roof of the CEVA tunnel in some parts), 4 BRTs, 3 trams.

schedule, the new regional rail service – the first cross-border metropolitan rail service in Europe – will serve Geneva, the Canton of Vaud and, above all, Annemasse and the neighboring French departments (Ain, Haute-Savoie). After a year and a half of operation, Annemasse station is thus becoming the second most important interchange hub in the Auvergne-Rhône-Alpes region behind Lyon Part-Dieu. Let's try to draw up an initial assessment.

Let us show its impact on mobility: Geneva-Annemasse in 23 minutes, as opposed to more than 50 minutes previously. This project is not new, since it dates back to the 19th century, when a link was missing between the French rail network and Switzerland[8]. Preparatory work began in the 1850s and a Franco-Swiss agreement for the construction of a link between Geneva and Annemasse was signed in 1881. The project was even imagined in 1912. The rise of the automobile and Franco-Swiss rivalries put it on hold and it was not until 2011 that work began on the project, which will lead to its inauguration on 15 December 2019.

In all, there are 230 km of railway lines in Switzerland and Auvergne Rhône-Alpes with a central axis in a 16 km tunnel, 2 km of, which in France leads to the Annemasse station, which has been modernized, as well as its surrounding areas. This rail service stops at 45 stations in France and Switzerland (including 4 new underground stations in Geneva), which has enabled the city to launch numerous urban and housing projects, with a current terminus at Coppet station, near the castle of Germaine de Staël (1766-1817)[9]. It is currently the largest cross-border railway network in Europe. It consists of 6 lines: L1 L2 L3 L4 L5 and L6 (see diagram below). It offers a service with a wide range of hours from 5:00 to 00:30 on weekdays between Annemasse and Geneva. The frequency reaches 6 trains per hour and per direction between Annemasse and Geneva. On the other branches of the network, the frequency is 2 connections per hour with interconnections designed with the TER trains of the Auvergne Rhône-Alpes Region. Finally, a great deal of work has been done on both the Swiss and French sides to improve interconnections with the public transport networks, to develop park-and-ride facilities and multimodal interchange centers. The use of bicycles is growing rapidly and, during the rush hour at the end of the day, many cross-border commuters are equipped with folding bicycles to get home.

As for the rolling stock, each country wanted to use its national manufacturer to provide the rolling stock, i.e., 40 brand new comfortable trains. Alstom, on the French side, produced the 17 French trainsets[10] for € 210 million and Stadler, on the Swiss

8 See the very interesting issue of the Revue Générale des Chemins de Fer (R.G.C.F.) - Nr. 296 of September 2019 [11].

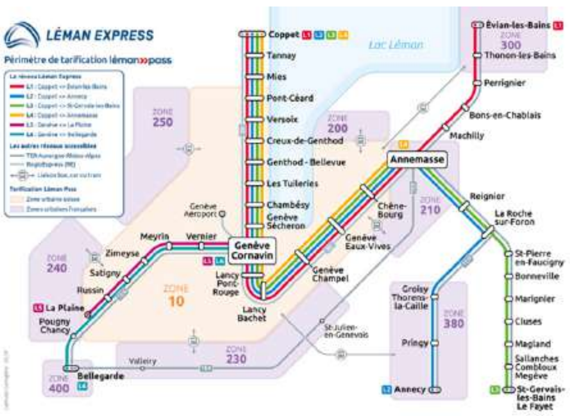
9 A proud opponent of Napoleon, who exiled her to Coppet. She was the first to describe, in the romantic wave of the first half of the 19th century, Germany as a homogeneous space, certainly disunited at that time but driven by a dynamic of artistic, literary and scientific creativity, which displeased the emperor.

10 The Auvergne Rhône-Alpes Region has indicated that it has ordered ten more train sets for reinforcement.

side, built the 23 Swiss trainsets. The rail service is timed with a high frequency, for example from Annemasse but also from the other major centers of Greater Geneva, which poses formidable operating difficulties in the event of incidents or delays. Annemasse nevertheless remains a real railway frontier as it is also the terminus of the Swiss Regio Express trains, which have Saint-Maurice as their destination, serving Geneva and the CEVA stations.

The entry into service of the Léman Express should enable a reduction in motorized traffic of 12 %, which is enormous. Despite some operating difficulties due to bottlenecks on the SNCF regional network and problems in recruiting SBB drivers under the pressure of the pandemic, the Léman Express has found its public with 45 000 passengers at the beginning of March 2020 [9], close to the target of 50 000/day. A peak was reached around 26 February 2021 with 49 000 passengers per day. Thus this rail service allows first of all French people with a border permit to reach their place of work in Switzerland. Annemasse, for its part, is betting on the development of tourism with a welcome reception center and mobility center. On the Geneva side, the 4 underground CEVA stations have made it possible to rethink mobility and urban planning in the refuge city. CEVA is thus accompanying a new direction in mobility in Geneva and is used as a mode of urban transport: 50 % of the flows concern local travel in Geneva and 50 % cross-border travel.

Figure 2. Transport plan



Organization of the links:

1. Coppet – Annemasse with L1, L2, L3, L4 and Regio Express connections

Monday to Sunday, from 5am to 12:30 pm: a train every 15 minutes

Friday and Saturday nights: one train every hour, all night, between 00:30 and 5:00.

RegioExpress trains are extended to Annemasse from Saint-Maurice, Vevey and Lausanne (stop at Lancy-Pont-Rouge and Genève-Eaux-Vives), with a train every 30 minutes from Monday to Friday and one train per hour at the weekend.

Annemasse – Evian-les-Bains – Annecy – St-Gervais-les-Bains-Le Fayet.

2. L1, L2, L3 and TER:

One connection per hour, in both directions, and two connections per hour, during peak hours.

The connections are direct or in connection (Annemasse or La Roche-sur-Foron) with the TER, the TER buses or the Léman Express buses.

3. Coppet – Geneva

A train every 15 minutes from Monday to Saturday and every 30 minutes on Sunday.

4. Geneva – La Plaine

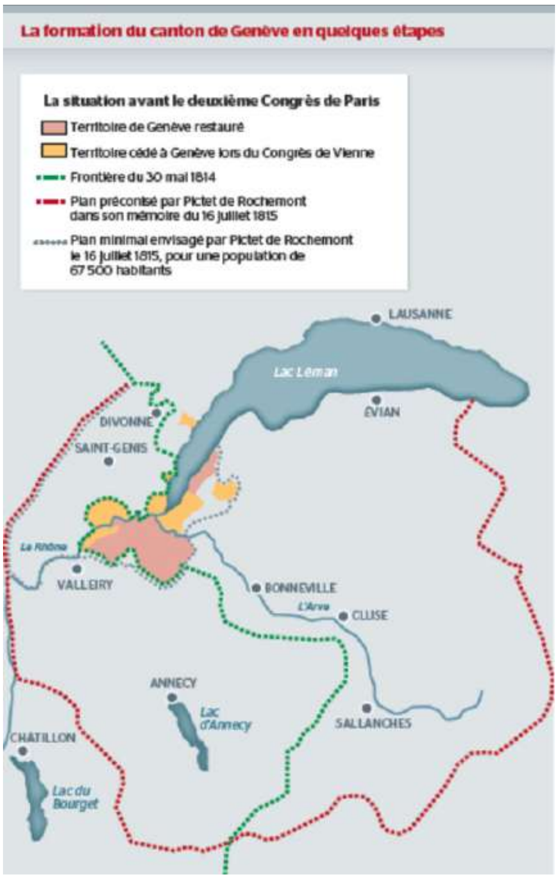
Monday to Saturday: a train every 30 minutes, then every hour in the evening. On Sunday, a train every hour.

5. Geneva – Bellegarde (Ain)

Monday to Friday: every hour, during rush hour.

It is interesting to note that the hinterland of the new Léman Express service, i.e., its area of influence, corresponds roughly to the *"Greater Geneva of 1815"* desired by the Genevan diplomat Pictet de Rochemont at the Congress of Vienna in his memorandum published on 16 July 1815. Taking advantage of the French defeat at Waterloo, the plan - see diagram below – recommended integrating the Arve valley, Annecy and its lake and a good part of the Ain department into Geneva. Fortunately, the intrigues and diplomatic finesse of the Prince of Talleyrand and his team at the Kaunitz Palace in Vienna made it possible to counter this proposal!

Figure 3. Geneva at the Vienna Congress 1815



Source: [8].

CLEAR AND TARGETED FUNDING

This section aims to make an ex-post assessment[2] of the amounts invested in the project. In keeping with a tradition that is deeply rooted in Swiss public management, the work was completed on schedule, in December 2019, without any major cost overruns. This did not prevent a few start-up failures, which a longer running-in period, from a more French perspective, would perhaps have helped to limit.

The Auvergne Rhône-Alpes Region was at the heart of the financial package for the financing of the Léman Express as shown in Table 1. It is contributing 52 % (€ 320 million) of the total funding on the French side, which amounts to € 612 million. If we add the necessary work on access, park-and-ride facilities, stations, the Annemasse technical centre and work to reinforce the rail infrastructure, the Auvergne Rhône-

2 See Issue 296 of the Revue Générale des Chemins de Fer (September 2019) for a precise analysis of the projected financing of CEVA and the Léman Express rail service.

Alpes Region estimates its total financial effort at € 400 million in 2021. To this must obviously be added the coverage of the operating costs of the Léman Express service, which will vary greatly depending on the periods of confinement and the use of teleworking, which will reduce the commercial revenue.

To speak of the Auvergne Rhône-Alpes region is to forget that Switzerland is the main contributor to the financing of this infrastructure, which is primarily built in Switzerland: with a total bill of € 1,8 billion, Switzerland contributes three times more than France. This helps to explain, in part, why Lémanis, as a Euroregional cooperation grouping (ECG), is 60 % owned by the SBB and 40 % by the SNCF.

Table 2. Balance sheet for the financing of the Léman Express

France		**Switzerland**	
Auvergne Rhône-Alpes region share - CEVA + Léman express		Total cost CEVA + Léman express	
Infrastructure (CEVA - 2km in France)	55 m €	234,2 m €	1 390 billion € for the 14km of CEVA in Switzerland, the rolling stock (20 Stadler Flirt) and 5 new stations
Railway equipment (17 Régiolis trains - Alstom (+10 in reinforcement)	210 m €	210 m €	
Regional stations (18 SNCF Réseau stations)	36 m €	149,3 €	162 m: stations and crossings 53,5m: intermodality 230m to Geneva Public Transport (TP interconnections).
Maintenance workshop (Annemasse)	14,7 m €	14,7 m €	With approximately: 44 % Canton Republic of Geneva 56 % Swiss Confederation
Various	3,7 m €	3,7 m €	
	400 m € in total	611,9 million	1,835 billion

Source: Auvergne Rhône-Alpes Region, various cross-checks.

On the French side, most of the territory's players have participated in financing the French section of CEVA, i.e., 2 km for a total cost of € 234,2 million, which again shows a certain unanimity in the face of an infrastructure that is fundamental for today's and tomorrow's mobility in the cross-border metropolis of Greater Geneva. The Haute Savoie department is contributing € 65 million, the main funder, the

Auvergne Rhône Alpes region € 55 million, the State € 45 million, SNCF Réseau € 35 million, the EPCIs of Haute Savoie € 18,75 million, the Swiss confederation € 14,5 million and the European Union € 1 million for preparatory studies.

The action of the Auvergne Rhône Alpes Region has also focused on the stations of the Léman Express and their development, with good results, such as Annemasse, even if the development work was not completed by May 2021. For it is the 18 stations served by the Léman Express that the Region's action has mainly focused on. Out of a total budget of around € 150 million, it has financed a little over € 50 million, and this in all the areas of action:

- Alongside SNCF Réseau, for example, for the platforms and access to the station network (8 stations modernised in 2018 and 10 stations in 2019-2021), but above all for Annemasse station, with 30 % of the regional funding (total operation around € 14 million).
- Alongside SNCF Gare et Connexions with almost 50 % of the funding, especially for Annemasse station (a little over € 16 million in all).
- At the level of local authorities for developments and surroundings with an average project support of 20 %.

In the summer of 2021, many actions are still underway and the success of the Leman Express service calls for new actions to modernise and upgrade the service.

To date, the 2015-2020 CPER has made it possible to make the service operational: first of all, of course, the missing link of the CEVA in France (2 km), especially in a cut-and-cover section; then the reorganisation of the Annemasse track plan[2], the automated modernization of the previously manual signaling between Annemasse and La Roche-sur-Foron – this single track, with crossing points, is a common trunk line that opens onto two branches, those of Annecy and Saint-Gervais. modernisation of the third branch of the Léman Express towards Evian and Thonon, this station being controlled from Annemasse; and finally work to remove two level crossings at Etrembières and Reignier.

SNCF Réseau is waiting for a number of additional works that will improve the reliability of the network, which is a single-track network (except towards Bellegarde). There is currently talk of making the crossing points at Pringy and Saint-Pierre-en-Faucigny more robust, equipping them with GSM-R and installing storage tracks at Annecy and Saint-Gervais.

2 7 tracks now including 2 with Swiss type electrification allowing direct access to the SBB network.

Finally, the Region attaches importance to the reinforcement of video-protection in the vicinity of railway stations and subsidises the municipalities that act in this direction.

FUTURE PROSPECTS FOR THE LEMAN EXPRESS

After a year and a half of operation, badly affected by the successive crises of the COVID, which saw alternating periods of lockdown and recovery, but also use of teleworking and Therefore, a drop in travel, certain lessons can nevertheless be proposed to improve the robustness of the "Léman Express" system.

Infrastructure side

The central bottleneck of the "Léman Express" system remains, on the French side, a single-track railway infrastructure, with the exception of the Geneva-Bellegarde axis. The slightest delay on the French side leads to a domino effect of delays on train movements, which affects the timetable. Despite ongoing modernization, traffic management is still very manual, with 40 to 50 agents assigned to this task. Haute-Savoie was in fact very under-equipped in terms of rail infrastructure in favor of motorway routes. The Léman Express marks a major change of direction, which calls for new and indispensable investments in rail infrastructure investments, which are obviously complicated, in the name of the principle of territorial equity, in a privileged region and one of the richest in France!

The Léman Express must also meet the challenge of Franco-Swiss rail interoperability, from the different electrical voltage to the real-time passenger information system, which has proved very complex to interoperate between the two countries, at least at the beginning.

On the traffic side, Annemasse station now has 280 trains per day, compared with 70 before the new Léman Express service. Seven tracks are dedicated to operations, with two Swiss-type electric tracks, three tracks (C-D-E) for the Léman Express and two tracks for TER, TGV and Freight. SNCF Réseau experts predict that the station will quickly become saturated and are calling for new investments.

Finally, conflicts sometimes arise between the Lyria TGV, Léman Express trains, TERs and freight, for example for the transport of Evian water.

On the Swiss side, numerous works will be scheduled on the network. Geneva Cornavin station remains saturated and a major redevelopment plan will be launched in 2023 for many years (underground station), which will lead to work periods that conflict with the Leman Express services (L5 and L6 Geneva – Bellegarde).

Operational side

The strength of the new Franco-Swiss rail service is an end-to-end service with no load break at Annemasse (for lines L3, L2 and L1), which results in a very high traffic density with a train every 6 minutes at Annemasse. The interest is obviously a direct link between Annecy (L2), Saint-Gervais (L3) and Evian (L1) with Geneva via Annemasse. Since 5 April 2021, the Franco-Swiss Léman Express network has been operating at full capacity. At the very beginning, due to problems with the rolling stock and the timetable, but also since 18 May 2020 due to a lack of SBB drivers trained for France, all trains stopped at Annemasse and, with a change of train, a shuttle train left Annemasse for Geneva. Fortunately, the Lémanis teams managed to return to the initial end-to-end service (especially Annecy-Geneva direct) but this hesitation in Franco-Swiss management led to fears of the worst, namely a break in Franco-Swiss continuity and Therefore, a failure of the offer!

Punctuality remains good for trains that are not cancelled. In fact, if the expected train is more than 10 minutes late, it is cancelled because it becomes unmanageable to integrate it into the traffic. These cancellations are very much decried by customers, particularly on social networks. On the French reference basis (4 min 59s), punctuality is 98 % (TERs in the Auvergne Rhône-Alpes region have a rate of 89 %).

The hardware went through a burn-in cycle that resulted in some adjustments in the first few years of operation. The Stadler Flirt had serious software reliability problems that have been largely resolved today. The Alstom Regiolis trains also underwent some running-in adjustments. Driver recruitment was not easy on the Swiss side, with the labour market under great pressure due to a shortage of manpower. The Covid and the withdrawal of rolling stock handicapped the first months of operation, with a drop in supply to cope with these shortages.

Finally, the launch of the service in December 2019 coincided with an SNCF strike, which disrupted the tests and did not improve the complex but cordial relations between the Swiss and French managers.

A major challenge for the service is to achieve reciprocity in passenger flows between France and Switzerland, i.e., to make Haute-Savoie more attractive to Swiss tourists, for example to the Arve Valley and to Annecy. Lémanis is currently working in this direction (information campaign). It is a pity that the Annemasse station has been delayed by more than a year and a half in its development -, which should nevertheless be superb! Numerous park-and-ride facilities and improved station access have been built in this respect.

Pricing and Franco-Swiss intercultural management

The Léman Pass fare system is the great success of this fare community, both because of its simplicity (two fares, one French (classic TER unchanged) and the other Franco-Swiss for a cross-border journey[3]) and its low cost. This pricing system has led to changes in the organisation of inter-municipal cooperation in France, with mergers of inter-municipalities and genuine cross-border mutualisation. Thus, on 1 January 2019, a major merger of communes was agreed between the communes of Bellegarde-sur-Valserine, Châtillon-en-Michaille and Lancrans, which become Valserhône (approximately 16 500 inhabitants). These municipalities belong to the Greater Geneva area and are 30 km from Geneva and 15 km from the French-Swiss border. The L6 line of the Léman Express connects Bellegarde and Geneva Cornavin. In mid-December 2020, an agreement relating to the Léman Express fare community was signed between Valserhône – and its Mobi'Vals transport network – and the Léman Express for greater cross-border fare integration: investment costs are shared 50 %-50 % between the canton of Geneva and the French organising authorities[4], with Valserhône's share amounting to 2,13 %. Similarly, a distribution of the operating costs has been validated: Valserhône will have to contribute between 3300 and 4748 € per year to the scheme until 2024. The mayor of Valserhône observes this tariff integration with interest: "What is interesting in this system is that we are entering more and more into this cross-border mutualisation" [9]. What a project!

But it is in the ratio of revenue to expenditure (R/D), close to 20 %, that the new Léman Express service offers us its greatest surprise or disappointment! Indeed, in a privileged region with a high income, the R/D is at a lower level than the TER Auvergne Rhône-Alpes (R/D close to 30 %). The Léman Express is Therefore, largely subsidized by the taxpayer and/or the debt! The Auvergne Rhône-Alpes region estimates its financial contribution under the operating agreement with SNCF Voyageurs at € 27 million. The commercial revenues must be deducted from this amount, but during the periods of confinement or recourse to teleworking, they were very low, which led the region to add even more! The Region Therefore, compensates for the commercial revenue between France and Switzerland: the organising authorities[5] cover 100 % of

3 The Léman Pass ticket or season ticket allows you to use the trains, trams, buses, "mouettes genevoises" and transport networks of the 10 partner operators. It is extremely simple to use: all you need is a ticket to travel on cross-border public transport.

4 Currently 8 organising authorities: Republic and Canton of Geneva, Auvergne-Rhône-Alpes Region, Annemasse agglomeration, Grand Annecy agglomeration, Thonon agglomeration, GLCT public transport, Communauté de communes Pays d'Evian Vallée d'Abondance, Commune de Valserhône.

5 Six organizing authorities manage public transport on the French side. This institutional fragmentation, which is very French, poses formidable coordination problems. The French Geneva metropolitan area is currently considering a single transit authority. With a more integrated A.O. on the Swiss side, Geneva is considering an urban toll, the revenue from, which could be used to develop cross-border public transport services in particular.

the costs of public transport, in particular the Region for the Léman Express. There is Therefore, a certain gap between the level of fares and the rather high standard of living in the region. One explanation lies in the strong Swiss influence on the service, which aims to provide a strong incentive to use public transport (in the wake of the Swiss unireso[6] card, for example).

Finally, Franco-Swiss governance seems to be well organized around production committees every two months, and Franco-Swiss pairs at all levels for the management of the network and operations.

CONCLUSION

The Léman Express has confirmed its relevance as a quality and innovative alternative modal offer to the car. Its beginnings are promising after a running-in phase, which now seems to be over. The offer has found its demand, with 45 000 passengers per day on average.

Our interviews with the actors of the Léman Express system revealed three main areas of work:

1. The reliability of the rolling stock, and above all the avoidance of train cancellations, which are very badly perceived by passengers, but also the optimization of the passenger information system and making it truly interoperable between the French and Swiss systems.
2. Study and prevent future saturation of the service, which calls for reinforcement of the rolling stock, but above all the elimination of the infrastructure bottlenecks in France, i.e., the single tracks or at least the automation of their operation, towards Annecy, Evian and the Arve valley. It is also necessary to prevent future operating constraints linked to the numerous works on the Swiss side: Geneva (Cornavin station, Coppet axis[7]).
3. Study an extension to the Haut-Bugey in connection with the TER (regional express trains) because the hinterland of Geneva is growing.

In the long term, for the transport scientist involved in a reflection on European transport policy, the question arises as to the compatibility of this rail service with the European texts calling for competition in regional passenger rail services. This is not a question of competition on the market, as with rail freight, but of competition for the market in the context of tendering, in line with the provisions of the new rail

6 The unireso card offers a common tariff between three public transport companies in Geneva: the TPG (Geneva public transport), the CFF (Swiss Federal Railways) and the mouettes genevoises (shipping).

7 In the summer of 2021, for example, trains to Coppet stopped at Cornavin (Source: SBB).

law (Journal Officiel – law no. 2018-515 entitled "for a new rail pact"). Admittedly, these provisions only apply to France, but the Swiss authorities are following the developments of the major European railway reform very closely and sometimes draw inspiration from them. Would another operator be likely to promote an innovative, differentiated service with improved quality of service? And why not imagine, as should have been the case, a single common rolling stock for the entire network?

And finally, could we not imagine a total automation of the Léman Express service at a time when the autonomous car is making considerable progress in an unconstrained space, whereas the rail system is a simple, guided mode?

What about the future? Will the new configuration of mobility in the Greater Geneva area lead to new institutional adaptations, for example Franco-Swiss (a joint Franco-Swiss organizing authority) in order to advance even further in the network of European metropolitan areas? There are signs of this. The Leman Express network is just one step for Geneva on the road to regaining its natural place as a leading European metropolis. A vote in February 2014, by a large majority, made it possible to set up a railway investment fund (FIAF), which will enable the synergies of the Greater Geneva railway network to be strengthened. For example, traffic forecasts on the Swiss side between Lausanne and Geneva could increase from 50 000 journeys per day in 2010 to almost 100 000 in 2030, which should lead to a quarter-hourly interval for the Léman express and links to the canton of Vaud with a planned doubling of seating capacity. Geneva station, like Renens station, should undergo extensive development, in particular an underground extension for Geneva-Cornavin.

These prospects should provide strategic thinking for Lyon, the regional capital, as well as Annecy, Chambéry and Grenoble, in order to position themselves in the new European metropolis.

REFERENCES

[1] With my thanks to the editorial team of the RGCF who allowed me to have interviews with the Management of Lémanis and SNCF Réseau in Haute-Savoie.
[2] Interviews with the Rhône-Alpes Region and the Pôle métropolitain du genevois français.
[3] Cantonal Transport Office (2019), Statistical Yearbook of Transport.
[4] ALPRAIL association for the promotion of railways in the Lake Geneva region.
[5] France Stratégie, Marie Dégremont (2019), Mobility in the Greater Geneva

area: what avenues for a balanced and sustainable territorial development, nr. 02, May

[6] Guihéry L. (2019), "The new Léman Express CEVA Cornavin - Eaux-Vives - Annemasse rail link: the new Hinterland of Greater Geneva?", Revue Générale des Chemins de Fer, nr. 296, September, pp. 8-14.

[7] Guihéry L. (2020), "Genève et ses frontières : du fier particularisme genevois à la métropole d'Europe ouverte", in Les Frontières, edited by Raymond Woessner, pp. 264-273, Atlande.

[8] Tribune de Genève (2016), Tuesday 15 March.

[9] Le Dauphiné libéré (2020 and 2021).

[10] Le Monde (2021), "à Annemasse, l'argent suisse creuse les inégalités", Isabelle Rey-Lefebvre, 4 June.

[11] The Revue Générale des Chemins de Fer (2019), in its issue 296 of September, had conducted an exhaustive study of the CEVA project and the new Léman Express.

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Quality Evaluation of Timetables in the Non-Metropolitan Area: A Case Study of the South Bohemia Region

VLADIMÍR ĽUPTÁK, ONDREJ STOPKA, LADISLAV BARTUŠKA, MARTIN JURKOVIČ

Abstract The presented manuscript deals with the issue of evaluating the quality of transport connections in an opted territory in relation to passenger transport. The aim of this manuscript is to design a new guideline procedure to evaluate timetables, either ex post or ex ante. The very idea of objectifying the timetables' evaluation in passenger transport is that there has not yet been stipulated any relevant guideline for a comprehensive evaluation of timetables and any specific indicators for evaluating the quality of transport connections in a transport territory. First of all, the manuscript summarizes the general qualitative indicators that are consequently implemented in the particular transport territory. Determined indicators are interconnected to the existing transport territory, as well as timetable being in operation. Such an interconnection of qualitative indicators will thereafter have a synergistic effect on the evaluation of certain transport connections, or for the entire transport territory. This entails an initial point for elaborating a set of relevant criteria for the overall transport connection quality evaluation. The second part of the manuscript consists of an application of such a designed theoretical guideline to the opted transport territory, in our case, railway transport network of the South Bohemian region was chosen. The very findings of the manuscript encompass the transport connection quality evaluation in terms of adherence to the timetable from one particular tariff point to 17 other specified tariff points.

Keywords: • Transport Territory • Railway Transport Network • Timetable • Qualitative Indicators • Transport Connection Quality Evaluation

CORRESPONDENCE ADDRESS: Ondrej Stopka, Assoc. Prof., PhD., Ing., Vladimír Ľupták, PhD., Ing., Ladislav Bartuška, Ing., Faculty of Technology, Institute of Technology and Business in České Budějovice, Okružní 517/10, 370 01 České Budějovice, Czech Republic, e-mail: luptak@mail.vstecb.cz, e-mail: stopka@mail.vstecb.cz, bartuska@vstecb.cz, Martin Jurkovič, PhD. Ing., Faculty of Operation and Economics of Transport and Communications, University of Žilina, 010 26 Žilina, Slovakia, e-mail:martin.jurkovic@fpedas.uniza.sk

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

Transport per se has become a part of everyday life. At present, passengers can utilize multiple modes of transport for their carriage. These encompasses, for instance, transport by passenger car, bus, trolley, train, metro or other means of transport. The function of transport infrastructure or network is to comprehensively operate and supply a certain geographic agglomeration by transport services [1]. Hence, transport network may be deemed as one of the fundamental attributes for the functional national economy. It can be declared that, from a spatial perspective, the EU transport network including the Czech transport network are rather well developed and to a sufficient extent covering such transport territories of interest [2].

The provided quality of transport connections within a certain network is substantially associated with services ensured by transport sector, whereby the its crucial objective is to satisfy the requirements of customers for high-quality, flexible, rapid, and above all, safe carriage of passengers and even cargo [3]. This is emerged by the fact that the process of evaluating the transport connection quality is carried out in a non-systematic approach, no matter the level of interactions of carried passengers within transport system concerned. The ideas, wishes, needs, requirements and expectations of customers, being observed by establishing procedures meeting the "Regulation (EC) No 1371/2007 of the European Parliament and of the Council of 23 October 2007 on railway passengers' rights and obligations", need to be defined with priority to comprehend the investigation and evaluation of the transport connection quality on a certain transport network [4].

The quality of transport services provided is, however, perceived differently from the standpoint of transport service user; i.e., passenger, and transport service provider; i.e., transport operator, as well as from the point of view of the whole society. Nowadays, achieving a uniform, sustainable, integrated and efficient transport system requires providing transfer links and interconnections throughout all the modes of transport. The availability of destinations and the frequency of transport connections represent the most imperative aspect in regard to interest of passengers in public transport [5].

The subsequent parts of the manuscript are focused on as follows: (a) compiling a literature review section presenting numerous topic-related literature sources dealing with the subject of public passenger transport in terms of adherence to timetables, qualitative indicators, as well as qualitative evaluation of transport connections in a variety of territories; (b) designing the very guideline procedure for the transport connection quality evaluation involving all the input data sets and describing individual indicators, as well as all the relevant research steps; (c) elaborating a case study of the South Bohemia region comprising an overview of the findings and a proper discussion of these results including their potential benefits; and last but not least, (d) composing the final section of the paper justifying individual conclusions from the conducted study, as well as suggesting the potential topics relating to further research possibilities in this area of expertise. The whole procedure may be regarded as a guideline concerning the transport connection quality evaluation in terms of adherence to the timetable from one particular tariff point to other tariff points; and that is where the innovation approach of our research lies.

LITERATURE REVIEW

A large number of scientific studies deal with the quality evaluation of passenger transport services within a specific territory, its urgency resulting from the growing demands of passengers and tightening environmental measures on meticulous and advanced transport planning. For instance, the publications [6-14] systematically analyze the issue in question.

The study [6] explores the quality evaluation and coordination of timetables in air passenger transport, providing impressive results from tests conducted on four international airports. Large airports, such as London Heathrow and Paris Charles de Gaulle have longer waiting times than the smaller airports Frankfurt and Schiphol even though one would expect shorter waiting times given the higher frequencies of service. The reason is that the flight co-ordination is less efficient. The literature [7] focuses on the stability and regularity being essentials for a well-established timetable meeting specific customer requirements. In the article, the authors discuss the passenger timetable of 2003 drawn from a design of the Ministry of Transportation of North Rhine-Westphalia. The regional scheme included approx. 5 300 daily-run passenger trains, satisfying all administrative requirements for the service frequency, stops and so on,

The publication [8] presents brilliant and inspirational ideas suggesting the probability evaluation of planned train connections' likely delays and the subsequent renewal of the delayed timetables. The evaluation identifies the possible problems in the services, such as excessive waiting time, non-seamless transfer, and high possibility of delay. The authors also discuss the improvement of these questions by certain adjustments on the timetable. The indices for evaluation and the adjustment technique on timetable are then implemented in a specific case study on the Hu-Ning-Hang railway located in China, followed by the discussions of the merits of the proposed indices for timetable evaluation and possible improvement.

The manuscript [9] proposes a different point of view on planning transit networks. Guihare and Hao deal with an original subject with respect to the traditionally sequential planning process in public transit, networks This problem aims at modifying the network's timetables without tendering the vehicle and driver schedules obsolete. The objective is to improve the quality of service for passengers through number and quality of transfers This approach goes in the opposite direction compared to the usual approach, which schedules resources once timetables me set. Scientific work [10] discusses the quality evaluation of timetables using DEA method. The paper suggests an evaluation index for the quality of train timetable forming and solves the problem with a data envelopment analysis (DEA) method. The article [11] examines the impact of the quality in terms of introducing timetables based on the current demand for the passenger railway transport. Wheat and Wardman are also concerned with the appropriateness and component weightings within the composite index Generalized Journey Time. This particular index is used to model railway demand in Great Britain and is composed of station-to-station journey time, service headway and a penalty for the need to change trains.

The paper [12] emphasizes the thematic-closest topic to the submitted article. The crucial aim of the paper is to define and quantify the criteria having the greatest effect on traffic accessibility in suburban areas; i.e., to develop a model of traffic accessibility. This model concerns traffic accessibility in suburban areas, wherein an urban public transport system is operational and represents a qualitative approach to research. Research shows that factors, such as a network of public transport lines, a network of accessible roads in a settlement, travel time, and timetables are of great significance while describing and generating a new model. This model was tested in 23 suburban districts with regard to the needed walking time. The Fuzzy AHP (FAHP) method, one of the most popular methods for multi-criteria decision making, was used.

Furthermore, as likewise in our manuscript, even Klapita et al. (2020) outline an approach methodical guideline according to, which it would be possible to efficiently evaluate transport services in railway transport provided by the carriers, namely, in the Slovak Republic conditions [13]. The secondary aim of the suggested methodology is to promote environmentally friendly modes of transport, which means growth in a share of railway transport in the transport market. On the other hand, Liu and Cao (2019) investigate the evaluation indexes of bus service quality, involving bus system mobility, station accessibility, transfer connection, as well as waiting expectation, and analyze the relevant data when using Rasch model [14].

All the research studies analyzed above deal with a specific part of the quality evaluation in association with timetables and transport services. The presented article, nevertheless, extensively explores the issue and suggests the theoretical guideline comprehensively addressing the examined topic in compliance with the European Legislation being concerned.

DESIGNING A GUIDELINE PROCEDURE FOR THE TRANSPORT CONNECTION EVALUATION

The suggested guideline is based on evaluating established criteria of connections between selected tariff points at the network. The key principle of this guideline procedure is to evaluate a specific connection. What must be determined is whether a working day or weekend connection is to be dealt with; alternatively, an evaluation of a specific working day, Saturday or Sunday must be worked out. Subsequently, summarizing indicators for transport connections relating to the section throughout the examined network are developed. The new guideline encompassing a partial quality evaluation of the transport connection in a certain territory should suggest a comprehensive evaluation defined by individual steps. The interconnection of each indicator must result in an objective consideration in terms of the transport quality. It means considering all the transport connections on the examined network. The adopted guideline comprises several steps as follows:

1. choosing a specific transport territory,
2. choosing a set of transport connections,
3. choosing relevant tariff points in the transport territory,
4. choosing a search engine to find transport connections,
5. choosing qualitative indicators,
6. evaluating individual transport sections,
7. evaluating the whole connection throughout the transport sections,
8. evaluating the transport connections in the specific transport territory.

Choosing a specific transport territory

In this step, the passenger transport network (railway, road, air, water, integrated transport systems, etc.) is selected, which will be the subject of the quality evaluation. The specific choice may be defined in terms of mode of transport, operator, transport network or other criteria, and possibly also including integrated transport system lines [15].

Choosing a set of transport connections

In this step, specific connections should be selected. The choice depends either on the particular operator who provides transport services on the selected network, or on the kind of transport. Alternatively, all available connections as provided by all the operators are analyzed.

Choosing relevant tariff points in the transport territory

Relevant quality indicators that serve as performance indicators for a particular connection between tariff points should be included in a comprehensive evaluation of the connections incorporated in a timetable.

The minimum quality standards for the comprehensive evaluation of an individual connection within a selected transport network (within a geographical area) are determined on the basis of the following indicators [16]:

- average travel speed,
- average speed until the final stop,
- average waiting time.

For a comprehensive evaluation, the quality of the connections at all tariff points within the selected transport network should be analyzed. Alternatively, a set of tariff points may be chosen for the quality evaluation being representative for the examined transport territory as a whole.

Choosing a search engine to find transport connections

In this step, a search engine for transport connections needs to be specified according to input criteria. Manual searching in timetables is the prime searching technique. However, websites, applications for seeking out transport connections or offline mobile applications are also currently used for this purpose. The individual parameters for searching for suitable connections (i.e., setting the date of departure, time of departure, maximum number of transfers, etc.) must be set properly [17,18].

Choosing qualitative indicators

Under the proposed guideline, the following indicators are used to evaluate the quality of the connections on a particular route:

- Number of connections "N_s" for the examined day includes both direct lines and transfer lines. This indicates the number of alternatives divided over time that passengers have to travel from point A to B [19].
- Average waiting time "W_i" refers to the amount of time spent by passengers waiting for a particular connection at the place of departure or starting point. It is defined as half the time between the departure of two sequential connections:

$$W_i = \frac{(T_{odX+1} - T_{odXi})}{2} \, [h], \quad (1)$$

where:

T_{odXi} – time of departure of the evaluated transport connection from a tariff starting point,

T_{odXi+1} – time of departure of the following transport connection from a tariff starting point.

Route length of the transport connection "L_i" refers to the distance traveled in kilometers (mostly tariff) by the mode of transport used for a particular connection. This does not always mean that the shortest possible route for the connection is used. As a result, this criterion, together with that of travel time, is classified as less important [20].

Kind and number of modes of transport that a connection is comprised of. This factor defines the quality of transport service connectivity [21].

Travel time "T_{pi}" is calculated from the moment a passenger departs from their first starting point on the route to the moment of arrival at the final destination (tariff point). It is calculated as follows:

$$T_{pi} = T_{pr} - T_{od} \, [h], \quad (2)$$

where:

T_{pi} – travel time [h],

T_{pr} – travel of arrival at the final tariff point [h],

T_{od} – time of departure from the starting tariff point [h].

Number of transfers "N_{pi}" refers to the total number of transfers until the passenger reaches their final destination. This is the main criterion taken into account by passengers. Under ideal circumstances the connection should be provided direct [22,23].

Transfer time "T_{wi}" refers to the aggregate time that passengers spend waiting for the i-th connection at transfer points while traveling on a particular connection.

$$T_{wi}=\sum (t_{i2dep} - t_{i1arr})[min], \quad (3)$$

where:

t_{i2dep} – time of departure of the connecting train at the stop of i-th transfer [min],

t_{i1arr} – time of arrival of the connecting train at the stop of i-th transfer [min].

Destination arrival time "T_{Di}" is calculated from the moment of a passenger's arrival at the stop at the tariff starting point from, which they are due to begin their journey to the moment of arrival of the last taken connection at the final stop at the output tariff point. This amounts to the sum of the average waiting time and travel time [24]:

$$T_{Di} = W_i + T_{pi} [h], \quad (4)$$

where:

W_i – average waiting time between two successive connections [h],

T_{pi} – travel time [h].

Travel speed "V_{pi}" is calculated as the ratio of the traveled distance to the travel time.

$$V_{pi} = \frac{L_i}{T_{pi}} [km \cdot h^{-1}], \quad (5)$$

where:

L_i – route length of the connection [km],

T_{pi} – travel time [h].

Destination arrival speed "V_{Di}" is calculated as the ratio of the route length to the destination arrival time.

$$V_{Di} = \frac{L_i}{T_{Di}} [km \cdot h^{-1}], \quad (6)$$

where:

L_i – route length of the connection [km],

T_{Di} – destination arrival time [h].

Evaluating individual transport sections

In order to implement the designed guideline procedure successfully, more ways of evaluating the quality of individual connections in a passenger transport network need to be considered. For this research study, the quality of a connection will be investigated according to the following:

Option 1 – Number of transfers,

Option 2 – Destination arrival time,

Option 3 – Travel speed,

Option 4 – Destination arrival speed.

After processing the evaluation of the connectivity of one transport route, particular routes between tariff points on the transport network should be evaluated. This requires the careful selection of tariff points. In order to correctly evaluate a particular connection on a specific route, a table showing all the connections needs to be drawn up (see Table 1) [25].

Table 1. General evaluation of connections on a route

Serial number of n-th connection	Station/stop X departure [hh:min]	Station Xj arrival [hh:min]	Average waiting time W_i [h]	Route length L_i [km]	Trains (types)	Travel time T_p [h]	Number of transfers N_p	Transfer time T_w [h]	Destination arrival time T_d [h]	Travel speed V_p [km.h-1]	Destination arrival speed V_D [km.h-1]
1	T_{odXi}	T_{prXj}	W_i	L_i		T_{pi}	N_{pi}	T_{wi}	T_{Di}	V_{pi}	V_{Di}
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
n											

Evaluating the whole connection throughout the transport sections

During the very investigation of the transport connections on a section, selected indicators are translated into average values. This is done for the purposes of conducting the final comprehensive quality evaluation of the whole route within the selected transport network. Table 2 comprises suggestions for useful indicators, which should be monitored over a 24-hour period.

Table 2. Route evaluation

Serial number of n-th connection	Station/stop X departure [hh:min]	Station Y arrival [hh:min]	Average waiting time W_i [h]	Route length L_i [km]	Trains (types)	Travel time T_p [h]	Number of transfers N_p	Transfer time T_w [h]	Destination arrival time T_d [h]	Travel speed V_p [km.h-1]	Destination arrival speed V_D [km.h-1]
1											
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
n											
		Average value per route:					ø N_p	ø T_w	ø T_d	ø V_p	ø V_D

For each route, average criterion values for all the considered connections within a selected transport network must be calculated i.e., average number of transfers (ø N_p); average transfer time (ø T_w); average destination arrival time (ø T_d); average travel speed (ø V_p); and average destination arrival speed (ø V_D) [26-28].

Evaluating the transport connections in the specific transport territory

The last step of the suggested guideline procedure consists of the quality evaluation of connections according to selected indicators, such as the average number of transfers (ø N_p); average transfer time (ø T_w); average destination arrival time (ø Td); average travel speed (ø V_p); and average destination arrival speed (ø V_D). The designed guideline and selected ratios allow the comparison and evaluation of individual timetables within different periods illustrated in the ensuing Table 3 [29,30].

Table 3. Comparative analysis of timetables

From X to the tariff point	Indicator	From X to the tariff point	Indicator	From X to the tariff point	Indicator
Timetable X_1		...		Timetable X_n	
Tariff Point A	.	Tariff Point A	.	Tariff Point A	.
.		.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
Tariff Point Z	.	Tariff Point Z	.	Tariff Point Z	.
Average per connection		Average per connection		Average per connection	

CASE STUDY OF THE SOUTH BOHEMIA REGION

1. step – choosing a specific transport territory – A case study was carried out on the Czech Railway Administration Network. The study included all carriers providing passenger railway transport in the region of South Bohemia on 12th December 2019.

2. step – choosing a set of transport connections – What was chosen was one district town with connections to the county seat, self-governing regions and district towns with railway stations or stops, railway junctions, end-to-end points of the lines, intersection and turning tracks, completions of line segments and tourism centers.

3. step – choosing relevant traffic points on the network – Seventeen tariff points on ZČR network were selected to evaluate the quality of transport connections. The research was conducted from Strakonice between the following tariff points: Lipno nad Vltavou, Horní Dvořiště, České Velenice, Jindřichův Hradec, Veselý nad Lužnicí, České Budějovice, Blatná, Písek, Milevsko, Bechyně, Tábor, Volary, Černý Kříž, Český Krumlov, Březnice, Třeboň a Slavonice. The date of the research was Thursday 12th December 2019 from 00:00 am to 11:59 pm.

4. step – choosing a search engine; all the transport connections were found on www.idos.cz from Charps Company.

Figure 1. Map of the railway network in the South Bohemia region with labeled tariff points

5. and 6. steps – choosing indicators and evaluating individual transport sections – Connection Strakonice – Lipno nad Vltavou was used as an example. Nine connections within 24 hours were found. Number 6, which leaves Strakonice Station at 3:07 pm and arrives at Lipno nad Vltavou Station at 5:44 pm is considered to be the best connection. This connection involves two changes with the average waiting time 1 hour in Strakonice. Selected quality indicators of the connection show as follows: destination arrival time T_d = 3,62 h, travel speed V_P = 50,45 km/h and destination arrival speed V_D = 36,50 km/h.

Table 4. Quality indicators of the transport connection of Strakonice – Lipno nad Vltavou

Serial number of the connection	Departure [hh:min]	Arrival [hh:min]	Average waiting time Wi [h]	Distance Li [km]	Types of trains	Travel time Tp [h]	Number of transfers Np	Transfer time Tw [min]	Destination arrival time Td [h]	Travel speed VP [km.h-1]	Destination arrival speed VD [km.h-1]
1	4:57	7:45	6,08	132	R, Os, Os	2,80	2	22	8,88	47,14	14,86
2	7:07	9:45	1,08	132	R, Ex, Os	2,63	2	25	3,72	50,13	35,52
3	9:07	11:45	1,00	132	R, Os, Os	2,63	2	20	3,63	50,13	36,33
4	11:07	13:45	1,00	132	R, Ex, Os	2,63	2	25	3,63	50,13	36,33
5	13:07	15:45	1,00	132	R, Os, Os	2,63	2	20	3,63	50,13	36,33
6	15:07	17:44	1,00	132	R, Ex, Os	2,62	2	24	3,62	50,45	36,50
7	15:07	19:14	0,00	132	R, Os	4,12	1	74	4,12	32,06	32,06
8	15:35	19:14	0,23	132	Os, R, Os	3,65	2	37	3,88	36,16	33,99
9	17:07	19:57	0,77	132	R, Os, Os	2,83	2	20	3,60	46,59	36,67
Average values per transport section							1,89	29,67	4,30	45,88	33,18

7. step – evaluating connections of the specific network; each transport section must be provided with average indicators for further evaluation. Section Strakonice – Lipno nad Vltavou comprises the average number of transfers $øN_p$ = 1,89, average transfer time $øT_w$ = 29,67 hours, average destination arrival time $øT_d$ = 4,30 hours, average travel speed $øV_P$ = 45,88 km/h and average destination arrival speed $øV_D$ = 33,18 km/h.

The ensuing Figure 2 depicts individual destination arrival speed values for the transport section Strakonice – Lipno nad Vltavou.

Figure 2. Travel speed indicators for the transport section Strakonice – Lipno nad Vltavou

As mentioned, Figure 2 summarizes detected destination arrival speed values for the section Strakonice – Lipno nad Vltavou. The speed represents one of the qualitative indicators for evaluating the connection on a passenger transport network. The average speed on this transport section equals to 33,18 km/h. This figure is required for a comprehensive evaluation of the transport connection quality from Strakonice to the examined tariff points within the region of South Bohemia.

8. step – Evaluating the transport connection on the specific network – The final step involves analyzing all connections from Strakonice to other 17 selected tariff points on the railway network within the region of South Bohemia – 17 sections in total. Each section was looked through for all existing connections on 12th December 2019 within 24 hours. All individual connections between Strakonice and each tariff point individually were provided with clear tables containing values from, which the average values were calculated; these are as follows: the number of transfers Np, total transfer time Tw, destination arrival time Td, travel speed Vp and destination arrival speed VD. These figures were compiled into a comparative analysis of the selected quality indicators for evaluating the connection on the transport network. What displayed the highest quality regarding the relocation and travel speed is the section from Strakonice to České Budějovice. The only direct, connection from Strakonice

Station is to Blatná Station, yet it is at the same time the slowest alternative.

Table 5. Comparison of results of the transport connection quality on the transport section Strakonice – Lipno nad Vltavou

From Strakonice to station	Average travel speed Vp (km.h-1)	From Strakonice to station	Average destination arrival time speed VD (km.h-1)	From Strakonice to station	Average transfer time Tw (min)
České Budějovice	67,94	České Budějovice	46,60	Blatná	0,00
Veselí nad Lužnicí	63,87	Veselí nad Lužnicí	45,93	České Budějovice	0,95
Horní Dvořiště	61,92	Jindřichův Hradec	40,46	Volary	1,15
České Velenice	55,00	Horní Dvořiště	37,17	Milevsko	4,00
Jindřichův Hradec	54,29	České Velenice	36,90	Tábor	7,83
Tábor	51,19	Tábor	36,50	Horní Dvořiště	10,88
Milevsko	48,60	Třeboň	34,41	Březnice	11,57
Český Krumlov	47,25	Lipno nad Vltavou	33,18	Veselí nad Lužnicí	11,59
Písek	46,20	Slavonice	31,46	Písek	14,14
Lipno nad Vltavou	45,88	Český Krumlov	28,24	Jindřichův Hradec	16,25
Třeboň	44,97	Březnice	27,34	Bechyně	20,00
Slavonice	39,81	Bechyně	25,62	České Velenice	23,09
Březnice	39,41	Volary	23,84	Český Krumlov	26,50
Blatná	38,74	Milevsko	21,98	Lipno nad Vltavou	29,67
Bechyně	38,08	Černý Kříž	20,27	Černý Kříž	33,50
Volary	34,25	Písek	19,86	Třeboň	54,30
Černý Kříž	30,95	Blatná	15,73	Slavonice	64,67
Average	47,67	Average	30,91	Average	19,42

DISCUSSION

In the conducted case study, the proposed guideline procedure for evaluating the quality of transport connections on the railway network of the South Bohemian Region territorial scope was implemented [28]. The city of Strakonice was determined to be the examined tariff point. Using the general procedure described in the initial sections of the manuscript, we gradually applied it to a case study in order to verify its accuracy and define the quality of transport connections, as well as transport sections from this tariff point [29]. In the case study of the South Bohemia region, the investigation of one specific section of the railway network from Strakonice to Lipno nad Vltavou out of a total of 17 designated sections was chosen as an example. 9 connections were identified on the given railway network during 24 hours, and their relevant average values (see Table 4) are as follows [32]:

- number of transfers N_p = 1,89,
- transfer time T_w = 29,67 min,
- destination arrival time T_d = 4,3 h,
- travel speed V_P = 45,88 km.h-1,
- destination arrival speed V_D = 33,18 km.h-1.

The same approach was implemented for each transport section, wherein all the connections were identified in 24 hours on the examined day. The last step consisted of analyzing all the sections altogether. The findings can be interpreted in tabular form – Table 5 summarizes the relevant indicators (average travel speed Vp, average destination arrival speed V_D, average transfer time T_w) that investigate (evaluate) the transport connection quality on the transport section under examination [33].

Among the potential benefits of the presented article, we can embrace as follows [34,35]:

- design of a uniform guideline procedure as an approach for investigating and evaluating the quality of transport connections on the transport network in railway passenger transport applicable on any transport network,
- theoretical definition of qualitative indicators for evaluating the quality of transport connections specified in the timetable within the transport processes with a special emphasis on the time factor:
  - travel speed (km.h-1),
  - destination arrival speed (km.h-1),
- application of the designed approach on each opted transport network and for various modes of transport on this network, including integrated transport systems,
- specification of requirements of the public passenger transport customer for a better transport connection declared in the timetable based on the suggested qualitative indicators,
- by using the designed guideline, it is possible to compare indicators for different

variants of timetables, both ex ante and ex post,

- specific support for the objectives of EU transport policy with respect to passenger transport, with an emphasis on the quantification of qualitative indicators, evaluation processes of relocation on the transport network.

CONCLUSION

The proposed guideline may be applied as an instrument for the comprehensive analysis and visualization of reliable indicators in terms of transport services within a specified transport territory or for the organization of public passenger transport in relation to performances in the public interest. For the procedure to be applied successfully, it is necessary to retrieve reliable data on passenger transport (e.g., ticket sales, flows of passengers, etc.), as well as make precise calculations with the use of appropriate software. After processing the data, the research outcomes can be presented in detail by tables and diagrams. Through extensive use of the guideline, operators and entities responsible for providing transport services in certain region can analyze territorial transport services regarding the performances in the public interest and, subsequently, accurately evaluate existing or planned timetables while taking users into careful consideration.

The research study in this article focused on the sustainable development of railway passenger transport. Notwithstanding, the guideline may also be applied to other modes of transport, as well as integrated transport systems. The guideline procedure may, for example, be implemented when evaluating the transport connection quality of various transport modes within a specified transport territory.

The suggested guideline procedure provides a material basis for evaluating the drawing up of timetables for a specified transport network using the suggested qualitative indicators. Similarly important is the fact that the designed guideline allows comparing different timetable options to be carried out within a specified transport territory.

In regard to recommendations for further research, development and application of the designed guideline procedure, the possibility of programming and software implementation of the proposed evaluation on the certain transport network. In such a case, a whole array of subprograms and procedures must be developed in the program source code. At the same time, in this context, it is imperative to specify particular criteria and determine the levels of compliance of these criteria so that the calculation can be automated as much as possible. With software support, it would be possible to apply the designed approach to entire transport networks from each tariff point to each tariff point. The guideline can serve as an instrument to analyze and visualize the suggested indicators of certain territory transport serviceability for the organization of public passenger transport in terms of services in the public interest. For the very implementation, it is necessary to obtain the relevant data from sources related to passenger transport (e.g., data on ticket sales, passenger flows, etc.) and execute software calculations on them. After the data retrieval and computations, an outcome is to compile clear tabular and graphical reports, as it is designed in the guideline procedure and implemented in the case study conducted.

ACKNOWLEDGEMENTS

This manuscript was supported as part of the research project entitled "Autonomous mobility in the context of regional development LTC19009" of the INTER-EXCELLENCE program, the VES 19 INTER-COST subprogram. It is also a part of the results of the Project VEGA No. 1/0128/20: Research on the Economic Efficiency of Variant Transport Modes in the Car Transport in the Slovak Republic with Emphasis on Sustainability and Environmental Impact, Faculty of Operation and Economics of Transport and Communications: University of Zilina, 2020-2022.

REFERENCES

[1] David, A., & Madudova E. (2019). Identifying the derived utility function of transport services. 13th International Scientific Conference on Sustainable, Modern and Safe Transport, TRANSCOM 2019 (pp. 1096-1102). Novy Smokovec, Slovakia.

[2] Dlugos, M. Peceny, L. Mesko, P., & Sulko, P. (2017). The Impact of Delays of Freight Trains in JIT System on Example One Track Line. MATEC Web of Conferences 134. DOI: 10.1051/matecconf/201713400011.

[3] Gasparik, J., Zitricky, V., Abramovic, B., & David. A. (2017). Role of CRM in supply chains using the process portal. Business logistics in modern management (pp. 385-404). Osijek, Croatia.

[4] Sipus, D. & Abramovic, B. (2017). The possibility of using public transport in rural area. Procedia Engineering 192, 788–793.

[5] Drdla, P. (2014). Osobní doprava regionálního a nadregionálního významu [Passenger transport of regional and supraregional importance], University of Pardubice, 412p.

[6] Rietveld, P. & Brons, M. (2001). Quality of hub-and-spoke networks; the effects of timetable co-ordination on waiting time and rescheduling time. Journal of air transport management, vol. 7 (4), 241-249. DOI: 10.1016/S0969-6997(01)00012-6.

[7] Demitz, J., Hubschen, C., & Albrecht, C. (2014). Timetable stability - using

simulation to ensure quality in a regular interval timetable. Computers in railway six, Book Series: Advances in transport, 15, 549-562.

[8] Ho, T.K., & He, Y.Q. (2008). Evaluation on Service Quality of Railway Timetable. Traffic and transportation studies, 688-696.

[9] Guihare, V., & Hao, J.K. (2010). Improving Timetable Quality in Scheduled Transit Networks. Lecture Notes in Artificial Intelligence, 6096, 21+.

[10] Jiang, F., Ni, S.Q., & Yu, D.B. (2015). Train Timetable Forming Quality Evaluation: An Approach Based on DEA Method. Modelling, computation and optimization in information systems and management sciences - MCO 2015 - PT II, Book Series: Advances in Intelligent Systems and Computing, 360, 437-448, DOI: 10.1007/978-3-319-18167-7_38.

[11] Wheat, P., & Wardman, M. (2017). Effects of timetable related service quality on rail demand. Transportation research part a-policy and practice, 95, 96–108; DOI: 10.1016/j.tra.2016.11.009.

[12] Stankovic, M., Gladovic, P., Popovic, V., & Lukovac, V. (2018). Selection Criteria and Assessment of the Impact of Traffic Accessibility on the Development of Suburbs. Sustainability 10(6), 1977. DOI: 10.3390/su10061977.

[13] Klapita, V., Černá, L., & Liu, X. (2020). Methodological Procedure for Evaluation and Valuation of Additional Services in Rail Freight Transport. LOGI – Scientific Journal on Transport and Logistics 11(1), 57–65. DOI: 10.2478/logi-2020-0006.

[14] Liu, J., & Cao, J. (2019). Research on public transport service quality based on the Rasch model. Journal of Wuhan University of Technology (Transportation Science and Engineering) 43(2), 208–212. DOI: 10.3963/j.issn.2095-3844.2019.02.006

[15] Rai. H.B., Verlinde, S., Merckx, J., & Macharis, C. (2017). Crowd logistics: an opportunity for more sustainable urban freight transport? European Transport Research Review 9. DOI: 10.1007/s12544-017-0256-6.

[16] Cerna, L., Zitricky, V., & Ponicky, J. (2016). Income and price elasticity of demand for transport services in rail passenger transport in the Slovak republic. Mathematical methods in economics, MME, 2016; 126–131.

[17] Chen, Z.H., & Haynes, K.E. (2017). Impact of high-speed rail on regional economic disparity in China, Journal of Transport Geography 65:80–91. https://doi.org/10.1016/j.jtrangeo.2017.08.003.

[18] Vojtek, M., Kendra, M., Zitrický, V., & Daniš, J. (2017). Principles of logistics applied to railway passenger transport. MATEC Web of Conferences. 134. DOI: 10.1051/matecconf/201713400061.

[19] Tsami, M., & Nathanail, E. (2016). Guidance Provision for Increasing Quality of Service of Public Transport. Procedia Engineering 178, pp. 551–557. DOI:

10.1016/j.proeng.2017.01.108.

[20] Chowdhury, S., Zhai, K., & Khan, A. (2016). The Effects of Access and Accessibility on Public Transport Users´ Attitudes. Journal of Public Transportation 19, 97–113. DOI: 10.5038/2375-0901.19.1.7.

[21] Prokudin, G., Chupaylenko, O., Dudnik, O., Dudnik, A., & Omarov, D. (2016). Improvement of the methods for determining optimal characteristics of transportation networks. Eastern European Journal of Enterprise Technologies 6. 54–61. DOI: 10.15587/1729-4061.2016.85211.

[22] Ciuffini, F. (2014). A method for evaluating the frequency effect on the overall travel time. Ingegneria Ferroviaria 69, 803–821.

[23] Langen. P.W., Figueroa, D.M.L., Donselaar, K.H., & Bozuwa, J. (2017). Intermodal connectivity in Europe, an empirical exploration. Research in Transportation Business and Management 23, 3–11. DOI: 10.1016/j.rtbm.2017.02.003.

[24] Gasparik, J., & Zitricky, V. (2010). A New Approach to Estimating the Occupation Time of the Railway Infrastructure. Transport 25, 387–393. DOI: 10.3846/transport.2010.48.

[25] Camaj, J., Masek, J., & Kendra, M. (2016). Model of the Location the Marshalling Yards in Slovak Conditions.. Transport means 2016: proceedings of the 20th international scientific conference: Juodkrante, Lithuania.

[26] Camaj, J., Masek, J., Dolinayova, A., & Danis, J. (2016). Possibilities to Evaluation Railway Tracks in Conditions of the Slovak Railways. Conference on Traffic and Transport Engineering (ICTTE 2016).

[27] Allard, R.F., & Moura, F. (2018). Effect of transport transfer quality on intercity passenger mode choice. Transportation Research Part A – Policy and Practice 109, 89–107. DOI: 10.1016/j.tra.2018.01.018.

[28] Sommer, C., & Lambrecht, F. (2016). Concepts for tenant tickets for connecting habitation and transport. Transportation Research Procedia 19, pp. 40–48. https://doi.org/10.1016/j.trpro.2016.12.066.

[29] Ma, S. & Deng, Y. (2016). Simulation analysis on stability of train working diagram for intercity railway. China Railway Science 37, 122–127. DOI: 10.3969/j.issn.1001-4632.2016.02.17.

[30] Nagy, E., & Csiszár, C. (2015). Analysis of delay causes in Railway passenger transportation", Periodica Polytechnica Transportation Engineering 43(2), 73-81.

[31] Sładkowski, A., Cieśla, M., & Krupa, B. (2018). Evaluation of Transport Processes Quality with Servqual and TUL Methods. LOGI – Scientific Journal on Transport and Logistics 9(2), 61–72. DOI: 10.2478/logi-2018-0019.

[32] Lizbetin, J. (2018). Comparing trains operated in Western Europe from passenger viewpoint. MATEC Web of Conferences 235. 10th International

Scientific Conference Horizons of Railway Transport, HORT 2018, Strecno, Slovakia. DOI: 10.1051/matecconf/201823500008.

[33] Brumercikova, E., Bukova, B., Rybicka, I., & Drozdziel, P. (2019). Measures for increasing performance of the rail freight transport in the north-south direction. Communications - Scientific Letters of the University of Zilina 21(3), 13–20.

[34] Carboni, A., & Deflorio, F. (2017). Quality and energy evaluation of rail-road terminals by microsimulation. Transport Infrastructure and Systems – Proceedings of the AIIT International Congress on Transport Infrastructure and Systems, TIS 2017, Rome, Italy,pp. 617–624. DOI: 10.1201/9781315281896-81.

[35] Caban, J., Zarajczyk, J., & Małek, A. (2019). Possibilities of using electric drives in city buses. 23rd International Scientific Conference on Transport Means 2019, Hotel Gabija Palanga; Lithuania, pp. 543–547.

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY
AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Using Advanced Technologies to Improve Urban Mobility/ Accessibility of People with Disabilities

METKA DERNOVŠEK, NATAŠA REBERNIK, MATEJ BRUMEN,
TOMISLAV LETNIK, KATJA HANŽIČ

Abstract Accessibility is one of the key priorities to improve urban mobility for people with disabilities. They have various limitations in terms of negotiating their way in urban environments, such as safely using road infrastructure, accessing public transport, entering buildings etc. In an ideal world, urban space would provide accessible infrastructure and services to all. However, in real-world, many elements of the built environment present obstacles to unhindered movement of people with disabilities, which can be managed with suitable navigation. The main aim of the article is to present a new generation of personalized navigation platform that provides integrated indoor and outdoor routing services, while considering personalized preferences for optimal path finding, particularly adjusted to the requirements of people with disabilities.

Keywords: • Urban Accessibility • Smart Mobility • Inclusive City • Personalized Solutions • People With Disabilities

---

CORRESPONDENCE ADDRESS: Metka Dernovšek, Bsc., Nataša Rebernik, PhD., Tomislav Letnik, PhD., Katja Hanžič, Bsc., University of Maribor, Faculty of Civil Engineering, Transportation Engineering and Architecture, Smetanova ulica 17, Maribor, Slovenia, e-mail: metka.dernovsek@um.si, e-mail: natasa.rebernik@um.si, e-mail: tomislav.letnik@um.si, e-mail: katja.hanzic@um.si, Matej Brumen, Bsc., University of Maribor, The Faculty of Electrical Engineering and Computer Science, Koroška cesta 4, Maribor, Slovenia, e-mail: matej.brumen@um.si

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

With the increasing number of people with disabilities (hereinafter PwDs), there is a need to improve their mobility and accessibility, especially in urban areas. Accessibility is strongly linked to independent mobility and is essential for the quality of life of PwDs [23]. There are more than 87 million acknowledged PwDs (excluding those younger than 16 years) in European Union alone [13]. Understanding the needs of PwDs and recognizing the importance of urban planning to accommodate those needs is one of the crucial tasks for governments and public agencies.

Governments are faced with great challenges on addressing the growing complexity of cities and considering the wide variety of citizens' needs to increase the independence of people with impaired mobility by creating an accessible and safe urban space. These safe and accessible routes need to have even and slip-resistance surfaces, safe pedestrian crossings, proportionate ramps, reduced curb height, extended green lights at pedestrian crossings, etc. [34].

For navigation systems to be of use for PwDs, they must: a) contain relevant accessibility information, b) utilize accessibility information in a meaningful way (real-time navigation) to address specific mobility challenges, and c) present accessibility information or the result of computation on accessibility data through easy-to-access and easy-to-use interfaces.

The paper presents a new generation of personalized navigation system for PwDs, which is based on enhanced navigation maps and routing algorithms. It takes into consideration various mobility limitations of PwDs, their needs and preferences.

LITERATURE OVERVIEW

Assisting PwD is essential to facilitate their daily life activities. Many systems and approaches have been developed to improve their mobility and enable fast, easy, and comfortable ways of traveling. These include navigational options within many existing services primarily serving vehicles, bicycles, or public transport users. In the last decade, the interest in developing a new generation of navigation serving pedestrians on a broader scale has also emerged. Literature review shows that the focus of pedestrian navigation services may be on one, some, or all aspects of pedestrian services [18]. Ren and Karimi [35][36][37][38] have, for instance, developed several different map-matching algorithms suitable for wheelchair users, both based on a single positioning sensor (GPS) and on integrated sensors. These algorithms require real-time data to estimate user's position accurately and continually.

To assist people in navigating obstacles, several real-time navigation systems [42][44] [28][6] and services [29][24][45][17] have been developed specifically for wheelchair users and visually impaired people. Due to increase of non-accessible routes and spaces in urban areas, an increasing number of geo-crowdsourcing services have emerged alongside, which can be used to collect accessibility information on the built environment [19]. The most known are AXS Map[2], CAP4Access[3], route4u[4], project Sidewalk[5], ROUTE4ALL[6].

A lot of work focused on obstacle detection and autonomous navigation within outdoor navigation using GPS, and other sensors had been reported [15], [48], while accessible route planning is somewhat neglected. Application of GPS and GIS in developing wheelchair-accessible navigation maps was tried. Kurihara et al. [21] presented a general architecture of GIS for assisting users in creating obstacle-free street maps by using highly accurate GPS. Sobek and Miller [41] developed a web-based system as a tool for routing pedestrians with various abilities and analytical evaluation of existing infrastructure. Menkens et al. [25] performed an extensive wheelchair user needs study, on, which the development of a mobile social navigation and support system EasyWheel was based. More recently, Ajmi et al. [2] presented a real-time adaptive planning algorithm for routing wheelchair users through an obstacle-free optimal path based on an augmented reality system. Devigne et al. [9] conceptualized a shared-control algorithm that provides assistance while navigating with a wheelchair in an environment consisting of negative obstacles.

Despite the increasing demand for such dedicated services, most navigation systems, including Google Maps, Apple Maps, Garmin, TomTom, Bing Maps, etc., currently support very limited trip planning and navigation for PwDs or the visually impaired. In any case, information on the accessibility of the built environment (incline, pavement, curb, etc.) is needed. Even though this area has been extensively researched and several technological solutions, including robotics, augmented reality, vibrotactile haptics, were conceptualized, very few of these systems provide real-time navigation assistance to wheelchair users, especially indoors.

Navigation systems strongly rely on quality maps with vast variety of attributes. Because classical maps do not provide appropriate basis, the use of crowdsourcing maps are suggested. Open Street Maps (hereinafter OSM) seem to be the most promising one although there is still an issue with reliability and completeness. For that purpose, several tools have been created to assess the quality of provided data

2 http://www.axsmap.com/
3 https://www.cap4access.eu/index.php?id=intro
4 https://route4u.org/
5 https://sidewalk-sea.cs.washington.edu/
6 http://www.route4all.eu/en/

[46].

Overall, the navigation for PwDs focus on specific aspects of a navigation service (map-matching, real-time routing, routing based on geo-crowdsourced data). An application that includes a base map of accessibility, trip planning, and real-time navigation could be a better approach. Existing solutions are based on broad user groups needs and do not offer personalized solutions and utilize limited or subjective criteria in routing solutions [19].

To address the needs of PwDs (independent mobility, enhanced quality of life, increased employment opportunities), a personalized solution that could safely guide users in a real-time environment in a timely manner is needed.

METHODOLOGY

Typically, the components of a personalized navigation system include a digital map database, a navigation system, and a routing system. Latter is the most important component in any navigation as it computes an optimal route from point A to B, given the user's preferences. For wheelchair navigation, routing requires a specific digital map database that represents the geometry and topology of the network segments together with added attributes. The most important parameters needed for attribution of the personalized wheelchair navigation are: width, length, slope, surface type, surface conditions, curb and traffic [20].

The pedestrian access guidelines define four critical sidewalk characteristics that need to be considered when planning wheelchair routes. The sidewalks should have at least 360° clearance width and not be blocked by obstacles (signs, traffic poles, etc.), sidewalk grade and cross-slope should not exceed 5 % and 3 %, respectively, to be safe for wheelchair users. Walking surface should be firm, stable and slip-resistant without cracks. Curb ramps should be provided at every intersection allowing access for wheelchair users between a sidewalk and a street [3]. Table 1 provides a summary of determined parameters and values that were set for the pedestrian network topology.

Table 1. A summary of parameters for topology of the pedestrian network

Parameters	Description	Attributes		
Width	Clearance width of a sidewalk	Yes (> 90 cm)	Limited (~ 90 cm)	No (< 90 cm)
Length	Geometric distance of a pedestrian path segment		Distance (m)	
Slope	The steepness or grade on the pedestrian path segment		Degree of slope (°)	
Surface type	Material of surface type	Paved	Cobblestone	Dirt
		Asphalt	Sett paving stones	Mud
		Concrete	Ground	Sand
		Paving stones	Gravel	Grass
Surface conditions	Cracks, uneven surfaces			
Curb	The edge of a raised path nearest the road	Raised (> 3 cm)	Flush (0 cm)	Yes
		Lowered (~ 3 cm)	Rolled	No
Traffic	Passage of people along path segments that depend on day and time	High	Low	None

For personalized routing, route preference quantification and route calculation is needed. The first determines a weight indicating user's preference for each segment. Weighted segments are then used in the route calculation, where an algorithm considers each segment's weight to determine an optimal route. Once each parameter is weighted, the impedance level score of each segment can be determined by aggregating the weighs of all parameters with their corresponding segment's attributes values. The impedance level score for each segment may vary for different users depending on their preferences. Higher impedance level scores indicate higher difficulty level while traveling along the segment [20].

The aim of the navigation system for wheelchair users is to provide real-time navigation functions with a position accuracy of 3 meters or even less, similar to pedestrian navigation [43]. In the navigation system, also map matching technique has to be carefully considered. While there are many map matching algorithms specifically designed for cars, primarely based on Dijkstra algorithm, some features could also be implemented for wheelchair routing, especially for traveling on a sidewalk. This calls for additional parameters (stairs, sidewalk slope, curb type, uneven surface, etc.). Namely each wheelchair user has different ability level and personal routing preferences thus personalized attributes present an essential parameter in creating a routing function [10].

Accessibility maps are one of the most critical data for wheelchair routing and navigation. For instance, Beale [7], Karimi [19] and Ponsard [32] all focused on the maps that provide obstacle data and routes that are difficult to overcome with wheelchairs. The quality of such maps would have a significant impact on the quality of the final service. Currently, OSM provide wheelchair users with one of the most comprehensive databases in terms of attributes required for wheelchair routing [26]. Most OSM routing services simply execute conventional graph-based finding algorithms with the data in the OSM database, while a possible solution open area routing could be to calculate a Euclidian straight line between point A and B, considering it would fail to provide a usable route in case of an obstacle (fences, natural barriers, etc.) intersecting the straight line. In open areas with no network constraints, the most commonly used routing services could fail to provide a practical solution for pedestrians and wheelchair users, despite the set algorithms for path finding in open areas [14]. In the proposed system the deployed method consists of two parts. The first part refers to data acquisition and feature extraction, while the second part relies on topology transformation, dynamic path filtering and weighting, and routing. To construct detailed navigation maps, we need to first digitize real world paths into accurate spatial polyline features and describe their purpose via attribution.

Additionally, features can be obtained from OSM, where they are digitized manually through crowd-sourcing or they can be extracted automatically from other spatial sources (LiDAR) with the use of user guided processes in the spatial software [12]. Point clouds can be acquired by using the LiDAR technology, from, which it is possible to model real world by constructing the digital terrain (DTM) and surface models (DSM).

Geometry features, such as path slope, width, and maximum height difference are extracted by combining polyline features and DTM data (heights). Next, a topology analysis and generation of graph features compatible for routing algorithm is performed by extracting vertices at line intersections and line features between intersection points with all attributes from the original features. The output consists of two feature layers compatible with pgRouting [31]: a) vertices, which are primarily intended for closest point search, and serve for starting and ending point of navigation; b) edges, that consist of path parts, which are linked to their vertices and attributes used for filtering and dynamic weighting in the later stage.

Routing is then performed via a set of advanced SQL queries on the database backend first by selecting the paths that match the given set of attributes (filtering), estimating the costs based on defined rules, and performing the actual routing by using the Dijkstra algorithm. Filtering steps and navigation rules for cost estimation are configurable and support a variety of scenarios that range from vehicle transportation to pedestrians and even specialized scenarios for PwDs.

USE CASE – CITY OF MARIBOR

This research work conceptualizes, designs and implements a mobile wheelchair navigation and support system for indoor and outdoor environment on the case of the city of Maribor (Slovenia).

The system is tailored to the needs and requirements of wheelchairs users, as it offers users detailed information about obstacles in the urban areas (e.g., sidewalk pavements, street inclines, shop entrances and public transportation) and helps wheelchair users to avoid them. With the built-in feedback system, all users are active producers of information, which can create new routing possibilities thus offering various target groups – people with limited mobility, elderly, etc. extended navigation and mobility options.

A taxonomy for wheelchair users is proposed to create a personalized navigation system (Table 2). It focuses on urban environment and different aspects of supporting pedestrian PwDs in moving in a controlled and safe way on a specific route. A special feature of this system is its suitability for indoor and outdoor navigation.

Table 2. A taxonomy of navigation support tasks for wheelchair users

	Navigation system tasks	
Outdoor environment mapping	Intersection identification	Identifies the location of road intersections (a point where two or more roads meet); it represents a critical safety POI for PwDs.
	Crosswalk identification	Identifies an optimal marked location, where PwDs can cross a road, e. g. zebra crosswalk.
	Pedestrian traffic light identification	Identifies the location and orientation of pedestrian traffic lights.
	Sidewalk identification	Identifies the existence and location of a sidewalk/pavement, where PwDs can walk safely.
	Public transportation identification	Defines the locations of public transportation stations and the line numbers.
Indoor environment mapping	Entrance identification	Identifies the main entrance of the building and the doors to indoor facilities, rooms, shops, etc.
	Elevator identification	Identifies the location of elevators and the floor level it reaches.
	Public restroom identification	Identifies the existence and location of restrooms with wheelchair access.
	Escalator identification	Identifies the location of escalators and floor level.
	Floor level identification	Identifies the floor level, where the user is located.
	Parking space identification	Identifies the location of wheelchair accessible parking spaces.
Journey planning	Localization	Identifies the initial start point of the journey, e. g. home.
	Route selection (pedestrian routing, public transportation routing)	Finds the best (optimal and safe) route to reach a specific destination.

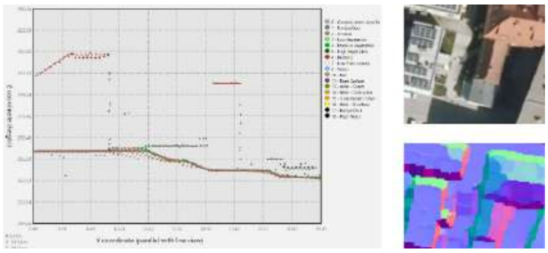
The main phases were identified, which encompass the indoor and outdoor navigation system area, from environmental planning, through journey planning added by real-time navigation later on. Each of these phases consists of task breakdown structures, whereas the tasks comprise the range of actions and challenges that wheelchair users need to overcome to get from an initial point to the selected destination safe and in a timely manner.

The indoor and outdoor environment mapping phase provides relevant location-specific information to support wheelchair users in journey planning. It defines the locations together with information of street elements (intersections, crossings, sidewalks, etc.) and building elements (doors, elevators, restrooms, etc.) Therefore, enriching available maps with essential information for journeys of wheelchair users. By gathering up-front data this processing phase underpins the remaining navigation phases. The journey planning is critical for building the confidence and knowledge to undertake a pedestrian journey to a new and unfamiliar route. This phase starts with determining the start location. Based on the user's destination the algorithm then selects the safe and optimal route, using the information from the indoor and outdoor environment mapping phase. Lastly, wheelchair users need support for challenges in real-time navigation including real-time environment understanding, street crossing, obstacle avoidance, and use of public transportation. This phase of the ION navigation system is still under development.

The mapping system was developed in Gemma Fusion Suite (hereinafter GFS), a desktop GIS application used for feature digitalization and map generation by incorporating vector features from known formats or databases, raster images consumed from local or remote data sources, and LiDAR sources. Based on the integrated OSM service, the mapping system was upgraded with data for the city of Maribor. The use of an existing collaborative, freely editable database for geospatial information about POIs, roads, and paths is important for any personalized navigation system. Input data needed for creation of a mapping system for wheelchair users are routes and corridors, which ensure access to buildings, inclines and slopes, types of surfaces, and (im)passable obstacles on a specific route. In GFS footways, crossing, steps, and sidewalk vector shapefiles were created, adding general attributes (name of the street with incline and surface type), accesibility atributes (stroller and wheelchair access, tactile paving, type of kurb and its height) and attributes referring to stairs (numbner of stairs and handrail).

Due to insufficient and unclear data from LiDAR, additional data had to be gathered manually. Figure 1 shows the case of LiDAR data for stairs at the "Ob bregu" street. From the LiDAR data it was impossible to determine the stairs' steepness and if they are accessible for PwDs. For automated data processing, the LiDAR data need to be more precise and accurate; otherwise, the automated process will be flawed, resulting in an inadequate mapping system.

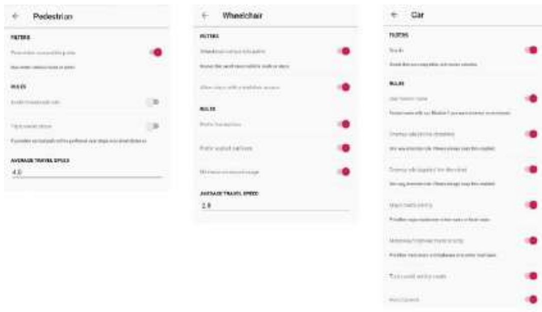
Figure 1. Data for stairs at the "Ob bregu" street obtained from LiDAR (left), aerial photo (top) and extracted normals (bottom)



Public infrastructure in Maribor is not in an optimal state and finding and optimal route while navigating the city is very challenging for wheelchair users. The proportion of wheelchair accessible crossroads in Maribor is around 80 %, while there is only 40 % of wheelchair accessible sidewalks due to lack of ramps, presence of barriers or damaged surfaces. A navigation system with a feedback service is a good solution for PwDs, as they can provide first-hand experience about optimal/usable routes, as well as on routes inaccessible to people with specific mobility impairment.

In the scope of the study, three test areas in the city of Maribor were defined, one being the Europark shopping centre, the second Municipality of Maribor building and the third an extended area of city centre. The test points were chosen on the fact that they present a challenging area for PwDs, e.g., lack of sidewalks, uneven surfaces, high slopes, wheelchair accessible ramps, etc. For these areas the navigation mapping system was upgraded and tested in a real-time environment. For testing purposes, an application ION (Indoor and Outdoor Navigation) was created, which provides and manages the map-based central user interface on the mobile client, displaying information about POIs, paths, streets, sidewalks, etc., with enriched accessibility information. The application can be downloaded to Android devices and requires an active data (Wi-Fi or mobile data) and Bluetooth connection. In the app, three user profiles are integrated that can be modified to one's personal needs: wheelchair user, pedestrian and car. For each user profile, specific rules and filters set by the user can be activated (e.g., stairs or crossroads avoidance, incline or surface preference (see Figure 2)).

Figure 2. Rules and filters for car, pedestrian, and wheelchair user in ION navigation



After setting the route preferences, the wheelchair users can navigate the city by clicking on the start and end location. Once the locations are defined, the system fully automatically displays the route without requiring any additional input. The navigation will consider the parameters set in the mapping system and guide a wheelchair user on a barrier-free, personalized, and optimized route. The navigation is not limited to streets as in standard navigation systems, as it also includes sidewalks, bicycle lanes, and pedestrian paths. It is adapted and optimized to the previously defined parameters for wheelchair users, such as max. curb height, min. path width, max. incline, etc. (Table 1). If an obstacle not identified in the mapping system is encountered, the user can provide the details on it through the feedback system. The obstacle is promptly integrated into the mapping system, providing the user with a new route to avoid the reported obstacle. The feedback system is equipped with a wide array of pre-determined obstacles, so the users can click on the most appropriate one. If encountered obstacle does not fit any pre-determined obstacles, the user can manually insert the obstacle into the system. The feedback system is modified to a user profile. For wheelchair users, it refers to physical obstacles, street crossings, path limitations, quality of the route and building entrance. To guarantee a high user acceptance rate, the application is designed as simple and user-friendly as possible.

A personalized user-group approach in GIS applications gives an advantage over standard navigation systems as it allows better coverage of the great demand for user-specific data, since each type of disability requires different information and recognizes obstacles individually. From an economic point of view this can be seen as a disadvantage though, since PwDs account for "only" 15 % of the world population [47]. However, real-time navigation providing accessibility information may benefit an array of users, e.g., elderly, temporarily disabled due to an injury or illness, parents with strollers, etc. Another advantage is that the new GIS technology can retrieve information through the internet so digital information can be updated more frequently and easily. However, real-time information rarely exists, and the availability, amount, and costs of targeted specific data are restricting factors. Since the amount and detailed data are crucial for PwDs, these aspects can also be defined as weaknesses. Another important aspect is the technology factor. With the complexity of applications and the need for additional and more assistive devices, only technology-affine persons would be able to use these types of applications. This aspect coincides with the cost factor as people with low income will not be available to afford them. Also, a new trend can be identified in the use of GIS for disability-related issues with the integration of participative tools to implement transdisciplinarity. This is important for GIS used on the expert level to monitor and improve such applications permanently. With the fast pace of new technological improvements, complex devices and new (crowd-sourced) data, these developments show a lack of accuracy and comprehensive availability, which is basically essential for PwDs. In order to provide reliable results, GIS-based systems have a significant demand for up-to-date and real-time information, which consequently causes high monitoring needs [49].

CONCLUSION

From an urban perspective, the environments tend to be designed to fit the needs of a fully active citizen, so the need to address the barriers for an array of citizens with various impairments is of paramount importance. As cities have hardly any recorded data on street and sidewalk pavements, curb boarder heights, sidewalk widths, street inclines, etc., there is an imperative need to address, locate and reduce barriers in cities to fit the smart and inclusive city demands. Open areas, where wheelchair users are moving, are usually not as well-regulated as the roads and streets in terms of activities that can be carried out in such areas, and this makes the environments more open to temporary changes and obstacles compromising the reliability of the planned routes.

The proposed solution can be used to identify issues and improve accessibility for wheelchair users. At the same time, it can also be used to test and visualize the potential effects of proposed changes to urban design areas. However, designing holistic digital tools to help design cities and digital tools for people is not an easy task. The diversity and complexity of the lives of PwDs need to be considered for the technology to efficiently penetrate the human and spatial dimensions and ease their lives in the urban areas.

As a part of future research, the inclusion of additional personalization parameters and types of accessibility information data, geo-crowdsourcing services, and integration with other technologies, like social networks and pedestrian navigation services that provide real-time guidance, is proposed. To update the GFS database automatically, a technique to filter the quality data from geo-crowdsourcing services will have to be developed, including a validation tool for the data quality. From this upgrade, an extended mobile navigation and support system for wheelchair and visually-impaired users, including more support features will be conceptualized, designed, implemented and possibly pushed to a stable product, ready for the worldwide market.

ACKNOWLEDGEMENTS

This research work was funded by the Republic of Slovenia, the Ministry of Education, Science and Sport and the European Union from the European Regional Development Fund.

REFERENCES

[1] Access City Award. (2021, March 12). Retrieved from https://ec.europa.eu/social/main.jsp?langId=en&catId=88&eventsId=1871&furtherEvents=yes#navItem-1%20 %20in.

[2] Ajmi, F. A.-B. (2019). An innovative system to assist the mobility of people with motor disabilities. IEEE International Conference on Systems, Man and Cybernetics (SMC). Bari.

[3] Albreht, A. K. (2010). Prostor za vse. Priročnik za načrtovanje brez ovir v zunanjem javnem prostoru. Maribor: Mestna občina Maribor.

[4] Bailey, M. C. (2007). Development of Vision-Based Navigation for a Robotic Wheelchair. IEEE 10th International Conference on Rehabilitation Robotics, (pp. 951-957).

[5] Baklouti E., A. N. (2016). Autonomous wheelchair navigation with real time obstacle detection using 3D sensor. Automatika 57 (3), 761-773.

[6] Basso, M. M. (2021). A Real-Time GNSS/PDR Navigation System for Mobile Devices. Remote Sens.

[7] Beale, L. F. (2013). Mapping for wheelchair users: Route navigation in urban spaces. The Cartographic Journal.

[8] Carlone, L. N. (2010). Rao-blackwellized particle filters multi robot SLAM with unknown initial correspondences and limited communication. IEEE International Conference on Robotics and Automation, (pp. 243-249).

[9] Devigne L., P. F. (2019). A shared control solution for safe assisted power wheelchair navigation in an environment consisting of negative obstacles: a proof of concept. IEEE International Conference on Systems, Man and

Cybernetics (SMC). Bari.

[10] Ding, D. P. (2007). Design considerations for a personalized wheelchair navigation system. Annual International Conference of the IEEE Engineering in Medicine and Biology Society.

[11] European Commission. (2021). Union of Equality: Strategy for the Rights of Persons with Disabilities 2021-2030. Luxembourg: Publications Office of the European Union.

[12] Hewett, M. (2019). Automating Feature Extraction with the ArcGIS Spatial Analyst Extension.

[13] Hine, J. S. (2000). Using Technology to Overcome the Tyranny of Space: Information Provision and Wayfinding. Urban Studies 37(10), 1757-1770.

[14] Hong, I. &. (2016). Assessing Raster GIS Approximation for Euclidean Shortest Path Routing. Transactions in GIS. 20(4), 570-584.

[15] Imamura, M. T. (2004). Outdoor waypoint navigation for an intelligent wheelchair using differential GPS and INS. SICE Annual Conference, (pp. 2193-2196).

[16] Jacobson, R. D. (1994). Navigation for the Visually Handicapped: Going Beyond Tactile Cartography. Swansea Geographer 31.

[17] Jingao, X. E. (2021). Smartphone-Based Indoor Visual Navigation with Leader-Follower Mode. ACM Transactions on Sensor Networks.

[18] Karimi, H. A. (2013). Pedestrian Navigation Services: Challenges and Current Trends. Geomatica 67 (4), 259-271.

[19] Karimi, H. A. (2014). Personalized accessibility map (PAM): A novel assisted wayfinding approach for people with disabilities. Annals of GIS. 20(2), 99-108.

[20] Kasemsuppakorn, P. &. (2008). Data requirements and a spatial database for personalized wheelchair navigation. The 2nd International Convention on Rehabilitation Engineering & Assistive Technology. Bangkok.

[21] Kurihara, M. N. (2004). Use of highly accurate GPS in network-based barrier-free street map creation system. IEEE International Conference on Systems, Man and Cybernetics, (pp. 1169-1173).

[22] Levine, S. P. (1999). The Navchair Assistive Wheelchair Navigation System. EEE Transactions on Rehabilitation Engineering: A Publication of the IEEE Engineering in Medicine and Biology Society. 7(4), 443-451.

[23] Matthews, H. B. (2003). Modelling Access with GIS in Urban Systems (Magus): Capturing the Experiences of Wheelchair Users. Area 35(1).

[24] Mehigan, T. J. (2012). Harnessing Wireless Technologies for Campus Navigation by Blind Students and Visitors. ICCHP 2012, (pp. 67-74). Linz.

[25] Menkens, C. S.-A. (2011). EasyWheel - A Mobile Social Navigation and Support System for Wheelchair Users. Information Technology: New Generations (ITNG), (pp. 859-866).

[26] Mobasheri, A. (2017). A rule-based spatial reasoning approach for OpenStreetMap data quality enrichment; case study of routing and navigation. Sensors. 17(11).

[27] Mongus, D. L. (2014). Ground and building extraction from LiDAR data based on differential morphological profiles and locally fitted surfaces. ISPRS Journal of Photogrammetry and Remote Sensing. Vol. 93, 145-156.

[28] Najafi, M. N. (2019). An adaptive distributed approach for the real-time vision-based navigation system. Measurement. Vol. 145, 14-21.

[29] Palazzi, C. E. (2010). Path 2.0: A Participatory System for the Generation of Accessible Routes. IEEE Multimedia and Expo (ICME), (pp. 1707-1711). Singapore.

[30] Petrie, H. J. (1997). Mobic: An Aid to Increase the Independent Mobility of Blind Travellers. British Journal of Visual Impairment 15.

[31] pgRouting. (2021, August 12). Retrieved from https://pgrouting.org/: https://pgrouting.org/

[32] Ponsard, C. E. (2016). A Mobile Travel Companion Based on Open Accessibility Data. International Conference on Computers Helping People with Special Needs (pp. 245-252). Springer International Publishing.

[33] Rebernik, N. M. (2019). A 4-dimensional model and combined methodological approach to inclusive Urban planning and design for ALL. Sustainable Cities and Society. Vol. 44, 195-214.

[34] Rebernik, N. O. (2017). A Vision of a Smart City Addressing the Needs of Disabled Citizens. Accessibility 4.0. Malaga.

[35] Ren, M. &. (2009a). A Chain-Code-Based Map Matching Algorithm for Wheelchair Navigation. Transactions in GIS. 13(2), 197-214.

[36] Ren, M. &. (2009b). A Hidden Markov Model Based Map-Matching Algorithm for Wheelchair Navigation. The Journal of Navigation. 62(3), 383-395.

[37] Ren, M. &. (2012a). A Fuzzy Logic Map Matching for Wheelchair Navigation. GPS Solutions. 16(3), 273-282.

[38] Ren, M. &. (2012b). Movement Pattern Recognition Assisted Map Matching for Pedestrian/Wheelchair Navigation. The Journal of Navigation. 65(4), 617-633.

[39] Roongpiboonsopit, D. (2011). Navigation Recommender: Real-Time iGNSS QoS Prediction for Navigation Services. University of Pittsburgh.

[40] Salhi, K. K. (2015). Trajectory Planning in Dynamic Environment Based on

Partially Map Updating Using Multi-robot System for an Intelligent Wheelchair. IEEE International Conference on Systems, Man, and Cybernetics, (pp. 737-742).

[41] Sobek, A. D. (2006). U-Access: A web-based system for routing pedestrians of differing abilities. Journal of Geographical Systems. Vol. 8, 269-287.

[42] Tee, Z. H. (2009). Smartguide System to Assist Visually Impaired People in a University Environment. i-CREATe 2009. Singapore.

[43] Usui, S. (2005). Evaluation of Positioning Accuracy for the Pedestrian Navigation System. IEICE Transactions on Communications, (pp. 2848-2855).

[44] Velázquez, R. P.-E. (2018). An Outdoor Navigation System for Blind Pedestrians Using GPS and Tactile-Foot Feedback. Applied Sciences. 8.

[45] Wan, X. G. (2019). Mobile Crowdsourcing for Intelligent Transportation Systems: Real-Time Navigation in Urban Areas. IEEE Access.

[46] Wheeler, B. S. (2020). Personalized accessible wayfinding for people with disabilities through standards and open geospatial platforms in smart cities. Open Geospatial Data, Software and Standards.

[47] WHO. (2020). Retrieved from https://www.who.int/news-room/fact-sheets/detail/disability-and-health.

[48] Wu, Y. H.-Y. (2005). The development of M3S-Based GPS NavChair and tele-monitor system. IEEE Engineering in Medicine and Biology 27th Annual Conference, (pp. 4052-4055).

[49] Zimmermann-Janschitz, S. (2018). Geographic information systems in the context of disabilities.Journal of Accessibility and Design for All. Vol. 8(2).

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Adaptation of European Railways to the Digital Economy in the Era of Energy and Climate Transformation

BARTOSZ GRUCZA, WOJCIECH PAPROCKI

Abstract European railways are the complex system. According to the First Rail Directive 1991/440/CEE all state railway entities should be divided ("debundling") into two segments: infrastructure management and rail operators (both in passenger and cargo traffic). This decision caused the European railways to lose the features of an open system, gradually losing the ability to interact and communicate with the environment and falling into entropy. Digital transformation models focus on vertical integration and horizontal integration of an organization. To meet these requirements the proposed solution for European railways is to delegate the competences of passenger rail management (infrastructure, rolling stock and human resources) at the level of regional governments or at the level of agglomeration authorities (city or association of cities); to create of a vertically integrated European high-speed rail company with a separate network of high-speed lines, rolling stock and staff; to create of a European vertically integrated railway company with network infrastructure, rolling stock and human resources specialized in freight.

Keywords: • European Railways • Transformation • Digital Economy • Systems Approach • Vertical Integration

CORRESPONDENCE ADDRESS: Bartosz Grucza, PhD, Wojciech Paprocki, PhD, SGH Warsaw School of Economics, al. Niepodległości 162, 02-554 Warsaw, Poland, e-mail: bgrucz@sgh.waw.pl, e-mail: wpapro@sgh.waw.pl

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

European railways are the specific example of the system. In the description of their functioning, one can use the terms that were defined in the so-called systems theory. The current situation of railways is special because of political, environmental, economic and social conditions. This is because of the huge discrepancy between the description of the desired state of this mode of transport, presented in the documents relating to the European (EU) transport policy, and the actual state of affairs.

The basic research question is: how the railway in Europe should be shaped so that its functioning has the features desired by all stakeholders. The first stage of considerations is the presentation of systems theory and the formulation of a proposal on how to conduct a critical assessment of the methods and tools of rail management in the period from 1991 to 2019, considering the need to find management methods and tools that should be used in the third decade of the 21st century, i.e., in the period of expansion of the digital economy in the conditions of energy and climate transformation.

In 1991, Directive 91/440 EEC was published [1], which was the foundation of structural changes in rail transport in Western Europe (excluding Switzerland). In 2019, which closed the epoch of functioning of the global socio-economic system in the conditions before the COVID-19 pandemic, rail transport, as part of two sectors of the economy: mobility and logistics, reached the state of entropy (deep instability). Restrictions on the mobility of societies and trade in goods observed since the beginning of 2020 have become a factor revealing the features of this instability. Interventions by regulators and owners (investors) of entities that act as infrastructure managers and as railway operators (passenger and freight) in the past months (03'20 to 08'21) show a complete lack of agency. Railways in Western and Central Europe, i.e., in the EU-27 and Switzerland, do not show the ability to adapt to the changing conditions of the mobility and logistics sectors, nor to take part in the development of the digital economy.

The second stage of considerations concerns the proposals for changes in the functioning of the railways in the coming decades. When defining these proposals, it is considered that changes in the rail transport network infrastructure require the implementation of projects, the preparation and implementation of, which as an investment project may take from at least a few, or rather ten years, to two or three decades. This means that the noticeable changes in the functioning of railways in Europe can not be achieved earlier than the middle of the 21st century, assuming that the relevant decisions are taken before 2025.

Railways as a system

Increase in the complexity of the studied objects, both natural and artificial, meant that scientific methods based on the principle of causation, deductive inference and reductionism did no longer describe, and explain, properties and behavior of complex structures comprising elements related to interdependence [2]. The breakthrough achievements leading to the emergence of new science paradigms, allowing to bypass these limitations, were Max Planck's quantum theory, Werner Heisenberg's uncertainty principle and Niels Bohr's principle of complementarity. The principal representative of the new trend was Ludwik von Bertalanffy, considered being the founder of systems theory, who first presented his concept in a universal approach in the journal Science in 1950, writing, inter alia,[3]:

The properties and modus operandi at higher levels of the organization are not explainable by summing up the characteristics and modus operandi of their components when tested separately. However, when we know the set of constituent parts and the relationships between them, the higher levels of the organization can be explained by their constituents.

Another pillar that built the new scientific paradigm, known as the systemic paradigm, was cybernetics. In the second half of the twentieth century, a new meta-discipline of systems science emerged, based on holism, synthesis, and reduction and inductive reasoning. Systems science has a new view of the world, relies on a quest to understand the man and his environment as mutually interacting elements of a single system, taken from multiple perspectives and in different ways, always as a whole. Based on systems sciences, various specific theories of systems and a general theory of systems have developed, which is to fulfill the role of a universal language combining various areas of interdisciplinary communication into a single whole. In systems science, a new scientific paradigm has emerged, known as holism, or the systems approach. The systems approach is looking at the whole, through the role and function of parts considering cause-and-effect relationships (often implicit, non-linear and distant in time). They are characterized by a switch:

- from the emphasis on the components of the system to focusing the central attention on the whole,
- from static to dynamic and process structure,
- from linear chain metaphor to network metaphor,
- from striving to get full knowledge about the tested object to its approximate description.

The basis of the systems approach is thinking in terms of systems[4], based primarily on a synthetic research procedure, which can be simplified to the following three stages:

- the identification of the entire system comprising analyzed elements (e.g., subsystems),
- evaluation and description of the properties of the system and its dynamic behavior,
- determining the properties of individual system elements and their behavior over time, considering the impact of these elements on performing the functions of the entire system.

The systems approach has gained particular importance, especially in recent years, because of the increasing number of so-called large-scale problems. These are problems in both military and civilian systems, in terms of production and services, viewed from different perspectives: technical, economic, social, environmental and political. The reasons for these problems are complex interactions between elements and states of the system and unpredictable changes in the environment caused by forces of nature or deliberate terrorist or criminal activity.

Effects of rail disintegration - loss of the open system attribute

Organic systems at the level of a cell, a complex organism and a population of organisms exist based on a constant exchange with their environment. This exchange is critical to sustaining life and the form of the system, since interaction with the environment is essential for its maintenance. Often, Therefore, it is said that living systems are "open systems", subject to a continuous cycle of: using inputs, their internal and total transformation, preparing the product and feedback (through, which one element affects the next one). The concept of openness emphasizes the fundamental importance of the mutual dependencies between the environment and the internal functioning of the system. The environment and the system should, Therefore, be perceived as being in a state of interaction and mutual dependence. The opposite of the open nature of biological and social systems is the "closed" nature of many physical and mechanical systems, however, openness may vary as some open systems may only respond to a relatively narrow range of contributions from the environment [5].

The system environment comprises those elements that are not part of it, and are related to it, i.e., they affect the state of the system or the system affects them. This influence occurs through the system inputs and outputs. Inputs are all ways of influencing the system, and outputs are all ways of influencing the environment by the system. An open system has inputs and outputs. Closed systems are isolated from the environment, do not affect them, and their elements are only influenced by other elements of the same system. Inputs and outputs that are used to transmit matter or energy are called supply ones, and those that are used to transmit information are called informational. Inside the system, between the inputs and outputs, there are processes of matter, energy and information transformation, called transformation processes. The behavior of system can Therefore, be considered in the sequence: input - transformation - output.

European railways, because of conscious actions of the regulator, focused rather on the pseudo "internal" competition between fragmented entities created based on previously integrated enterprises covering the entire value chain, ceasing to pay attention to the changing needs of the environment, customers and the expected higher standards of handling the mobility of goods and people.

Entropy of European railways

The measure of disorder is entropy, which refers to the European railways, not being able to compete with air and road carriers. Open systems - thanks to the fact that they draw matter, energy and information from the environment - can not only counteract entropy and maintain the state of internal order, but can also increase this state, i.e., to achieve negative entropy. Those being able to maintain order are called organized systems; those that have the ability to lift it are called self-organizing systems. Open systems are capable of maintaining a state of equilibrium despite disturbances caused by external and internal changes. This state of equilibrium is maintained by a process known as homeostasis. The concept of feedback is related to the process of homeostasis. It consists in the fact that at the system input there are information not only about the state of the environment, but also about the state of its outputs. In case of European railways this mechanism needs to be rebuilt. The effectiveness of both passive (homeostasis) and active (expansion and development) adaptation processes is a prerequisite for the survival of an organization in the environment. In addition to the ability to adapt and self-organize, open systems also have the ability to achieve a specific ultimate state under different initial conditions (equifinality), e.g., distinct possibilities and limitations of action due to local and regional specificity.

It seems that the only chance for railways to restore its features of open system is to use the opportunities posed by the digital economy and standards of Industry 4.0. The need for a complex change of technological transformation, process and organization shall be linked to the change of business model and value chain integration across the entire product lifecycle. The key condition for this successful transformation is the advanced use of digital solutions and data resources. Its goal is to mass personalization of service provision in response to the individual needs of customers [6].

There are more and more models describing the digital transformation process from the perspective of the affected entity. They are most often based on three pillars: processes, technology and organization. An example of such a model can be the SIRI concept (The Singapore Smart Industry Readiness Index).

Figure 1. SIRI model

Source: The Singapore Smart Industry Readiness Index. Catalysing the transformation of manufacturing , Economic Development Board, Singapore, 2017.

The key components of process layer of this model supporting transformation are the vertical integration and horizontal integration, and these are far more difficult in the current decentralized model of operation of the railway. As Peter Senge wrote in his bestseller "The Fifth Discipline":

"Sometimes it happens that people still split an elephant in half. Unfortunately, instead of two small elephants, they get a terrible mess. I mean a very complicated problem in relation to, which the principle of leverage cannot be applied, because its secret lies in interactions that are imperceptible to an observer who focuses only on one component of the entire system" [7].

It is impossible to meet better the needs of rail customers and lead them along the road to the digital economy without restoring integrated functionality to railways.

Initial proposals for changes in the rail system in Europe

In Europe, planning the development of the socio-economic system is becoming more and more important. It takes place at the expense of limiting the freedom of action of economic entities, both from the public and private sectors. In the centralization process of decision making by the authorities of the EU one can observe occurrence of immanent practice to deform the originally defined objectives and means of achieving them. This results from the disclosure of permanent, overt or latent obstruction by public authorities at the level of government administration of individual European countries or from the public authorities at the regional level. The process of institutional transformation is underway within the system that is commonly referred to as the "European Community". If the authorities of individual countries play the role of the "administrator" of the national rail network infrastructure in the next decades, the railway will be deprived of the possibility of vertical "re-integration". Therefore, the possibility of creating one vertically integrated railway company in Europe, i.e., managing infrastructure, rolling stock and human resources, will be blocked. The railways will Therefore, not be able, in an institutional form, to integrate the management processes of critical resources.

Introducing Directive 91/440 / EEC was based on the belief that by selecting infrastructure managers in the rail system, it would be possible to integrate management processes in a transaction form. Network infrastructure managers (monopolists on the scale of each member state) would provide access services (including traffic control) to the network infrastructure to all railway operators on a non-discriminatory basis. The experience of the past thirty years shows that the transactional relations between infrastructure managers and operators are not satisfactory for the operators, and consequently the operators do not have an effective influence on operational processes. This is the reason that passenger and freight operators can not prepare a range of services corresponding to the needs of its clients - the passengers and shippers. The lack of punctuality in running trains and the inability to guarantee the delivery date of shipments are two disadvantages of railways, the permanent presence of, which drastically reduces the attractiveness of rail services for customers.

If the railroad were to become an "open system" - one capable of responding to external signals, it would be reasonable to consider implementing a project in Europe that would expect radical changes in this mode of transport. The key features of this change would be:

1. Delegating the competences of passenger rail management (infrastructure, rolling stock and human resources) at the level of regional governments or at the level of agglomeration authorities (city or association of cities).
2. Creation of a vertically integrated European high-speed rail company with a separate network of high-speed lines, rolling stock and staff.
3. Creation of an European vertically integrated railway company with network infrastructure, rolling stock and human resources specialized in freight.

In the digital economy, the conditions are created to efficiently and effectively manage resources in these railway companies (point 2 and point 3), as well as to bring about a functional integration between regional railway companies and other passenger transport systems within the agglomeration.

There is a gap in this proposal for interregional passenger services. Considering that in the perspective of 2050, emission-free road vehicles (cars and buses) and airplanes may appear in transport, it is worth considering whether there is a need to maintain the existing railway network, built in the 19th century, outdated and in need of modernisation, in order to continue interregional rail services, which will continue to operate at commercial speeds between 40-60 km/h.

REFERENCES

[1] Council Directive 91/440 / EEC of 29 July 1991 on the development of the Community's railways, https://eur-lex.europa.eu/eli/dir/1991/440/oj (accessed on 02/09/2021).

[2] L. Bukowski, The place of logistics in applied sciences, Scientific journals of the Silesian University of Technology, Series: Organisation and Management, 193/2017.

[3] L. von Bertalanffy, General system theory. "Main Currents in Modern Thought", No. 71 (75), 1955.

[4] G. Weinberg, An introduction to general systems thinking, Wiley, New York 1975.

[5] G. Morgan, Images of organization, Polish Scientific Publishers PWN, Warsaw 1999, p. 48.

[6] K. Śledziewska, R. Włoch, Digital Economy. As new technologies are changing the world, Warsaw University Press, Warsaw 2020, p. 133.

[7] P.M. Senge, The Fifth Discipline, Oficyna Wolters Kluwer Business, Warsaw 2012, p. 8.

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Saturation Flow at Nested Signalized Intersection: A Case Study in Niğde

HATICE GÖÇMEN DEMIR, YUSUF KAĞAN DEMIR, CANSU ZORLU

Abstract Saturation Flow is a main variable of capacity, green time, and cycle time at signalized intersections. Also, Saturation Flow is an important meter for determining the performance of traffic flow, as well as evaluation of planning, design, and operation in addition to application of them. Saturation Flow, which can be calculated by using empirical and theoretical relations, is affected by many parameters, such as road and traffic conditions, driver behaviors and environmental factors, which are also sensitive. In this study, saturation flow was calculated by discharge headway, which are observed indirectly for each lane at the nested signalized intersection. The total width of the intersection at, which the study was conducted is 40 meters, and it has a circular island having 16 meters in diameter. The intersection is a nested controlled intersection because secondary signaling is set up in the island in addition to regular-primary intersection signalization. Hence, the vehicles are queuing around the island and spilling over the middle and right lanes. Statistical analysis was performed, and headways distributions were modeled. Mean headways were estimated from the best distributions and the effect of the obtained saturation flows on the traffic flow performance was evaluated with the SIDRA. It has been observed that there are meaningful differences right, middle and left lanes in the Bor-Niğde approach. The fact that the initial loss time is higher in the middle lane, the queue length is higher in the left lane revealing the characteristic feature of nested signalized intersection, which affects the saturation flow. The results obtained show that it is necessary to carry out studies in terms of planning and operation to increase the performance of the intersection.

Keywords: • Saturation Flow • Nested Signalized Intersection • Probability Modelling

---

CORRESPONDENCE ADDRESS: Hatice Göçmen Demir, Asst. Prof., Nigde Omer Halisdemir University, Nigde, Turkey, e-mail: hgocmen@gmail.com, Yusuf Kağan Demir, Asst. Prof., e-mail: ykdemir@gmail.com, Cansu Zorlu, M.S. Std., e-mail: cansuzorlu@gmail.com

 ISBN 978-961-95633-0-4

INTRODUCTION

Saturation flow is a macro variable in determining the performance of traffic flow at signalized intersections [1]. The graphical representation of this traditional definition of Webster and Cobbe [2] stating that the saturation flow value is obtained when there is a fixed vehicle queue and 100 % green time (Figure 1). This graph represents the flow of traffic at a constant value (saturation flow value) until the queue is empty, a few seconds after the start of the green period. Different definitions have been made for the saturation flow over time. In HCM 2010 [3], Saturation Flow is defined as the number of vehicles that can pass in one hour at a signalized intersection if the green time for a given lane is constantly on. ARRB Report 123 [4] defined the saturation flow as the maximum constant departure from the tail of the vehicles during the green period. In HCM [3], 1900 vehicle/hour/lane is predicted, which is an ideal value for saturation flow. The rectangular line in Figure 1 also shows the ideal state of the saturation flow value in an approach at a signalized intersection [5]. In Figure 1, the horizontal axis indicates the durations of the phase in that approach, and the vertical axis reveals the mobility of the vehicles at the intersection at the relevant times. As can be seen, while the vehicles are waiting at the red light, they move when the light turns green. The first vehicles at the beginning of the queue experience a delay until the signal changes and they start moving. This time due to the delay is called the initial loss time. Then the difference between the discharge headway of the vehicles decreases and the flow becomes homogeneous after a while. This section, where the flow is homogeneous, shows the saturation flow [6]. The saturation flow may start between the third and sixth vehicle in the queue [5].

The following formula is used for the average saturation headway:

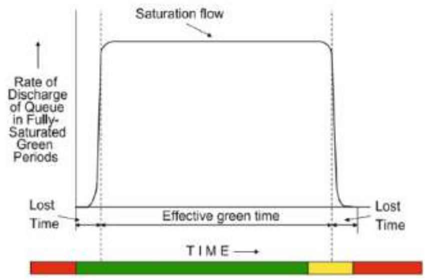
$$\overline{hs} = \frac{1}{n}\sum_{i=1}^{n} h_{si} \qquad (1)$$

As a result, the saturation flow value is calculated as shown below:

Table 1. Descriptive statistics of headways (seconds)

Lane	Sample Size	Mean	Std.	Min.	25 %	50 %	75 %	Max.
Left	288	2,420	0,934	1,0	2,0	2,0	3,0	6,0
Middle	252	2,238	0,965	1,0	2,0	2,0	3,0	6,0
Right	148	2,527	0,965	1,0	2,0	3,0	3,0	5,0
All	688	2,376	0,957	1	2	2	3	6

Figure 1. Saturation Flow Diagram [6]

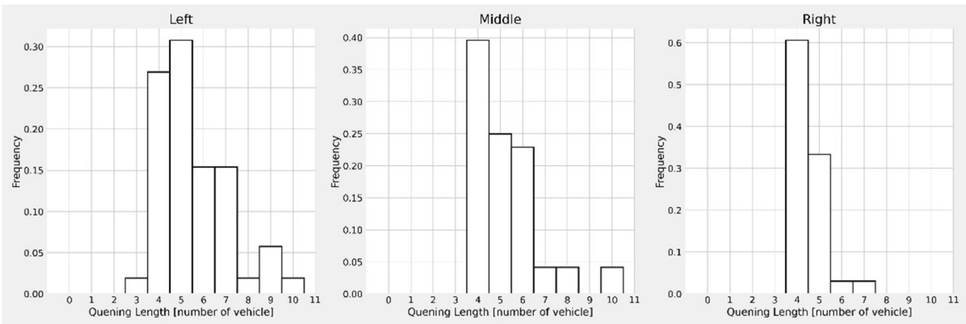


$$S = \frac{3600}{hs} \tag{2}$$

Studies show that the saturation flow changes under non-ideal conditions, which is affected by many parameters, such as traffic, road, environmental conditions, and human behavior. Saturation flow varies for each intersection or even for each approach. In this respect, Çetin and Murat [6] stated that determining true value of saturation flow is difficult.

When the studies on saturation flow are examined, there are correlations between saturation flow and the factors (road, traffic, and geometric conditions) that can affect the saturation flow. These models are derived empirically, linear, or multiple regression models.

Figure 2. Frequency of queuing length



Correlations have been developed between saturation flow, depending on factors, such as lane width [2], environment type and lane width (ARRB Road research center), number of lanes, speed limit and slope [5], turning radius of left turning lane [7]. In many studies, the regression was used to find this effect. The models give successful results in simple traffic scenarios where several factors are effective. In many studies conducted today, the amount of traffic and the width of the intersection approach are considered. The fit of regression models and the prediction of saturation flow in complex traffic conditions are not successful [8]. In the method of finding the saturation flow with correction factors, the saturation flow in ideal conditions, which is defined as the base saturation flow value, is calculated by reflecting the effect of some correction factors. Similar equation was suggested in the German Highways Capacity Manual [9], and it was seen that the saturation flow was calculated using two dominant variables among many variables affecting the saturation flow.

The aim of this study determined the Saturation Flow at nested signalized intersection. The signalized intersection located on Atatürk Boulevard, in Niğde, which is controlled by a fixed time signalized system that a second signal control is applied around central island was preferred. The saturation flow was determined in the approach in the direction of Bor-Niğde, and the effect of the characteristic features of the intersection on the saturation flow was revealed. In determining the Saturation flow, discharge headway based on the observation of vehicles in the field were used.

STUDY AREA

In order to find the saturation flow according to discharge headway, it is necessary to obtain the interval values of the vehicles in terms of time in the lanes of the approach of the study area Junction. In order to obtain these values, indirect observations were made from the video footage taken between 16.20-17.20 on 05.03.2019 Tuesday, 16.00-17.00 on 09.05.2019 Thursday, and 16.55-18.20 on 02.10.2019 Wednesday. The main reason for making the video footage between these hours is that the traffic was observed at certain intervals before, it was determined that it was the busiest time.

Table 2. Probability distributions for left lane

Dağılım	Alpha	Beta	Gamma	Mu	Sigma	Lambda	AIC_c	BIC
Gamma_2P	0,37	6,47					761,65	768,93
Loglogistic_2P	2,30	4,35					774,08	781,36
Lognormal_2P				0,80	0,41		774,46	781,74
Normal_2P				2,42	0,93		780,79	788,07
Exponential_2P			1,00			0,70	782,48	789,77
Gumbel_2P				2,91	1,09		888,23	895,51
Loglogistic_3P	0,92	0,71	1,00				890,80	901,70

Table 3. Probability distributions for middle lane

Dağılım	Alpha	Beta	Gamma	Mu	Sigma	Lambda	AIC_c	BIC
Loglogistic_3P	0,45	0,49	1,00				531,67	542,16
Exponential_2P			1,00			0,81	616,10	623,11
Gamma_2P	0,41	5,45					665,66	672,67
Lognormal_2P				0,71	0,45		669,67	676,68
Loglogistic_2P	2,09	3,91					678,35	685,37
Normal_2P				2,24	0,96		700,21	707,22
Gumbel_2P				2,76	1,17		809,12	816,13

Table 4. Probability distributions for right lane

Dağılım	Alpha	Beta	Gamma	Mu	Sigma	Lambda	AIC_c	BIC
Normal_2P				2,53	0,96		412,54	418,45
Gamma_2P	0,42	6,02					415,69	421,61
Exponential_2P			1,00			0,65	425,58	431,49
Lognormal_2P				0,84	0,44		427,64	433,56
Loglogistic_2P	2,42	4,06					429,62	435,54
Gumbel_2P				3,01	0,97		439,56	445,47
Loglogistic_3P	0,92	0,65	1,00				468,86	477,69

Table 5. Probability distributions for right lane

Dağılım	Alpha	Beta	Gamma	Mu	Sigma	Lambda	AIC_c	BIC
Exponential_2P			1,00			0,73	1820,66	1829,71
Gamma_2P	0,40	5,89					1846,19	1855,24
Lognormal_2P				0,78	0,43		1875,67	1884,72
Loglogistic_2P	2,24	4,08					1888,53	1897,58
Normal_2P				2,38	0,96		1895,34	1904,39
Loglogistic_3P	0,73	0,59	1,00				1905,18	1918,74
Gumbel_2P				2,88	1,10		2137,56	2146,61

In the examination, the descriptive statistics of the discharge headway (hi) in terms of time (according to the composition of the lanes) of all vehicles waiting in the queue on the approach (Figure 2), after they started to move at the green time. The longest queuing observed on approach was in the left and middle lane with 10 vehicles.

Vehicle headway is a microscopic variable that defines traffic flow. In smart vehicle and simulation studies, modeling of the distribution of vehicle headway is used. The average value (h) of the headways, which determines the performance of the simulation models, is equal to the inverse of the traffic flow value (q) (q=1/h). Headway models that reflect the impact of traffic are also a useful tool for analyzing road capacity and evaluating the effectiveness of traffic management strategies being implemented. Headway models are also used to distribute delays and generate appropriate strategies. All these indicate that gap models are the main research area in many traffic flow theory and vehicle simulation [10], [11].

Table 6. Saturation flows estimated from probability distributions

		Mean	**S.D.**	**Median**	**%95 Confidence Limits**		**Saturation Flow**
Lane	Chosen Distribution	S	S	S	Left (s)	Right (s)	veh/h
Left	Gamma_2P	2,420	0,951	2,297	1,095	4,167	1488
Middle	Exponential_2P	2,238	1,239	1,858	1,063	4,711	1609
Right	Normal_2P	2,527	0,962	2,527	0,945	4,109	1425
All	Exponential_2P	2,376	1,377	1,954	1,070	5,125	1515

Distribution fit tests were carried out in order to find the distribution that fits the vehicle headway in terms of time. Phyton software was used for distribution fit tests [12]. The maximum likelihood method was used to test the probability distribution that the discharge headway fit. Parameters are estimated for normal, gamma, exponential, lognormal and general extreme distributions (Table 2, 3,4,5).

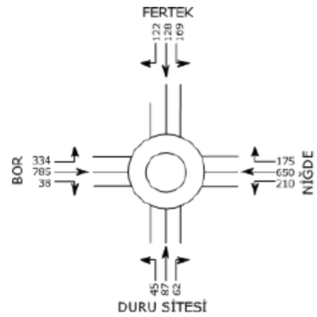
The success of the fit of the distribution was made according to the AIC and BIC criteria.

Considering the AIC'c and BIC criteria for lane discharge headway distributions according to the tables, Gamma for the left lane, three-parameter log logistic for the middle lane, Normal for the right lane, and two-parameter Exponential distribution for all lanes are considered suitable distributions.

The mean, standard deviation, and median values for the lanes according to the distribution parameters and the saturation flow values calculated accordingly are shown in the Table 6.

The SIDRA simulation program was used to see the effect of the saturation flow, obtained by the saturation headway, under actual demands (Figure 3).

Figure 3. Demands in the intersection



The following sequence is followed to model the traffic flow in the SIDRA program:

- Introducing the intersection geometry to the computer program (information, such as the number of intersection approach, lanes, flow directions and numbering of flow directions)
- Entering traffic data into the program (Entering traffic flow rates, Peak Hour Factor, approach and intersection speeds for each stream)
- Entering the phase plan and signal times of the intersection into the program.

Following strategies were applied to measure saturation flow value on the intersection and the common performance variables, to measure performance results, are listed in Table 7.

Table 7. Performance of the intersection

Performance Variables	Saturation Flows (pcu/h)			
	I	II	III	IV
	1900	1800	(1488,1601,1425)	1515
Travelling speed (Average) km/h	31,3	32,4	22,9	23,2
Travelling time (Total) veh-h/h	82	79,1	111,9	110,8
Saturation degree	0,989	0,974	1,263	1,240
Effective intersection capacity (taş./sa)	3353	3403	2626	2674
Control delay (Total) veh-h/h	39,19	36,46	66,02	64,85
Control delay (Average) sec	42,6	39,6	71,7	70,4
Intersection level of service	LOS D	LOS D	LOS E	LOS E
95 % Que length - (Worst Lane) veh	25,8	27,4	38,5	37,2
Fuel consumption (Total) L/h	288,8	278	328,5	326,9
CO_2 (Total) kg/h	678,6	653	771,9	768,3
HC(Total) kg/h	0,067	0,064	0,079	0,078
CO (Total) kg/h	0,821	0,803	0,871	0,868
NOx (Total) kg/h	0,223	0,211	0.238	0.238

I – The default saturation flow rate, the value of 1900 (psu/h) recommended by TRB for all lanes has been entered into the program.

II – Saturation flow was calculated from median of all lane's discharge headways.

III – After probability distributions had been estimated for each lane discharge headways, mean of each distribution were used to calculate saturation flow.

IV – After probability distribution had been estimated for all lane discharge headways, mean of the distribution were used to calculate saturation flow.

CONCLUSION

Observed vehicle discharge headways were evaluated by statistical tests. First of all, the mean and medians of vehicle discharge headways for each lane were investigated. The average values of vehicle following discharge headways are 2,42 seconds in the left lane, 2,238 seconds in the middle lane, and 2,527 seconds in the right lane. medians are calculated as 2.0 seconds in the "left" and "middle" lane and 3.0 seconds in the right lane

In the study area, a second control is currently applied around the roundabout, independent of the intersection cycle time, and this causes a vehicle queue around the roundabout. The longest queue was formed in the left lane of the approach arm (with 10 vehicles).

The distribution of discharge headways is necessary to simulate traffic. The parameters of the probability distributions (Table 2, 3, 4, 5), which are frequently used in the study, were estimated using the observation data. AICc and BIC criteria were used to select the most suitable model. The distribution with the lowest AICc for each lane was accepted as the optimal distribution for that lane. However, although the AICc value is small for the middle lane, the exponential distribution was chosen for this lane, since the Beta parameter was less than one.

Using the estimated scale and shape parameters, the mean headways was found to be 2,42 seconds for the left lane, 2,24 seconds for the middle lane, and 2,52 seconds for the right lane. In the modeling using all lane data, the optimal probability distribution was found to be an exponential distribution. According to this distribution, the headway is 2,38 seconds for all lanes. For all lanes, the lowest headway that can be observed in the 95 % confidence headway was 1,07 seconds, while the highest interval was calculated as 5,13 seconds.

The traffic performance value from the simulation program reflects the importance of choosing the right saturation flow value from the area, which points to the importance of planning, design, and operation studies.

As a continuation of the study, it is aimed to reach the saturation flow value and intersection performance information at nested/regular signalized intersections in Niğde province and compare saturation flows between them by increasing the number of observation points and data.

REFERENCES

[1] J. Turner and G. Harahap, "Simplified saturation flow data collection methods," 1993.

[2] B. Webster, F.V. and Cobbe, "Traffic Signals," Road Research Technical Papers., 1996. https://www.scirp.org/(S(i43dyn45teexjx455qlt3d2q))/reference/ReferencesPapers.aspx?ReferenceID=1962597 (accessed Mar. 08, 2021).

[3] HCM, Highway capacity manual 2000. Washington, D.C.: Transportation Research Board of the National Academies, 2000.

[4] R. Akcelik, Traffic signals: capacity and timing analysis. Verrmont South: ARRB Transport Research, 1998.

[5] M. W. L. Bester C. J., "Saturation flow Rates," MATIELAND, 2007. [Online]. Available: https://repository.up.ac.za/bitstream/handle/2263/5838/002.pdf %3Bjsessionid %3D4FCD4E6450E063E61E9B02

[6] M. Çetin and Y. Ş. Murat, "Doygun Akımın Belirlenmesinde Sürücü Davranışına Bağlı Bir Matematik Yaklaşım," Teknik Dergi, vol. 24. TMMOB İnşaat Mühendisleri Odası, pp. 6399–6414, 2013.

[7] C. Shao, X.-H. Du, and G.-Q. Li, "Queuing vehicle headway statistic analysis at signalized intersection," Gonglu Jiaotong Keji/Journal of Highway and Transportation Research and Development, vol. 20, Aug. 2003.

[8] S. Biswas, S. Chakraborty, I. Ghosh, and S. Chandra, "Saturation Flow Model for Signalized Intersection under Mixed Traffic Condition," Transportation Research Record: Journal of the Transportation Research Board, vol. 2672, no. 15, pp. 55–65, Dec. 2018, doi: 10.1177/0361198118777407.

[9] H. D. Nguyen, "Saturation Flow Rate Analysis at Signalized Intersections for Mixed Traffic Conditions in Motorcycle Dependent Cities," in Transportation Research Procedia, Jan. 2016, vol. 15, pp. 694–708. doi: 10.1016/j.trpro.2016.06.058.

[10] S. Yin, Z. Li, and Y. Zhang, "Integrated Traffic Signal Control and Management Platform and ITS Application," Nov. 2008.

[11] D. Nam, D. Park, and A. Khamkongkhun, "Estimation of value of travel time reliability," Journal of Advanced Transportation, vol. 39, no. 1, pp. 39–61,

2005, doi: 10.1002/atr.5670390105.

[12] Python Community, "Welcome to Python.org." https://www.python.org/ (accessed Mar. 08, 2021).

SECTION 4:

DIGITALISATION, AUTOMATIZATION AND MODELLING

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Digitalisation in Public Transport as an Opportunity and Threat for Specific Target Groups: An Analyses of Several Use-Cases

ELMAR FÜRST, GERALD LAMPRECHT, BERNHARD LANDRICHTER

Abstract Digitalisation is impacting transport significantly. Using information and communication technologies (ICT), practically all processes in the transport domain change. Considering the transport service chain from a passenger's perspective, this contains acquiring information on travel alternatives, ticketing, payment, way-finding, check-in, on-trip-information, entertainment and service, getting information on deviations in route or time, check-out, etc. In terms of infrastructure, vehicles and transport management, the entire system has also been re-shaped due to the use of ICT. Innovations in the field will remain important game-changers. Faster ways of data processing (Artificial Intelligence – AI) and transmission (5G) will, for example, help to operate autonomous vehicles.

Such huge changes bear a variety of opportunities and threats: where processes become increasingly digital and the personal encounter between passenger and staff is gradually replaced by man-machine-interaction, there are lots of chances and risks related to possible social exclusion or inclusion of certain people. Persons who are not used – or able – to use computers or mobile devices could significantly suffer from digitalisation, while people with disabilities who were unable, so far, to acquire services in order to be mobile on their own, will profit.

Here we present the results of a qualitative study based on use-cases where substantial changes have taken place leading to inclusion or exclusion. The developments are classified and systemised and the effects of the developments are described and evaluated.

Keywords: • Digitalisation, Public Transport • Social Exclusion and Inclusion • Accessibility • People with Disabilities

CORRESPONDENCE ADDRESS: Elmar Fürst, Assoz.Prof. Priv.-Doz. Mag. Dr, Gerald Lamprecht, Mag. Bernhard Landrichter, Vienna University of Economics and Business, Welthandelsplatz 1, Vienna, Austria, e-mail: gerald.lamprecht@wu.ac.at

 ISBN 978-961-95633-0-4

INTRODUCTION

Digitalisation is an important trend, significantly impacting transport. Using information and communication technologies (ICT), practically all processes in the transport domain have changed or will change. Considering the transport service chain [11] from a passenger's perspective, this contains acquiring appropriate information on travel alternatives, ticketing, payment, way-finding, check-in, on-trip-information, entertainment and service, getting information on possible deviations of route or time, check-out, etc. In terms of infrastructure, vehicles and transport management, the entire system has also been re-shaped due to the use of ICT. This trend is still ongoing and innovations in the field will remain important game-changers. Faster ways of data processing (Artificial Intelligence – AI) and transmission (5G) will, for example, massively support the development of autonomous vehicles. This is supposed to become one of the most radical changes in transport, its use and its environment.

Such huge changes naturally bear a variety of opportunities and threats, which need to be adequately addressed. In this context, where processes become increasingly digital and the personal encounter between passenger and staff is gradually replaced by man-machine-interaction, there are lots of chances and risks related to possible social exclusion or inclusion of certain groups of persons. This should well be taken into consideration at all stages of the developments. For example, persons who are not used – or able – to use computers or mobile devices could significantly suffer from digitalisation, as they will struggle to excess these services as soon as there is no longer any staff looking after them. On the other hand, those persons with disabilities who were unable, so far, to drive a car on their own, will enormously profit from autonomous vehicles, when holding a driver's licence will no longer be necessary for individual mobility. These are only two examples out of a huge variety of consequences of digitalisation in transport.

Overall, one can say that technical progress needs to be taken as a fact significantly changing the face of the entire transport system. Neither will it be possible to hold back innovations and technical developments, nor could this be generally useful or recommendable. In order to benefit in the best possible way from positive developments and to avoid and cope with possible disadvantages, it is necessary to comply with accessibility regulations like the Web Accessibility Directive [4] or the European Accessibility Act [5] and to respect the principles of Universal Design [7]. Thus, finding an appropriate mixture of enforcement and voluntary action as a result of awareness, helps to avoid exclusion of certain target groups, to deliver the inclusion of these groups and – what is most important – to improve the quality of the transport system for all passengers.

After having discussed the state of research and practice within the theoretical background section, we present in this paper the results of a qualitative study based on a series of use-cases where substantial changes have taken place due to digitalisation and automation, presumably leading to inclusion or exclusion, respectively. Hereby, the developments are classified and systemised and the effects of the developments are described and evaluated. Eventually, conclusions are drawn and some strategies against adverse developments are proposed.

THEORETICAL BACKGROUND

Both, passenger and freight transport have massively changed over time, particularly over the last decades due to the functions made possible by digitalisation and automation [15]. The use of ICT leads to substantial cost reductions and to improved efficiency. It is not without reason, that these developments are often referred to as the fourth industrial revolution [16]. Regarding freight transport, logistics and Supply Chain Management, the substantial changes driven by digitalisation and automation are obvious [19] but also in passenger transport, many processes have been subject to change and this trend will remain. As passenger transport services are addressed to the general public, everybody using these services has to deal – and to cope – with the changes that have taken place. It goes without saying that these changes bring with them several opportunities and threats for the passengers and here in particular for some "vulnerable" target groups, such as the elderly, the disabled and other groups with difficulties caused by digitalisation [8 / 17].

Consequently, there are "winners" and "losers" of digitalisation and automation: Some people are strongly supported in their individual mobility, others are severely hindered from using the (public) transport system independently. In this respect and after having reviewed the existing literature, we identified a set of target groups affected in the described way by digitalisation and automation, in particular

- elderly people,
- people with physical disabilities,
- people with sensory disabilities,
- people with mental disabilities,
- people with learning and communication difficulties and impairments,

- people with limited knowledge of the national language (foreigners, tourists, migrants, etc.)[2]

These target groups need to be able to handle new technologies, otherwise they are unable to make their trips independently [6]. As digitalisation and automation are continuous and dynamic developments, new opportunities and threats are always likely to arise [13]. As a matter of fact, digital skills become increasingly important in order to successfully navigate through public transport systems and technology has to address the needs and requirements of all passengers including the respective target groups [20/ 14]. Mobility is an important factor for quality of life. Hence, especially for those, who rely on public transport services, their availability, accessibility and affordability are crucial. This holds true for urban settings and problems may even get worse in peri-urban or rural areas [12]. In addition, one has to emphasize the fact, that the proportion of the abovementioned targets groups will increase in the future and the demographic changes pose a particularly great challenge for modern mobility services [13]. Persons with mobility impairments and the aging population, who represent a significant part of the population, are changing the demands on mobility access and inclusion services. Furthermore, the proportion of people over 65 is expected to grow significantly over the next decades [2]. Since many areas of the transport service chain, that interact with passengers have been digitalised already, persons who are not tech-savvy get excluded. Older persons in particular are often not very familiar with the internet or digital devices and find it difficult to learn how to operate technical devices [13].

Digitalisation, however, has also an enormous potential as certain persons gain independence in mobility through innovations [3]. For example, persons not holding a driver's license or being unable to drive a car for other reasons, can take part in full individual mobility as soon as autonomous driving is available to its full extent. Another example is the improved availability of information on mobile devices enabling people to find their way without external assistance [12]. A further advantageous aspect of digitalisation is the chance to overcome language barriers (for information, ticketing, etc.) and specific apps are available to bridge the language and information gaps [7].

At public transport stops static and dynamic information can be provided via electronic devices in a tailored way so that physically impaired customers, whether visually or acoustically impaired, can use them [15 / 20]. Furthermore, ICT based travel planners and location based services have been introduced helping people to find their way [9]. Additionally, autonomous vehicles and car sharing markets have grown over the

2 For more information take a look at the ICF Cassification, for our purpose we defined our own target groups.

past years. In the near future, autonomous vehicles based on artificial intelligence (AI) combined with car sharing models will lead to a huge impact on mobility for disabled people [14]. Newly created mobility apps boost the future of public transport, since they are created for e.g., visually impaired people or wheelchair users, fitting their specific needs [10]. Furthermore, the process of planning, booking and reservation has been digitalised already in many countries to a significant level and information on deviations and interruptions can be disseminated via push notifications.

These are just some spotlights from a wide range of consequences of digitalisation and automation in transport. Thus, ICT fundamentally re-shaped people's mobility and new technologies open up room for many new useful and helpful applications [6].

There is, however, a downside, which needs to be taken into consideration: In order to achieve optimal mobility for all members of society, regardless of age, limitations, disabilities, impairments or income, accessibility guidelines must be implemented. This is the only way to avoid exclusion and to create a transport system that benefits all passengers. In the field of mobility, researchers have to join their efforts globally to overcome the barriers for the abovementioned target groups, since the effects of transport are similar worldwide and solutions are ubiquitarily applicable [1].

Having discussed the state-of-the-art literature we concluded, that benefits and threats arising due to digitalisation and automation should be examined closely, since it is impossible to stop it. It is of high importance, to define some important use-cases in order to develop a conceptional framework showing the key features to achieve social inclusion rather than social exclusion.

METHOD

For our investigation into opportunities and threats of digital developments in the field of transport we selected target groups of persons who are known to be mostly affected by the rapid changes in digitalisation processes, be it in a positive or negative manner.

1. elderly people
2. people with physical disabilities
3. people with sensory disabilities
4. people with mental disabilities

5. people with learning and communication difficulties and impairments
6. people with limited knowledge of the national language (foreigners, tourists, migrants, etc.)

Within our research, we identified some important areas where digitalisation has proven to have had a substantial effect on individual mobility: A series of six use cases has been set up, which has been analysed with regard to the respective changes due to the digitalisation and automation processes. These changes have been put in relation to the consequences for the different vulnerable target groups depicting whether exclusion or inclusion is induced by the digitalisation or automation processes. In order to present our key findings in a structured manner, we developed a 2 by 2 contingency table and applied it to the six cases included. For this purpose, we divided the "digitalisation" contingent into "ex-ante" and "ex-post", referring to the state before and after digitalisation, respectively. The "accessibility" contingent is divided into "non-compliant" and "compliant" representing exclusionary and inclusionary factors and aspects.

RESULTS

In our study, we did examine the following six use cases:

- Use-case 1: self service terminals (SSTs)
- Use-case 2: accessible payment terminals
- Use-case 3: electronic ticketing
- Use-case 4: static and dynamic information
- Use-case 5: mobility apps
- Use-case 6: autonomous vehicles

Applying our method, we first looked at the situation that was common for each of these use-cases before digitalisation took place ("ex-ante") and we looked at the accessibility of the way the services were provided in the times before digitalisation ("compliant" or "non-compliant"). Then we did the same for the way these services are provided by current digitalisation.

The results showed that according to the manner services were offered in the past and services are offered nowadays the challenges of how to approach them have shifted significantly by digitalisation. This means that some challenges were solved for at least some groups, while new challenges arose for the same or for other groups.

For example, before the introduction of self service terminals (SSTs) at airports, personal contact helped to adapt to the specific needs of people with disabilities and access was provided through a sales person; however, the downsides were: no autonomy, long waiting times, and sales points may be hard to find and inaccessible. After the introduction of SSTs, the situation looks different: the above-mentioned downsides disappeared and the autonomous sales process leads to shorter waiting periods due to more accessible sales points; no help is required, no reliance on other people necessary. However, digitalisation helped solving the old problems, but for different groups of people with disabilities it created new ones: touch screens are not always accessible, no haptic and acoustic feedback is given; the ticket machines may not be in the right height and Therefore, inaccessible for people in wheelchairs; the purchasing process, is not intuitive and raises difficulties for people with intellectual disabilities.

For the other use-cases, the results look mixed, too: the shift to digitalisation created not only solutions, but caused exclusions of different groups of people with disabilities.

As a further example and to highlight how we applied our method to get results, we show here how the result for use-case 4 "static and dynamic information" looks in detail:

For use-case 5 "mobility apps" and use-case 6 "autonomous vehicles" the picture looks different since these technologies and Therefore, the related services started coming into existence only with digitalisation.

In use-case 5, these new services have their own compliancy and non-compliancy issues concerning accessibility by the way the devices are designed and the services are provided to the affected groups.

In use-case 6, the current situation is marked by social exclusion for some groups like blind people since individual transport is not accessible – the situation is non-compliable. When autonomous driving will be developed at the final stage [18] of fully automation, social inclusion will be completely fulfilled and it can be expected that there will be no no-compliant issues.

DISCUSSION

The analysis has shown that the digitalisation and automation processes have, indeed, fundamentally changed the products and services involved in the use cases. There are some general principles, which can be derived from the analyses of the six cases presented for the domain of transport and beyond. Regarding the opportunities yielded by digitalisation and automation, there are new ways for tailor-made and individual solutions, improved independence, and reduced need for assistance. Being less reliable on others for the own mobility, mobile results in a better quality of life comprising new ways of participation and self-determination.

In order to let this come into reality, it is – of course – necessary to design tools and services in a way that (almost) everybody can use them. In fact, this is neither expensive nor impossible. It usually involves respecting the most important requirements like information, screens, displays and showcases at eyelevel to make them approachable by visually impaired persons but also by wheelchair users or growth restricted people; buttons or paypads must be positioned in a height and designed in such a way that they serve the needs of blind, visually impaired, wheelchair users, etc. Information should always be as accurate as possible, and the ideal situation certainly includes alternatives in case of interruptions and deviations or even emergencies. In all situations, the availability of an alternative is helpful, in some cases mandatory. This demands, for instance, the application of the "two-senses-principle", which means, information must be transmitted through – at least – two sensory channels. In addition to visual information, there should also be an acoustic output. Information on buttons or pinpads must be well-legible but should also be perceivable in a tactile way. As a "solution of last resort", a personal

Table 1. Static and Dynamic Information

	Digitalisation	
	ex-ante	ex-post
Compliant	• Printed signs, timetables and haptic feedback helped people with disabilities and other target groups to access information in easy way	• Real time info • Automatic and efficient route planning • Auditory feedback for visually impaired people • Timely feedback in case of emergencies tailored to the disability
	• No real time information • Static information no help in case of emergency • Auditory feedback not sufficient for deaf people	• Reliance on technical devices • Digital screens maybe not readable • Digital screens maybe not accessible for wheelchair users • Auditory feedback not sufficient for deaf people

encounter with a staff member needs to be provided; but to save costs and to improve availability, in particular digital tools and ICT can be used. As not all the available rules and regulations are obligatory or sufficient, optimal results will only be reached if entities issuing tenders or public service contracts include specific rules and guidelines on their own. Only if the people in charge take this responsibility for serious, adequate solutions will be implemented and benefits be generated for all users. From a technical perspective – and this is an important issue to stress in this context – it is almost in all situations possible to find and achieve solutions, which can equally be used by "vulnerable" passengers. It is Therefore, regularly a question of awareness and willingness and not one of technical feasibility, if digitalised and automated processes are implemented in a way that is acceptable and useable for all. In other words: digitalisation and automation can be used in a good way to improve tools and services and unfavourable effects can be generally avoided to a great extent. This results in good and accessible services and from the operational perspective in improved quality and efficiency and, thus in reduced costs.

CONCLUSIONS AND RECOMMENDATIONS

Mobility is important for all people and a major factor for quality of life. It has already reached some kind of a status as a fundamental right. Particularly when it is restricted like in times of CoViD, everybody can see how significant it is and how it determines the participation in societal life. Digitalisation and automation have changed and change mobility. Staff is gradually replaced by machines, many processes formerly done by hand, can now run automatically. Most younger people have fun in using digital devices, computers and handhelds; they take advantage of the many new opportunities. There are, however, people who cannot do this in a common way, be it due to a disability or as they are simply not able or used to work with computers or the like.

From the operational perspective, digitalisation and automation are attractive as they save costs and – at the same time – improve service quality. In times when society respects the rights of all people and acknowledges their equality, it is of crucial importance not to disregard the rights and requirements of vulnerable groups in general and in terms of mobility. This means that precautions need to be taken in order to prevent negative effects for these groups and not to lose them on their way to a self-determined life. In this respect, particular emphasis needs to be put on digitalised and/or automated processes in the transport domain. There are basically two ways to approach this topic, namely legal rules and regulations – enforcement – on the one hand and awareness and voluntary action on the other hand, respectively. Regardless of what kind of "mixture" is taken in order to "include" the groups of elderly and disabled people in the best possible way, it is important to respect the individual situations and abilities of those people, as well as to design tools and processes in a way enabling them to use them.

In this research, six use cases in the field of (public) transport were identified and analysed concerning the changes brought by digitalisation and automation and what effects the changes have for the vulnerable target groups. It can be seen that if needs and requirements of these groups are considered "from scratch" within planning and design processes and maintained in all phases and stages of the projects, there are (almost) no additional costs and the usability for the entity of all passengers is improved, significantly. Accessibility should Therefore, not be regarded as important or necessary for a small "niche" group of passengers, only, but as the optimal way to improve "universal functionality" with benefits for all.

In detail, the following conclusions and recommendations can be drawn:

- Respecting universal design and functionality improves the user-experience and comfort for all passengers.
- Accessibility is Therefore, a concept beneficial for all passengers – not only for some small target groups.
- Therefore, accessibility is also an important source for financial income of transport service providers as it enables the use by everyone.
- However, for some target groups the fulfilment of accessibility guidelines is a necessary precondition, and an independent self-determined use is not possible without it.
- Hence, the application of accessibility is recommended in all circumstances and without compromise.
- Whenever there are new developments like new designs, machines, apps, devices, services, etc., not only existing guidelines and regulations should be respected but people with disabilities, as well as representatives of older citizens should be consulted on a regular basis. This is particularly important in the context of disability and automation as those developments fundamentally change the (public) transport service chain and substantially impact the participation of target groups addressed in this paper.

REFERENCES

[1] Annika Busch-Geertsema, Thomas Klinger, Martin Lanzendorf (2018). The future of German transport and mobility research from a geographical

perspective. A viewpoint on challenges and needs, Journal of Transport Geography, 81, https://doi.org/10.1016/j.jtrangeo.2019.102537.

[2] Austrian Federal Ministry of Transport, (2018c) FTI-politische Agenda und Roadmap zur Ausrichtung der Programmmaßnahmen "Mobilität der Zukunft" (MdZ) im Themenfeld "Personenmobilität innovativ gestalten", https://mobilitaetderzukunft.at/resources/pdf/broschueren/FTI-Agenda_MdZ_Personenmobilitt_2018.pdf , Accessed: 15.02.2021.

[3] Creutzig, F., Franzen, M., Moeckel, R., Heinrichs, D., & Nagel, K. (2018). Leveraging digitalisation for sustainability in urban transport. Global Sustainability, 2, 1-6, doi:10.1017/sus.2019.11.

[4] Directive (EU) 2016/2102 of the European Parliament and of the Council of 26 October 2016 on the accessibility of the websites and mobile applications of public sector bodies; OJ L 327, 2.12.2016, 1–15.

[5] Directive (EU) 2019/882 of the European Parliament and of the Council of 17 April 2019 on the accessibility requirements for products and services; OJ L 151, 7.6.2019, 70–115.

[6] Durand, Anne & Zijlstra, Toon. (2020). The impact of digitalisation on the access to transport services: a literature review. 10.13140/RG.2.2.22686.97600.

[7] Gerard Craddock, Niamh Fawl, Tian Feng (2019). Universally Designed Public Transport Systems that are accessible and useable by everyone - an international collaboration, European Transport Conference, Dublin.

[8] Ahmed HASSAN, Rasha Abd El-Aziz, Meer Hamza, (2020). The Exclusion of People with Visual Disabilities from Digital Banking Services in the Digitalization Era, Journal of Electronic Banking Systems, Vol. 2020,10.5171/2020.519078.

[9] I.C.M. Karlsson, D. Mukhtar-Landgren, G. Smith, T. Koglin, A. Kronsell, E. Lund, S. Sarasini, J. Sochor, (2020). Development and implementation of Mobility-as-a-Service – A qualitative study of barriers and enabling factors. Transport Research Part A: Policy and Practice, Elsevier, 131, 283-295, https://doi.org/10.1016/j.tra.2019.09.028.

[10] Jana Stehlíková, Tomáš Řezník, (2018). An accessible Brno city centre forpeople with impaired mobility, Journal of Maps, 14:1, 81-87. https://doi.org/10.1080/17445647.2018.1526716.

[11] Jun Park, Subeh Chowdhury; (2018) Investigating the barriers in a typical journey by public transport users with disabilities, Journal of Transport & Health, 10, 361-368, https://doi.org/10.1016/j.jth.2018.05.008.

[12] Manuela Samek Lodovici, Nicoletta Torchio (2015). Social inclusion in EU public transport. Brüssel: European Union, https://www.europarl.europa.eu/RegData/etudes/STUD/2015/540351/IPOL_STU(2015)540351(SUM01)_EN.pdf, Accessed: 15.02.

[13] Mitteregger, M., Bruck, M., Soteropoulos, A., Stickler, A., Berger, M., Dangschat, J., Banerjee, J. (2020). AVENUE21. Automatisierter und vernetzter Verkehr: Entwicklung des urbanen Europas. Berlin: Springer-Verlag GmbH.

[14] Nikitas, Alexandros; Kougias, Ioannis; Alyavina, Elena; Njoya Tchouamou, Eric. (2017). "How Can Autonomous and Connected Vehicles, Electromobility, BRT, Hyperloop, Shared Use Mobility and Mobility-As-A-Service Shape Transport Futures for the Context of Smart Cities?" Urban Sci. 1, 4, 36. https://doi.org/10.3390/urbansci1040036.

[15] Padrón Nápoles, Víctor M.; Gachet Páez, Diego; Esteban Penelas, José L.; García Pérez, Olalla; García Santacruz, María J.; Martín de Pablos, Fernando. (2020). "Smart Bus Stops as Interconnected Public Spaces for Increasing Social Inclusiveness and Quality of Life of Elder Users" Smart Cities 3, 2, 430-443. https://doi.org/10.3390/smartcities3020023.

[16] Pernestål, Anna; Engholm, Albin; Bemler, Marie; Gidofalvi, Gyözö. (2021). "How Will Digitalization Change Road Freight Transport? Scenarios Tested in Sweden" Sustainability 13, 1, 304. https://doi.org/10.3390/su13010304

[17] Shrestha, Millonig, Hounsell, McDonald (2017). Review of public transport needs of older people in European context, Population Ageing 10, 343–361 (2017). https://doi.org/10.1007/s12062-016-9168-9.

[18] Wilhelm, B., Kotterba, S., & Orth, M. (2011). Teil II: Verkehr und Gesundheit. Tagesschläfrigkeit auslösende Erkrankungen und Verkehrssicherheit. In K. Golka, J. Hengstler, S. Letzel, & D. Nowak, Verkehrsmedizin- arbeitsmedizinische Aspekte. Orientierungshilfe für Praxis, Klinik und Betrieb, 67-79. Hemsbach: ecomed MEDIZIN.

[19] Yasanur Kayikci, (2018). Sustainability impact of digitization in logistics, Procedia Manufacturing, 21, 782-789, https://doi.org/10.1016/j.promfg.2018.02.184.

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Integration Opportunities of Drones into the Document Handling and Transporting

KRISZTIÁN BÓNA, GÁBOR KOVÁCS, CINTIA PÁRIZS

Abstract During the implementation of a value-creating process closely related information can be created, which must appear in a group, visually and usually in physical form. For this reason, they are arranged in documents, giving the reader the opportunity to interpret the information. In general, the management and transmission of records (collectively, document flow management) is a necessary but not value-creating activity in an organization, typically performed manually, in some cases using assistive devices, by operators. This can be a particularly difficult task if the place of dispatch and delivery are located far apart (e.g., in different buildings). There is a danger that as volumes increase, flows may become slow, opaque, and untraceable. The development of a paperless e-document and an e-signature system may be obvious to solve the problems arising from the continuous flow of documents. Unfortunately, due to the nature of the rules in the administration, documents appearing in physical form do not seem to be eliminated. These can be reduced in number but are unlikely to disappear for a long time to come. As part of our research on the use of drones in logistics systems, the idea arose to use drones to support the movement of documents. Among many other benefits, the use of drones can replace the human factor, which usually causes the most errors and mistakes, so the system can operate more efficiently with fewer errors and many losses can be eliminated. In addition, we face several interesting technological and organizational challenges in integrating drones.

Keywords: • Drone • Document Handling • Document Logistics

CORRESPONDENCE ADDRESS: Dr. Krisztián Bóna, associate professor, Dr. Gábor Kovács, senior lecturer Cintia Párizs, logistics engineer, MSc student, Budapest University of Technology and Economics, Faculty of Transportation Engineering and Vehicle Engineering, Department of Material Handling and Logistics Systems, H-1111, Budapest Bertalan L. u. 7-9., Hungary, e-mail: krisztian.bona@logisztika.bme.hu, e-mail: gabor.kovacs@logisztika.bme.hu, e-mail: parizs.cintia@gmail.com

 ISBN 978-961-95633-0-4

INTRODUCTION

Of the documents, the document is the most critical in administrative and value-creating processes, which is defined as "a means of proof, which proves the reality of the facts, data, statement, circumstance, act contained therein with probative value depending on the identity of the issuer and the method of exhibition" [1]. There are many types of documents (e.g., private document with full probative value) that can be important for the management of an organization. Because of these, managing and transmitting documents is a critical, typically confidential activity. In general value-creating work in an organization takes place in distant places, but still relatively close in space (e.g., in different office buildings). For this reason, we further consider the investigated material flow system as an intralogistics system in our model. In this type of intralogistics systems, document flow is typically a very lengthy process, with multiple steps, long lead times, and wait for signatures. It is often the case that documents are returned to the sender due to deficiencies or incorrect information. Furthermore, the situation is aggravated by the fact that the documents pass through relatively distant departments, which is why misunderstandings can be common. Many participants are involved in the flow and processes are not, or rarely, standards. In many cases, there are no flow metrics for flow time or costs. The only secondary data source is typically the so-called mailing book, in, which the document flow is recorded in writing. With the introduction of electronic document management systems in public administration, such as e-signatures or e-documents, digitization has begun, and this is expected to reduce the number of paper-based documents. At the same time, it should be seen that in many cases, unfortunately, different documents may be required in physical form as well, so presumably the document flow will remain, only its intensity will change. It follows that a solution must be found for the implementation of the logistics operation, for, which there are several suitable alternatives, from the transmission by human resources to the use of the most innovative technologies. Thus, the idea arose to use drones to perform logistics tasks Our goal is to first define and analyze the framework of document transport supported by drones as a logistics task. Thus, by definition, we will not deal in depth with e.g., with the control problems of the drones, as well as with the transport engineering issues, although we know that all of these are an important segment of the implementation of the system. We are also aware that both the physical implementation of the system and meteorology, as well as compliance with legislation, are important issues, but we will not address these in our current paper either. Currently, the focus of our research is on the realization of the logistics network, the types of documents and the flow of materials and information between the individual points.

SCIENTIFIC OVERVIEW

Drones

There is no doubt that drones can be used very widely, thanks to the rapid development of technology, such as participation in firefighting, search for missing persons [2]. Although the biggest focus today is on the user side of drones, there are still other interesting areas, such as flight and transport control. There have been several studies in the field of flight control, most of, which aimed to plan the management of the drone fleet, but there were also those in, which remote control of the drones was sought to ensure that control of the drone could not be taken over by an outside intruder [3]. Also, several future studies have been conducted, one on drone control with brainwave and the other on eye movement [4], [5]. In the field of transport management, the number of studies is significantly lower. Most of the research was on a health topic aimed at transporting a laboratory sample and examining whether the sample was damaged or altered during transport. Such a sample was, for example, insulin or various blood samples [6], [7]. In addition, another study that examines the drone-based transportation schedule considering failures should be highlighted. The research aims to develop a reliable delivery schedule by minimizing the number of failed deliveries [8].

In the field of logistics, there is the focus on the use of drones that can be integrated into wide logistics networks and supply chains. Based on the studies, despite various technological and legal obstacles, it is worthwhile to address the possibility of integrating drones because they can represent significant potential in logistics. The use of drones is also being studied in the field of city logistics [9]. Most of the research is looking at a drone-supported solution to last-mile tasks in urban environments. Last-mile transport delivers the right goods to the consignee, which is currently the most expensive and polluting part of the supply chain [10], as well as an increasing burden on the already growing road freight transport. In contrast, in intralogistics is given less focus in connection with the incorporation of drones into processes, but they can also be used to perform several tasks. The purpose of drone tasks is most often to reduce the human resources required for the processes in the warehouse, as well as to increase efficiency. Indoor flight is much more favorable for drones because it does not suffer as much from external environmental influences (wind, rain, etc.) as there are almost constant conditions in the warehouse (temperature, light conditions, etc.). The most common tasks to be performed include stock-taking, observing of the value creating objects and supporting of the order picking tasks.

Due to the widespread use of drones, it has become logical that their use should be regulated. Unmanned aircraft in Hungary also apply to European and Hungarian laws. In Europe, the European Union Aviation Safety Agency (EASA) monitors the use of drones. In 2019, the European Union adopted new laws laying down rules for operators and operations of unmanned aircraft. The exact legislation is contained in Regulations 2019/945 [11] and 2019/947 [12]. On 10 February 2021, the laws in force in Hungary, which are based on the two aforementioned decrees, entered into force.

From a legal point of view, there can be many problems with the system. The laws, for the time being, do not address certain situations, such as what happens if the drone crashes and a person or someone’s property is injured. Furthermore, there is a situation where people's privacy rights are violated due to cameras mounted on unmanned aircraft.

As we have read, many people are studying the possibilities of using drones, but we cannot take it for granted that drones can and should be used for all tasks, as in their current state they are still considered a hobby category product. Their use consists in placing a payload on it, which in most cases is a camera that can be used to examine the environment. So, we cannot be sure that these structures will be usable for freight transport tasks in the long run in their current state, so there will be a lot of research to be done on this topic in the future.

Document logistics

In order to remain competitive, companies and service providers must also pay special attention to efficient internal and external document flow. It is clear that developments are moving towards the use of electronic documents, with several studies on the transition to electronic documents [13] and patents on various coding [14] and document management systems [15], as well as electronic records also play an important role in the field of archiving. However, the use of electronic records raises several issues. One such problem is the protection of documents with watermarks [16] or digital signatures [17], which must be made tamper-proof. In the field of archiving, there may also be issues - even ethical - about, which documents should be made available electronically and, which should not [18]. There are studies, which observe the manual and machine notes, are also being prepared. This research revealed that the subject was able to write more words in each time in connection with typing, and the writing itself became more accurate [19].

The public sector (including educational institutions) has great potential for digital solutions. By using them, it could be possible for the individual organizational units involved in value creation processes to participate in a seamless document flow system and share information with each other, not in isolation from each other, but in full cooperation. In addition to public administration, healthcare is also one of the sectors where paper-based documentation is still present in large quantities. In other service sectors, such as banks, most paperwork is already paperless and electronic. Thus, digitization also provides banks with a demonstrable cost advantage [20]. In the case of transportation, there has been an effort to neutralize consignment note [21].

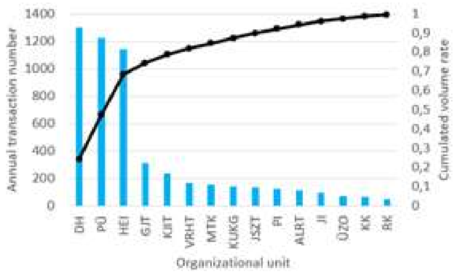
USE CASE

Our research is carried out at the Faculty of Transportation Engineering and Vehicle Engineering of the Budapest University of Technology and Economics. Currently, the document flow takes place through the courier, who transports the documents in a bag between the different buildings by walk. The courier makes two roundtrips a day, and delivers the mail of the departments, and serves the other requests related to the mailing. The morning tour takes an average of 93 minutes, while the afternoon takes an average of 46 minutes. The courier serves 17 organizational units, which include the departments, as well as other economic and human organizational units of the university. Documents are shipped in a sealed white A4 envelope along with the unit's own mailing book. The sending and receiving process of the documents is very simple. The needs for the document deliveries are registered by phone, and the documented in the mailing book without any time stamp day by day.

Process analysis

The transportation task that we have examined in our study can be easily delineated. The goods to be transported are characterized by low weight, small volume, and relatively frequent transportation transaction, and the examined system can be modelled as an outdoor but a closed intralogistics system. A transaction can be defined as a delivery event, i.e., a delivery task that arises between two organizational units. The pick-up and drop-off locations are well defined and can be in different buildings. In 2020, a detailed examination of the generated transactions in the system took place. We found out from the mailing books of the organizational units how many transactions took place at the most important units in the examined year 2019, that can be illustrated in the figure below (Figure 1).

Figure 1. 2019 document turnover [pc]



The departments are abbreviated to GJT, KJIT, VRHT, KUKG, JSZT, ALRT, and the other organizational units are the economic and human units of the university. A total of 5 430 transactions took place during the period under review. This large aggregate number of transactions shows that the flow is indeed significant and worth further consideration. What is immediately noticeable is that the annual number of transactions is exceptionally high for the first three organizational units, and significantly less for the other units. From the results thus obtained, the material flow intensity and material handling performance can be investigated between each building, which can be illustrated in Fig. 2 and Fig. 3.

Figure 2. Material flow intensity graph [transaction/day]

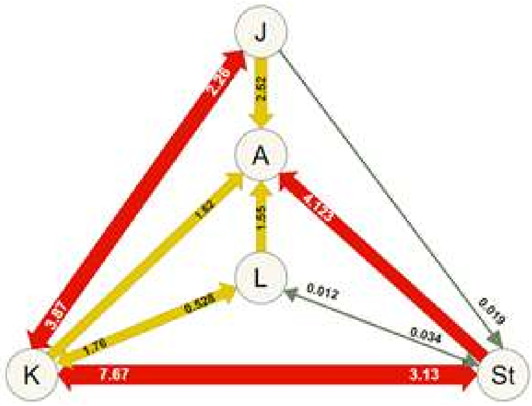
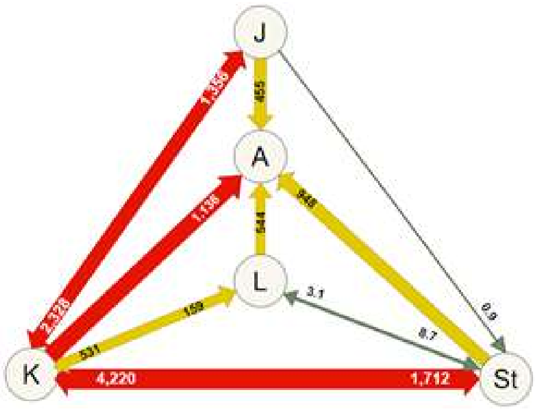
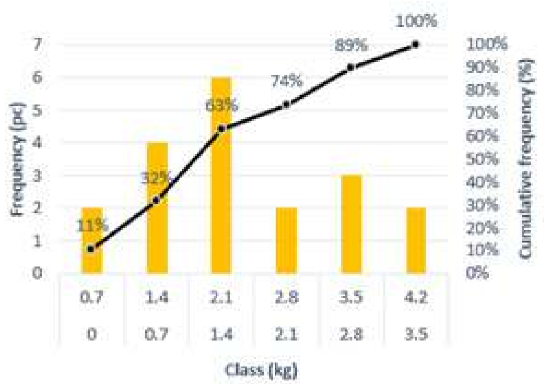


Figure 3. Material handling performance graph [material handling work/day



In Figure 2, the vertices of the graph indicate the buildings and the lines indicate the intensity of the relationship. The thickness of the lines is proportional to the intensity of the relationship, where there are two values on a line, the transaction is bidirectional and the value closer to the building shows the intensity there. The values on the lines are expressed in transaction / day units. For example, rounded up from building "J" to building "K", 4 transactions take place per day on average. The interesting thing about the graph is that building "A" seems to be functioned as a sink, but this is not entirely true. Building "A" could not be examined in detail, so we can only provide partial data in this regard. In Figure 3, the statements regarding the interpretation of the figure as in the previous case are also valid. The values at the lines are expressed in material handling work / day. Where the material handling work can be interpreted as the multiplication of the realized distance and the quantity between the pick-up and drop-off locations. What has changed compared to the intensity graph is that there is significant material handling performance between buildings "K" and "A", although the average daily transaction is small and the same is true for buildings "A" and "St", because the distances are larger between these buildings than the other cases. Beside on other interesting examinations, we also examined the work of the courier, focusing here mainly on the route that has been took, and the mass of unit loads that has been delivered. The route traveled by the courier averages 4,5 km per day. From the measured data we obtained that the courier carries an average unit load weighing almost 2 kg during a roundtrip. Respectively, with 95 % confidence, the confidence interval was 0,52 kg. Thus, we can state that with 95 % reliability, the expected value of the weight of the unit loads to be delivered will be between 1,45 and 2,5 kg. This can be shown in the histogram below (Figure 4). From this result, it is already possible to conclude the maximum carrying capacity of a drone that could potentially be used to replace the courier in these operations.

Figure 4. Histogram of the mass of the unit loads



REALIZATION OF DOCUMENT FLOW SUPPORTED BY DRONES

It has been seen in previous chapters that drones have a countless of applications, although they cannot move large masses or cannot be able to fly for long hours, they are still used to transport smaller packages in special cases. In several aspects, document delivery can be an ideal application because there is no extremely large mass of documents to be delivered and the individual buildings are located relatively close to each other. Nonetheless, there may be serious problems and challenges that need to be addressed in the future.

Research questions

The most difficult problem can be defined from the legal side. Therefore, the new drone supported document flow system must be fitted to the existing legislation. These rules significantly affect the different scenarios. For example, one of our plans in the future is for the drone to operate autonomously, but the relevant regulations do not yet exist in Hungary.

The control of the drone could work as planned in a semi-automatic system, where each operation is performed by the drone pilot (docking) and other operations autonomously by the drone (take-off and landing). However, it is true that there is a need for an operator with the appropriate competence in every case. However, the semi-automatic control can be further broken down into different development phases, depending on the extent to, which the drone pilot or drone performs the operations. Currently, the most important development direction is clearly to ensure the human oversight because human can make the correct decisions in almost all situations and based on the actual regulations the human control is obligatory. But the highest level of this development would be the fully autonomous operation.

Another significant challenge is how the drone delivers the unit load. Related to this, it is also a significant question of how and where to place this unit load so as not to cover the drone sensors. Another major challenge from the implementation side of the system is the docking and the document transfer. What should be the design of the docking station, where exactly should it be, and how should we hand over the documents to the administrators. We have not yet worked on the details of the design of the docking station, but the location of the docking stations was primarily designed on the roofs of the buildings, as the drone can land there more easily because there are less obstructions. Of course, it also depends on the structure of the building's roof whether the docking station can be placed there or not, and even getting to the roof is a serious safety issue. Another challenge in the field of classical freight transport is the question of how-to pick-up and receive the documents. Closely related to this is the design and operation of the Drone Transport Management System (DTMS). How can the administrator indicate his intention to send a document, and how can a distinction be made between traditional and urgent documents? After all, a great advantage of this system is that it can also handle ad hoc freight tasks. Thus, Drone Flight Control System (DFCS) should also connect to the DTMS. It can thus be seen that the system components are highly interdependent.

Transportation

The delivery area is given where the document delivery must be performed by the drone, as is the location of the affected buildings. Based on our observations it seems to be ideal from logistics point of view if the drone starts from the center of the flow and transports the documents to the other buildings. This can be the centralized transport organizing scenario (Figure 5). Another possible theoretical organizing scenario can be the so-called round-trip system (Figure 6).

Figure 5. Centralized transport organizing scenario

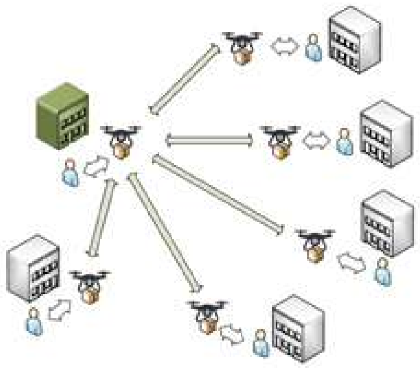
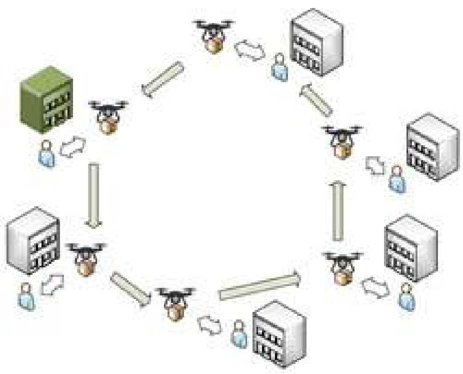


Figure 6. Round-trip transport organizing scenario



The drones will be operated according to a specified schedule. Each day, a dynamic schedule is compiled from the tasks of the day in the DTMS. During the day, the schedule in the DTMS may change as prompt requests arise. All sender or receiving points must be visited by the drones where there are any kinds of tasks can be defined in the transporting system. If prompt requirement arises while performing the schedule, it must be inserted into the agenda. This process can be defined as a dynamic optimization of the daily tasks in the DTMS.

In the case of the round-trip transport organizing, during the physical operation the administrator at the central sender location places the documents into the predefined unit load, then the drone takes off and takes them to the next programmed destination in the delivery plan. The administrator at the destination place takes over the relevant delivered documents and places into the transport unit the documents that must be delivered to other receiving locations. This handover process is performed at all destinations, at the end of the round-trip the drones return to the central sender location, where the administrator takes the documents addressed to it from the unit load and initiates the starting of the next flight if it is necessary. In the case of the centralized transport organizing, the drones serve only one route at a time between the central sender location and a predefined destination. So, a smaller unit load and even a lower load-bearing drone may be required, but the count of the flied routes can be higher, Therefore, the necessary number of the drones can be also higher. Additionally, the documents can be delivered in a transportation unit sealed with a barcode sticker, Therefore, this transaction can be also safer. Because of the small value of the expected flight time, the battery of the drone must be charged and/or replaced, if necessary, until the start of the next flight. In the investigated use case, based on our calculations, during the day, minimum two round trips can be required in case of the round-trip transport organizing, and much more in case of the centralized transport organizing, but it depends on the amount of the daily document and the occurrence of the prompt requests.

In the planned scenarios, the drone will always fly the same route (Figure 7), which has been planned considering the actual regulations. The green line indicates the route of the drones, the red line indicates the critical sections, and the yellow hexagons indicate the docking stations. It is considered a critical stage when the drones fly over a road or public space frequently used by students (Bertalan Lajos utca, Egry József utca).

Figure 7. Drone's preliminary flight route

The drones can only deviate from this designated route in exceptional cases. So, if the drones deliver the documents in a centralized transport organizing system, then they will be flied much more distances than if the round-trip organizing technique will be applied in case of same tasks.

Introduction of the system

So, as it can be seen in the previous, the aim of the research is to create a drone-supported transportation system for relatively light goods and in a strictly defined intralogistics network. First, the solution would initially be introduced in a pilot system in, which the drones would be gradually, more and more involved. But how can the way be defined, which ensure the continuous and safe operation?

In the first step, the drone is controlled by a drone pilot and delivers documents to only one designated building from the central building and the other buildings being traditionally served by the courier. At this stage, the drone pilot controls the drone completely manually, in each case in his visual line of sight (VLoS) for ensuring the safe operation and the drone would land in front of the building in a predefined landing position, where the administrator would take over the documents. The second step differs from the first in that the drones will serve not one, but two or more buildings.

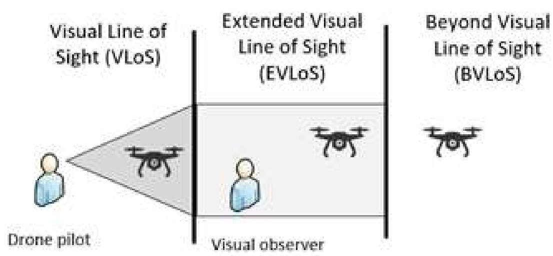
In the third step, the drones will serve all buildings and docking will be already done on the roof in case of the central building in a docking station using cameras and sensors, and for all other buildings, docking will be done in similar way as before.

Table 1. Evolutionary steps

Step	Serviced buildings	Control of drones	Role of drone pilot	Take-off and landing position	Courier	Range of vision	Flight control system
1.	One			In front of the buildings			
2.	Two or more				Yes	VLoS	Undeveloped
3.		Manual	Controller	On the roof / In front of the buildings			
4.						EVLoS	More advanced
5.							
6.	All of them				No		
7.		Semi-automatic	Controller/ Supervisor	On the roofs		BVLoS	Advanced
8.		Autonomous	Supervisor				Very advanced

The main differences in case of the fourth step are that docking takes place already on the roof using a docking station for two or more buildings and no longer needs a delivery service by couriers. Additionally, in the drone operation the extended visual line of sight (EVLoS) operation will be started to use, involving other observer operators in the process. In the fifth step, the drone pilot still controls the drones completely manually and the docking will be realized already on the roof for all buildings using a docking station. The range of vision is illustrated in Fig. 8.

Figure 8. Range of vision



In the sixth step, the beyond of visual line of sight (BVLoS) operation will be started to use in the transportation process, but the drone pilot manually controls the drones from the Drone Flight Control Center (DFCC), supported by the integrated cameras and sensors of the drones. In the case of the seventh step, it is already possible to switch to semi-autonomous control, in, which the drones perform the take-off and landing, and the drone pilot controls the flight of the drone from the DFCC.

And in the eighth final step, the drone operates in a fully autonomous mode and the drone pilot now has only one oversight role, possibly intervening if some unexpected event occurs. The above-mentioned evolutionary steps are summarized in Table 1. As a main finding can be mentioned that this way can be adapted in other fields as the transport concept has been defined to be able to apply in other intralogistics systems handling similar transporting tasks.

Technological challenges

There are also many kinds of technical problems that must be handled if a pilot system would like to be realized. Without wishing to be exhaustive, the following things should be considered: whether a unique designed and developed or a purchased drone can be better to use for the realization; the design and the realization of the transportation unit load; how can the charging and / or the replacing of the drone batteries be realized to ensure the continuous operation; design and realization of the docking stations; solving of the control problems for supporting the autonomous or the semi-automated operation, and so on. An important factor is the weather itself, how can be the drone prepared in extreme weather conditions it can carry out the transportation tasks. A significant question is the structure and development of the Drone Flight Control System (DFCS) and how the Drone Transport Management System (DTMS) relates to the already used registration system that we intended to apply during the system operation. The interconnection of the DTMS with the DFCS is also an important issue. Creating an optimizing of the drone transporting schedule and dealing with ad-hoc needs are both relevant issues. Furthermore, the physical location of the Drone Flight Control Center (DFCC) is also an important issue.

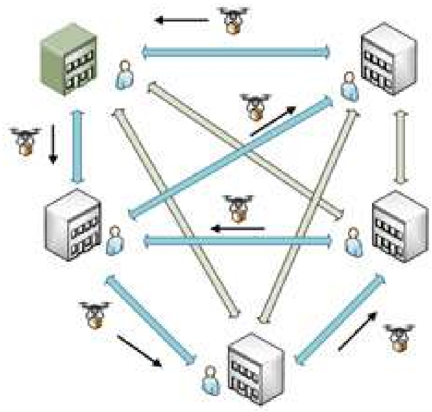
Physical realization

In the summer of 2021, the physical implementation of the pilot project began. In the experiment, we plan the test implementation of the tasks with a commercially available MAVIC 2 Enterprise ZOOM type drone. First, we investigated the implementation of the transportation unit load. In this step we examined two solutions. One is to have the transportation unit load under the drone and the other is to be above the drone. Placing the unit load below the drone body will quasi- "cover" the sensors at the bottom of the drone body. If it will be placed above the body, then the drone is able to take off, and able to use almost all sensors, so we chose this solution. In addition, two kinds of transport units have been tested, one is the so-called tube-type unit used in pneumatic transportation systems and the other is a special plastic folder. Application of a specially made fixing clamp structure and support brackets, it was possible to create a horizontal surface suitable for fixing the transportation unit load above the drone, to, which the transportation unit can be attached. A prototype of the designed structure was also completed and thus it became possible to physically test the designed solutions (Figure 9).

Figure 9. Prototype of the designed structure

Several flight experiments were performed, which found that in the case of the folder, the drone would fall slightly forward during take-off because the center of gravity of the structure was higher than usual. Because of this, in several cases, the drone could not take-off. The orientation of the folder was laid horizontally on the transport surface. It was also a problem that a parachute effect developed during vertical descent. In the case of the tube-type unit, there was a minimal pre-fall on take-off in the same way, but not to the same extent as in the case of the folder. With the tube-type unit, the drone was able to fly stably. In this case, the maximum weight of the handled and batched documents was 29 dag. So, the tube-type version seems to be suitable for developing of the pilot application.

Figure 10. Decentralized transport organizing scenario in case of the pilot system



Based on the results of the experiments it can be said that probably the planned transport organizing methods must be mixed and a so-called decentralized solution must be defined to optimize the flight routes of the drones (Figure 10). As can be seen, all buildings are connected to all buildings and the schedule of the drones is designed to keep the number of empty flights to a minimum. This type of solution may include the roundtrips or the centralized transport organizing methods, as well.

CONCLUSION

Drones can be widely used today to support a variety of tasks. There also seems to be great potential in the field of logistics for integrating drones into value-creating processes. In our article, we presented the basics of the concept of a drone-supported document transporting system that can be adapted to other areas and may not only be suitable for transporting documents, but anywhere where the nature of transport tasks is similar to the transporting documents. Due to the nature of documents in the public administration, it will be necessary to implement a paper-based document flow in the future, despite the fact that an electronic document system will be set up as a result of digitization. So, it is definitely worthwhile to deal with the support of high-volume flow in more detail, which is also supported by the results of our measurements in a pilot area. This topic is a big challenge, as there are several issues from a system organization, technology, and legal perspective as well. For this reason, according to our ideas, the introduction of the system concept we have defined should be implemented in a multi-stage form, with continuous testing, solving the problems that arise and detecting new challenges. Only this can ensure the development of a sustainable solution that works in the long run and fits well into the current environment.

ACKNOWLEDGEMENT

The research was supported by the Hungarian Government a co-financed by the European Social Fund through the project "Talent management in autonomous vehicle control technologies" (EFOP-3.6.3-VEKOP-16-2017-00001)."

REFERENCES

[1] https://idegen-szavak-szotara.hu/okirat-jelent %C3 %A9se.

[2] János Létai. (2014). Possibilities of using drones in firefighting interventions. Budapest.

[3] Woonghee Lee, Joon Yeop Lee, Jiyeon Lee, Kangho Kim, Seungho Yoo, Seongjoon Park, Hwangnam Kim. (2018). Ground Control System Based Routing for Reliable and Efficient Multi-Drone Control System. School of Elevtrical Engineering, Korea University, Seoul.

[4] Iuliana Martin, Myssar Jabbar Hammond Al-Battbootti, Nicolae Goga. (2020). Drone Control based on Mental Commands and Facial Expressions. University Politehnica of Bucharest. Bucharest.

[5] Roman Ibrahimov, Evgeny Tsykunov, Vladimir Shirokun, Andrey Somov, Dzmitry Tsetserukou. (2019). DronePick: Object Picking and Delivery Teleoperation with the Drone Controlled by a Werable Tactile Display. Intelligent Space Robotics Laboratory, Skolkovo Institute of Science and Technology, Moscow.

[6] Michelle Sing Yee Hii, Patrick Courtney, Paul G.Royall. (2019). An Evaluation of the Delivery of Medicines Using Drones. Institue of Pharmaceutical Science, Department of Pharmacy, Faculty of Life Sciences & Medicine, King's Collage London. London.

[7] Timothy Amukele, Paul M. Ness, Aaron A.R. Tobian, Joan Boyd, Jeff Street. (2016). Drone transportation of blood products. Department of Pathology, Johns Hopkins School of Medicine, Balitmore, Maryland.

[8] Maryam Torabbeigi, Gino J. Kim, Navid Ahmadian, Seon Jin Kim. (2021). An Optimization Approach to Minimize the Expected Loss of Demand Considering Drone Failures in Drone Delivery Scheduling. University of Houston.Houston.

[9] Snezana Tadic, Milovan Kovac, Olja Conkorilo. (2021). The Application of Drones in City Logistics Concepts. Faculty of Transport and Traffic Engineering University of Belgrade. Promet., 33(3), 451-462.

[10] Davis, S. E., Williams, S. E. & Boundy, R. G. (2016). Transportation Energy Data Book 35th edition Oak Ridge National Laboratory, Oak Ridge. TN, USA.

[11] Comission Delegated Regulation (EU) 2019/945.

[12] Comission Delegated Regulation (EU) 2019/947.

[13] Jeffrey Lewin, Amer Abuhantash. (2007). Computerization of Information and Paper Documents Flow System. An-Najah National University Nablus-Palestine.

[14] Scott Olechowksi, Shawn Eldridge, Cayce Ullman. (2014). Processing Encrypted Electronic Documents. United States Patent.

[15] Tim Boemker, Mark Keller, Chip Schock, Mark E. Kleingers, Philip E. Huff, Terrance P. Gieske, James D. Gersten, John E. Danner. (2013). Electronic Document Management System. United States Patent.

[16] Anna Melman, Oleg Evsutin, Alexander Shelupanov. (2020). An Authorship Protection Technology for Electronic Documents Based on Image Watermarking. Department of Complex Information Security of Computer System, Tomsk State University of Control System and Radioelectronics. Tomsk.

[17] A I Dzhangarov, M A Suleymanova. (2020). Electronic digital signature. Department of Programming and Information and Communication, Chechen State University.

[18] Mohamad Azri Mohamad Radzi, Saiful Farik Mat Yatin, Nurul Azira Najihah Mohd Fadzil, Syed Hamzah Jamallulail Syed Abdul Aziz. (2018). Document Preparation for Electronic Document Magagement System. Faculty of Information Management, Puncak Perdana Campus, UiTM Selangor, Malaysia.

[19] Christie Wroten, Susan Zapf, Ellen Hudgins. (2020). Effectiveness of Electronic Documentation: A Case Report. Rocky Mountain University of Health Professions, Provo, USA.

[20] Bülent Balkan. (2021). Impacts of Digitalization on Banks and Banking. Springer Nature Singapore Pte Ltd.

[21] Milos Poliak, Jana Tomicová, Marek Jaskiewicz, Natalia Zhuravleva, Gabriel Fedorko. (2021). Neutralization of Transport Documents in Road Transport. Transport Problems., 16(2), 87-100. DOI: 10.21307/tp-2021-025.

Maritime Traffic Prediction as a Basis for Air Pollution Estimation

DENNIS MARTEN, CHRIS BÜNGER, CARSTEN HILGENFELD

Abstract Undoubtedly, the reduction of emissions is one of the major cross-industry issues of today. In addition to more stringent ship- and fleet-specific technical regulations, efficient optimization and management of shipping traffic is one of the essential tools to support this process. In this paper we present our processing pipeline for near-real-time air pollution estimation of global shipping traffic for this purpose. We discuss the conceptual and technical challenges posed by the associated large volumes of incoming data, from the reception of AIS messages to the estimation of future voyage routes and their projected greenhouse gas emissions. The estimation of regional and ship-specific emissions, combined with clear visual processing, has the potential to plan or control maritime traffic and associated air pollution in a variety of situations.

Keywords: • PRESEA • EmissionSEA • Maritime • Routing • Next Port Prediction • Emission Calculation

---

CORRESPONDENCE ADDRESS: Dennis Marten, FleetMon | JAKOTA Cruise Systems GmbH, Strandstraße 87, 18055 Rostock, Germany, e-mail: marten@fleetmon.com, Chris Bünger, e-mail: buenger@fleetmon.com, Carsten Hilgenfeld, e-mail: hilgenfeld@fleetmon.com

 ISBN 978-961-95633-0-4

INTRODUCTION

Due to the IMOs target to reduce maritime emissions by 50 % by 2050 compared to 2008, the technical, as well as the organizational challenges for shipping companies and port authorities are noticeably increasing. For this purpose, limits for the technical and operational Carbon Intensity Indicators (EEDI/EEXI and CII) [1] will become mandatory from about 2023. Current approaches in this regard at the ship level primarily see the use of alternative fuels or the treatment of regular fuel oils with scrubbers, as well as the throttling of engine power to comply with these new limits. The throttling is directly linked to efficient scheduling on the part of shipping companies and port authorities. According to the ECSA, there is potential for optimization in this regard [2]. For example, the Rotterdam Port Authority found in an analysis of port calls that 50 % of all ships experience waiting times when entering the port. This is time that could have been compensated for by more efficient and slower engine modes (slow steaming) and Therefore, lower fuel consumption. To support the process of route optimization and scheduling management for shipowners and authorities, we at FleetMon are working on a monitoring system that calculates historical emissions, as well as AI-based predictions for future voyages and emissions. This system should enable the detection of port congestions or general scheduling conflicts and Therefore, allows port authorities to react proactively. Additionally, the predicted ship emissions can be used to warn authorities when regional emission exceedances will be reached.

In this paper we present our per-ship processing pipeline, which ranges from the reception of AIS messages to route prediction and emission calculation, including the calculation of Carbon Efficiency Index. The aim of this paper is to share conceptual and technical challenges we faced and had to overcome especially due to the amount of daily incoming data (more than 500 million AIS messages per day). The pipeline is significantly built on results of the three research projects EmissionSEA, PRESEA and MAREMIS, which are presented in the following section. Subsequently a brief overview of the state of the art of maritime emission calculation and traffic prediction is given. The processing pipeline for predicting expected routes and associated emissions is then presented step-by-step. In the concluding section, future work and connection points for further functionalities of the presented system are presented.

RESEARCH PROJECTS

In this section, we describe the three research projects of FleetMon whose results define essential parts of the here presented processing pipeline here. JAKOTA Cruise Systems | FleetMon itself is one of the largest global companies analyzing and distributing AIS data. With several thousand AIS stations, FleetMon manages one of the largest global AIS networks.

PRESEA[2]

In contrast to current or historical traffic situations, the clear representation of future (predicted) regional traffic is much more complex to realize. Nonetheless, this would be an important tool for logistical purposes and for compliance with safety and environmental regulations. Especially in cases of accidents that block narrow shipping lanes (e.g., the accident of the "EVER GIVEN" in March 2021), a traffic forecast facilitates the management of future shipping traffic in the region. The aim of PRESEA is the development of an AI-based near-real-time system that predicts and visualizes the actual maritime traffic in specific areas of the North and Baltic Seas up to 14 days [3]. In particular, the influence of the weather on vessel travel behavior is to be considered in the traffic forecast.

EmissionSEA[3]

The emerging regulations to reduce emissions described above have inherited a direct reporting obligation of CO_2 emissions. An approach that has already been being pursued with the program "Monitoring, reporting and verification" (MRV) of the EU in European Economic Area since 2018 for a selection of ships [4].

To provide an user-friendly tool to verify reported emission data for authorities and ship owner alike, the EmissionSEA project aims at developing an AIS-based methodology suited for the calculation of CO_2 emissions of individual ships and fleets. Besides AIS data, the derived model uses comparatively accessible vessel particulars, as well as meteorological and oceanographic environmental conditions [5] and is Therefore, suited for a wide range of vessels.

MAREMIS[4]

In MAREMIS, a spatial component is added to the ship-based emission calculation. In the project, a dynamic spatial emission transport model will be developed to estimate air pollution in urban and port areas from calculated ship emissions. This will involve the use of machine learning techniques trained on ship emission and air pollution data obtained from locally stationed sensors.

The model is intended to help port operators understand temporal and spatial relationships of ship emissions under given environmental conditions and derive

2 PRESEA; AI-based traffic forecast to increase maritime safety; www.presea.tech
3 EmissionSEA; Extrapolation of emissions from ships; www.emissionsea.tech
4 MAREMIS; AI-based calculation of air pollution emitted by ships and its dispersion

emission reduction strategies for cities and ports.

STATE OF THE ART

Although the implementation for the prediction of greenhouse gases emitted by ships has numerous different classes of problems, both large and small, we limit ourselves in a brief state-of-the-art analysis presented here to the two dominant topics of traffic prediction and emissions calculation. The overview is by no means exhaustive and is primarily intended to highlight interesting projects related to the topic presented here.

Traffic Forecast

Basically, there are two main approaches to predicting routes that have not yet been completed. First, statistical methods are used to derive probable trajectories from historical AIS data. An example is given in [6], where a model is learned using AIS data to find anomalies in ship routes, to detect ship defects, or to predict routes themselves. Similarly, it was shown in [7] and [8] that hidden Markov models are suitable for finding anomalous ship motion behavior or predicting trajectories.

Such approaches are primarily used for short time periods, e.g., for anomaly detection or to avoid ship collisions. Due to the comparatively rapid increase in uncertainty and propagation of errors, such approaches are rather unsuitable for estimating entire sequences of voyages.

Contrary to the first approach, the second class follows a targeted routing of ships, e.g., from port to port. A very good overview and discussion of different approaches with additional consideration of weather influences is given in [9]. The approach pursued by FleetMon is the calculation of the shortest path in a graph [10]. A similar approach is taken in [11]. Here, a graph is used to find the most cost-effective paths in terms of fuel costs in and around the Emission Control Area (ECA).

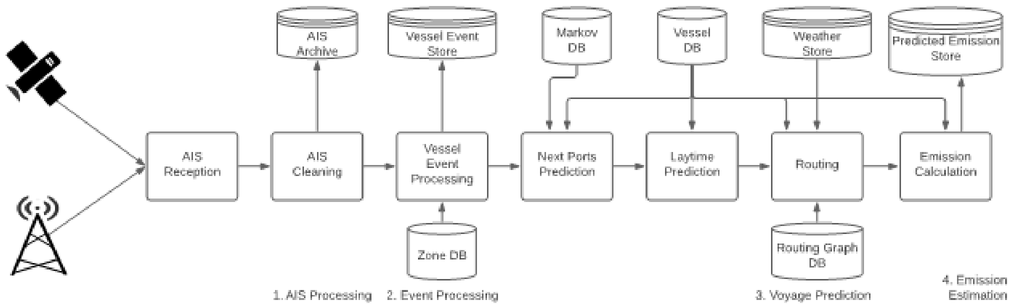
If the sequence of the next port calls of a fleet are known, the ship traffic can be predicted this way. The Markov approach developed in the context of PRESEA to predict future ports was presented and discussed in [3]. We are not aware of any similar approaches in this regard in the maritime context.

Emission Calculation

In accordance with current climate challenges, the calculation and estimation of emissions is a very lively field of research. An extensive historical overview of different used emission models is given in [12]. On the one hand, resistance models, like the STEAM model [13], [14], are described and their theoretical differences to power models or their extending admiralty models are presented. The latter is set up and discussed in a complex form in the greenhouse gas studies of the IMO [15]. The advantage of these is that, in comparison to the STEAM model, one only needs comparatively well available ship characteristics in addition to the AIS data. As will be described later, FleetMon is developing a hybrid system that uses an extended IMO model in addition to the results from EmissionSEA. This includes, for example, the integration of research results on the impact of scrubbers (see for example [16]), which are not yet included in the current iteration of the IMO. Another interesting project is presented in [17], where, in addition to calculating ship emissions, the spatial dispersion of emitted greenhouse gases from ships is simulated and analyzed using a chemistry transport model.

Similar to routing, in addition to the conceptual extension of existing approaches, the primary unique selling point of our pipeline is the technical implementation in near-real time and the spatial prediction of emission dispersion.

Figure 1. The Emission Prediction Pipeline



PROCESSING PIPELINE

In this section, we discuss step-by-step our pipeline from Figure 1 that predicts emissions from global maritime transport. Here, we mainly discuss technical and conceptual details.

AIS Processing

The initial processing of raw AIS data can be split into two phases: reception and decoding.

AIS Reception/Decoding

To manage millions of incoming AIS messages daily, we need a multi-node cluster running multiple TCP readers to process the input of hundreds of AIS streams. Those messages are piped into a multi-node message broker, which further distributes the messages via Publish/Subscribe to numerous AIS decoder processes. In our implementation, this results in a time-sorted stream of over 5000 AIS reports per second.

AIS Cleaning

Due to the overlapping reception ranges of antennas and satellites, the AIS stream is highly redundant. In addition, these duplicates sometimes arrive with a large time delay (network latency). To address this problem, selected kinematic parameters are hashed and indexed with respect to their location and time. In the near future, we plan to additionally consider the motion model of vessels more strongly in this process in order to further optimize the process. The stream of temporally sorted, plausible AIS data now created is fed to an AIS data archive and, furthermore, forwarded to the Event Processor for further processing.

Event Processing

The Event Processing is a fundamental part of FleetMon's data stack and provides a strong foundation for higher-level services that are built upon it. For this we use a multi-stage distributed event streaming architecture. Therefore, we chose the resilient, highly redudant Apache Kafka platform.

The cleared AIS stream is blended with detailed maritime spatial data from FleetMon's curated maritime geodatabase("Zone DB"). The latter includes, for example, port, terminal and berth zones, but also anchor zones or the Emission Control Areas (ECAs), which are important in the context of emission calculations. From these, primary and secondary events are calculated, which are aggregated in a further stage to business related maritime events, such as port calls or voyages.

The generated events are then archived in a dedicated store and parts of the events are forwarded to the following prediction stage. The NoSQL database system Apache Cassandra was chosen as a scalable and highly available event store.

Voyage Prediction

The calculated events provide a logical abstraction of the ship's behavior in an associated state space, which significantly reduces the amount of data to be processed and thus also reduces the technical requirements of the phases based on it. As a consequence, the conceptual part comes more into focus in the following.

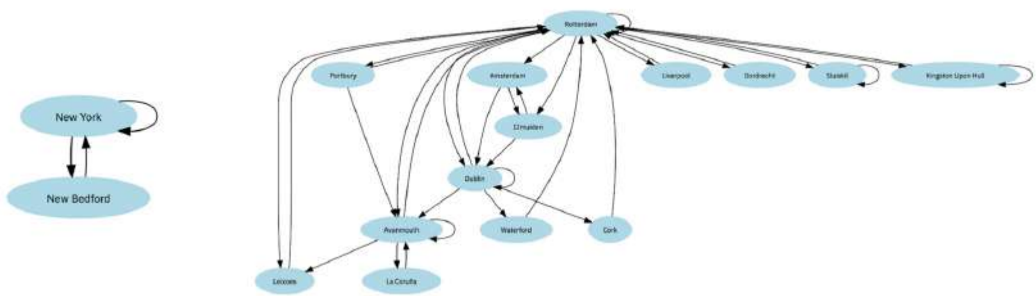
As can be seen in Figure 1, Voyage Prediction consists of three essential phases: The determination of future port sequences, the determination of the associated laytime and the determination of the actual route(s).

Next Ports Prediction

Determining the next port sequences is the basis of traffic prediction. For this purpose, we have chosen a Markov approach (AI model) that is based directly on the processed port call sequences from the previous phase.

In principle, the model is a stochastic process that assumes that the next destination port can be directly inferred from the sequence of the last k ports. Figure 2 shows the graph of port-to-port voyages of a passenger ship and a container ship. In the first case, it is easy to see that accurate predictions about future calls can be made with high probability using only a limited number of last port calls. The graph of the container ship ("Edith") is much more complex. However, the chronological list of port calls shows also that with comparatively few portcalls it is already possible to infer the next port with high probability.

Figure 2: Extracts of the port transition graphs of the passenger vessel "Spirit of New York" (left) and the container ship "Edith" (right).



Tests have shown that with 4-5 last ports very high probabilities can be achieved. For more detailed theoretical insights and an experimental evaluation of FleetMon's next port approach, please refer to [3].

Since then, we have added temporal weighting to the model. Here, the model is split into submodels, which correspond to their own Markov models for a given time range, and finally merged back into a global one. A stronger weighting of the more recent submodels ensures that changes in the travel cycles of vessels are better taken into account.

In [3] it is also described that the structure of the prediction process of the Markov approach is very favorable for direct processing in relational database systems, which makes the deployment as a service comparatively simple and minimizes network costs. We have experienced low latencies in test trials. However, with a high frequency of requests, it may be necessary to use additional database workers in the context of a distributed system.

Laytime Prediction

With the calculation of the sequence of future portcalls, the laytime of the ship in the respective ports must also be determined for the calculation of a complete schedule. Similar to the previous prediction process, the laytime prediction uses a statistical model that has been trained for every vessel on the previously processed historical port and terminal events and is constantly updated.

Here, it is important to automatically filter unwanted port entrances, such as those caused by GPS jitter or port zones that are too wide. This can be done for instance by removing statistically notable short in-port times.

In the future, we plan to improve the statistical model by detecting and incorporating other potential influencing factors, such as seasons or traffic conditions in the port, into the forecast.

Routing

With the calculated destination ports and the expected lay times, a complete schedule can be estimated with the help of the previously mentioned routing graph. The computation of the shortest path in a static graph, i.e., a graph in, which the edge costs are invariant with respect to time, is already widely available in software libraries and other suitable systems, such as geodatabase systems.

Therefore, from the user's point of view, the most important thing in this case is the appropriate modeling of the graph. For this purpose, edges should cover common sea-lanes and port approaches, and nodes should allow for reasonable intersections of the edges and implement navigation restrictions, such as a draught restriction at the beginning of a channel. Care should always be taken to ensure that an unnecessarily large number of graph elements do not negatively affect the latency of the database query. A negative aspect that must be taken into account is the high proportion of manual drawing of nodes and edges. For further details please refer to [10].

In the PRESEA project, we are currently investigating the possibility of including weather influences in the routing. This makes the graph dynamic and the cost (time) to traverse an edge depend on the weather data. In this case it can make sense to wait at a node (e.g., a port) instead of sailing around a storm. The necessary procedures are Therefore, much more complex and expensive and can hardly be found in common libraries. A very good overview, which we also follow, is given in [18] on finding the shortest path in a dynamic graph.

In addition to the emerging question of, which ship might travel through, which storm, these investigations also require an analysis of the influence of the wind or current on the speed or load of the ship's engine. We could already find clear correlations between wind or current and speed over ground for suitable relative inflow angles in first analyses of historical AIS and weather data. Therefore, we plan to learn a simple regression model from the historical data that maps the influence of weather on the reference speed of the ship.

Emission Estimation

The final phase of the pipeline calculates the estimated amount of greenhouse gases emitted. As indicated in the section State of the Art, we use a hybrid model, which consists of the EmissionSEA model and an extended Admiralty model of the IMO GHG studies. Both models are technically comparatively easy to scale by increasing the number of designated service workers and, Therefore, suitable for our application purpose.

The IMO model is a viable choice as it is accepted in the maritime world, its results are verified, it enables the calculation of all significant types of greenhouse gases (CO_2, NO_x, SO_x, PM, etc.) and it is continuously updated with each study. In addition, many fallbacks have been created through cluster analysis and regressions for missing ship data. The latter is a significant problem because for many ships crucial information, such as engine or fuel information is not available, incorrect or has different entries in the databases of different ship data distributors. This is also a reason why other more detailed resistance models are less suited for global maritime traffic emission calculation.

We extended each of the models by incorporating a scrubber model based on investigations in [16]. This resulted in significant changes in sulfur and particulate matter emissions and, Therefore, an improvement of the overall model in appropriate cases as desired.

The emissions are stored in the emission store. This allows for further analyses. Examples for this are spatial analyses of emissions and their dispersion (see MAREMIS), fleet emission analysis or the calculation of import carbon intensity indicators, like the EEOI or the CII.

CONCLUSION AND FUTURE WORK

In this paper, we have presented approaches, methods and challenges that arise in the prediction of globally emitted greenhouse gases from maritime traffic. In addition to an overview of the state of the art, we addressed the conceptual and technical aspects of our processing pipeline step by step in order to be able to process and ultimately visualize the enormous amount of incoming data in a near-real-time manner.

Our goal is to further improve the underlying submodules in various ways. For instance, we want to increase the level of detail of the weather influence of the routing. To this end, we are currently conducting studies using historical AIS data to investigate the influence of wind, waves and currents on engine load and ship speed. Subsequently, a regression model is to be trained, which incorporates the weather influence on the speed over ground into the edge crossing cost function for each ship class. The influence on the engine load will then be used to better map the influence on fuel consumption.

We are also working with shipping companies to evaluate our extended emissions module on real voyage data.

REFERENCES

[1] Bureau Veritas, "Report of the 76th Meeting of Marine Environment Protection Committee," 2021.

[2] European Community Shipowners' Associations, "A Green Deal for the Shipping Industry," 2020.

[3] D. Marten, A. Heuer and C. Hilgenfeld, "Scalable In-Database Machine Learning for the Prediction of Port-to-Port Routes," in Journal for Mobility and Transport, 2021.

[4] E. Union, "Reducing emissions from the shipping sector," 2019. [Online]. Available: https://ec.europa.eu/clima/policies/transport/shipping_en. [Accessed 31 8 2021].

[5] T. Hensel and C. Uge, "Green shipping: using AIS data to assess global emissions," Sustainability management forum, vol. 28, pp. 39-47, 2020.

[6] B. Ristic, B. La Scala, M. Morelande and N. Gordon, "Statistical Analysis of Motion Patterns in AIS Data: Anomaly Detection and Motion Prediction," in 11th International Conference on Information Fusion, Cologne, Germany, 2008.

[7] J. d. Toit and J. v. Vurren, "Semi-automated maritime vessel activity detectionusing hidden Markov models," in Proceedings of the 2014 ORSSA Annual Conference, Paris, 2014.

[8] K. F. Toloue and M. V. Jahan, "Anomalous Behavior Detection of Marine VesselsBased on Hidden Markov Model," in 6th Iranian Joint Congress on Fuzzy and Intelligent Systems (CFIS), Kerman, 2018.

[9] L. Walther, A. Rizvanolli, M. Wendebourg and C. Jahn, "Modeling and Optimization Algorithms in Ship Weather Routing," International Journal of e-Navigation and Maritime Economy, vol. 4, pp. 31-45, 2016.

[10] C. Hilgenfeld, N. Vojdani, F. Heymann, E. Wiessner, B. Kutschera and C. Bünger, "Generating a node in an AIS-based routing graph for improved Estimated Time of Arrival. (Big) Data challenge: using AIS for generating a routing graph," in Journal of Management and Financial Sciences, 2018.

[11] K. Fagerholt, N. T. Gausel, J. G. Rakke and H. N. Psarattis, "Maritime routing and speed optimization with emission control areas," Transportation Research, vol. 52, pp. 57-73, 2015.

[12] I. N. Brown and M. F. Aldridge, "Power models and average ship parameter effects on marine emissions inventories," Journal of the Air & Waste Management Association, vol. 69, no. 6, pp. 752-763, 2019.

[13] J.-P. Jalkanen, A. Brink, J. Kalli, H. Pettersson, J. Kukkonen and T. Stipa, "A modelling system for the exhaust emissions of marine traffic and its application in the Baltic Sea area," in Atmospheric Chemistry and Physics, 2009.

[14] J.-P. Jalkanen, L. Johansson, J. Kukkonen, A. Brink, J. Kalli and T. Stipa, "Extension of an assessment model of ship traffic exhaust emissions for particulate matter and carbon monoxide," Atmospheric Chemistry and Physics, vol. 12, pp. 2641-2659, 2012.

[15] Marine Environment Protection Comittee, "Reduction of GHG Emissions from Ships: Fourth IMO GHG Study 2020 – Final report," International Maritime Organization, 2020.

[16] Y. Zhang and H. Stripple, "Scrubbers: Closing the loop Activity 3: Task 4 Evaluation of exhaust gas scrubber systems for ship applications from a system perspective," IVL Swedish Environmental Research Institute, Stockholm, 2019.

[17] A. Aulinger, V. Matthias, M. Zeretzke, J. Bieser, M. Quante and A. Backes, "The impact of shipping emissions on air pollution in the greater North Sea region – Part 1: Current emissions and concentrations," Atmospheric Chemistry and Physics, vol. 16, pp. 739-758, 2016.

[18] A. Orda and R. Rom, "Shortest-Path and Minimum-Delay Algorithms in Networks with Time-Dependent Edge-Length," Journal of the Association for Computing Machinery, vol. 37, no. 3, pp. 607-625, 1990.

[19] N. Vojdani, M. Ahn and C. Hilgenfeld, "Aufbereitung von AIS-Daten der WSV-N für die Simulation von Seeverkehrssystemen," in Workshop der ASIM/GI-Fachgruppem, Stralsund, 2015.

[20] T.-H. Joung, S.-G. Kang, J.-K. Lee and J. Ahn, "The IMO initial strategy for reducing Greenhouse Gas(GHG) emissions, and its follow-up actions towards 2050," Journal of International Maritime Safety, Environmental Affairs, and Shipping, vol. 4, no. 1, pp. 1-7, 2020.

Solving the Public Transport Dilemma of Smaller or Second-Tier Cities Through Automation

EVELINE BEER, ELMAR FÜRST, SEBASTIAN KUMMER

Abstract Public transport systems have recently gained momentum as an important factor in increasing sustainability in cities. Metro systems, a key component, can be found in most metropolitan areas. In contrast, only few smaller cities – often referred to as "second-tier cities" – have metro systems as part of their public transport offering. Traditionally, the significant investment necessary to construct and operate has made this economically unviable. Automation, however, is found to be key in enabling the adoption of metro systems to local conditions while at the same time providing reliable and timely service for its users. This paper aims to identify the opportunities and challenges of automated metro lines for smaller cities. The analysis will be based on secondary data from existing metro projects. Reference will be made to worldwide projects with a focus on smaller European metro systems. The authors will analyse opportunities and challenges of automation by looking at infrastructure and train size, construction and operational costs, safety, efficiency, sustainability and the impact on the living standards of its users. The results show similarities and overarching themes in the analysed European metro systems. In particular, the authors identified three key factors: flexibility, sustainability and quality of life. This paper provides research into automated metro systems and aims to invite debate around this important infrastructure topic for future studies. It further discusses implications for introducing automated metro-systems in smaller urban areas to facilitate discourse between all stakeholders of such projects.

Keywords: • Urban Mobility • Automation • Transportation • Infrastructure

CORRESPONDENCE ADDRESS: Eveline Beer, Mag. MIM (CEMS), Elmar Fürst, Assoz. Prof. Priv.-Doz. Mag. Dr., Sebastian Kummer, Univ. Prof. Dr., Institute for Transport and Logistics Management, Vienna University of Economics and Business, Welthandelsplatz 1, 1020 Vienna, Austria, e-mail: eveline.beer@wu.ac.at

 ISBN 978-961-95633-0-4

INTRODUCTION

Transport in Europe accounts for almost a quarter of greenhouse gas emissions and is one of the drivers of air pollution in cities [8]. In urban areas, the figure is higher at about 40 % of all CO_2 emissions of road transport are accounted for by urban mobility [9]. Public transport as part of a sustainable urban transport system plays an important role in the fight against climate change and the goal of reducing greenhouse gas emission [14]. A Spanish research study found that public transport plays a key role in decarbonizing urban mobility with a focus on urban movements rather than longer distance trips [30]. Key in reducing the environmental effects of transportation is the modal shift, defined as the relocation of passengers from private cars to alternatives like public transport [10]. Fully automated metro, i.e. driverless trains, can play a key role in increasing the attractiveness and sustainability of the public transport system [33]. Urban rail infrastructure is commonly associated with capital or big cities with the financial means to construct and operate such systems [15]. With regards to automated metro systems, in 2018, almost 25 % of the global operating metro infrastructure have at least one fully automated line in operation. The majority of them represent medium (above 300 to 700 passengers per train) to high (above 700 passengers per train) capacity [32]. This is in line with the view that these systems only make sense in big cities [24]. However, given today's advanced standards of digitalization and automation and related factors, like the evolution of train infrastructure, being discussed later on, there is a case for smaller or second-tier cities to engage in the discussion.

To date, however, there has been a lack of understanding about the potential opportunity of automated metro systems for smaller or second-tier cities. As such, a comparative analysis of existing metro projects in European second-tier capitals may help to understand the challenges and opportunities for future projects. Such an analysis may also help stakeholders to grasp the potential of public transport in smaller regional centres. This paper, thus, aims to answer the following two research questions:

RQ1. What are the key factors that affect urban rail infrastructure projects in smaller cities?

RQ2. What are the opportunities and challenges of automated metro lines for second-tier city urban areas?

To answer these questions, the authors first identify the key factors and second, analyse the challenges and opportunities by looking at existing urban metro projects with a focus on Europe.

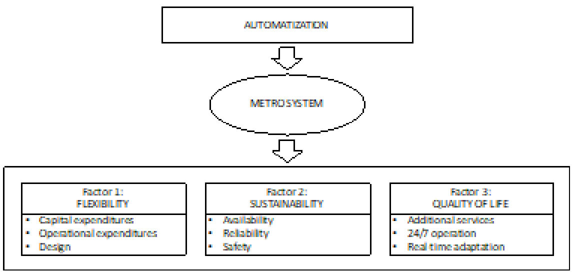
The remainder of this paper is structured as follows. In the next section, a literature review is being performed identifying the key factors. Then, these factors will be analysed as per the example of three existing fully automated metro systems in Europe. Furthermore, the authors will discuss opportunities and challenges of urban rail systems in second-tier cities. The paper concludes with the results of the analysis. In addition, the authors summarize the main insights and contributions of this research and outline scientific challenges and opportunities for future research.

LITERATURE REVIEW

The first fully automated metro system was introduced in 1983 in the city of Lille, France with the key objectives amongst others of increased safety and performance and low cost of operation [17]. Automation itself in metro systems can be determined by four standardized grades of automation [34]. For the purpose of this paper, only Unattended Train Operation (UTO) and hence the highest grade of automation will be discussed. While the biggest growth in metro automation can be seen in Asia, Europe comes second and is also the leader in conversion projects [32]. According to the Union Internationale des Transports Publics (UITP), fully automated metro systems offer various advantages for their eco-system and beyond in the areas of mobility, safety, economic balance, ecological imprint and customer service [33]. As mentioned in the introduction, new technologies with regards to automation of metro systems offer more flexibility in terms of construction, as well as operating costs. Both infrastructure and fleets can be optimized in cost terms due to improved line design, train frequency, optimal speed and adaptation to off-peak hours. A reduction in infrastructure costs can be achieved through shorter trains, hence shorter platforms and smaller stations. Regarding the fleet, optimized operations through automation enable investors and operators to reduce the overall amount of trains or the number of cars per train [33]. The flexibility fully automated trains and infrastructure offer is also of high importance in the operations of such systems. Efficiency is hereby a factor, both in terms of a better use of resources across the daily passenger volumes, but also in terms of energy savings [21]. In the case of the Prague Metro, Siroky et al. further found that one advantage of moving the planned expansion of one metro line to a fully automated system is an increase safety standard due to a fully mitigated human failure risk [13]. In addition, 75 % of fully automated metro systems worldwide are equipped with platform doors [7]. Higher service frequencies have also shown to provide wider economic benefits to the cities they run in [1]. An enhanced experience for passengers is given through higher flexibility when it comes to real-time adaption of train service, but also through higher safety and security measures through continuous monitoring and detection systems [7]. It is suggested that fully automated metro systems change the user experience through reduced waiting times and less crowding on platforms at an only low marginal cost [16]. Acceptance of users plays an important role and was found to be very high, ultimately leading to more sustainable mobility concepts for cities and sustainable long-term behaviour [19]. It was found that fully automated metro systems can increase productivity and efficiency in terms of more flexible and reliable operations [4]. Another study as well found that autonomous metro trains lead to more efficient and reliable passenger movements [6]. Metro systems in second-tier cities are found to be a clear alternative in order to reduce traffic congestion and hence foster sustainable development of urban transportation [38]. An increase in reliability of metro systems can be directly linked to operational efficiency [2].

Based on the prior literature review, the authors identified three key factors that can affect the decision of smaller or second-tier cities to consider a metro system. Firstly, automation impacts the capital and operational expenditures and offers flexibility in terms of number of trains introduced while in operation, hence Factor 1 is named Flexibility. Secondly, through automation does not only lead to higher availability, but also to higher reliability and enhanced safety, which attracts more passenger numbers over time. This hence enables a shift from personal vehicles to public transport and ultimately leads to a more sustainable transport eco-system. Factor 2 is hence named Sustainability. Thirdly and adding to the second point prior, a better customer service in terms of frequency, 24/7 overall service, as well as real-time adaptation in case of special events, can lead to an improvement in quality of life, hence the living standard of its users. Factor 3 is named Quality of Life. The three identified factors are presented in figure 1 below.

Figure 1. Identified factors



METHODOLOGY

Research approach

The methodology section of this paper includes the data collection and the data analysis parts. Firstly, the data collection provides details on the reports and data obtained. Secondly, the data analysis presents the methodology that is being used to analyse the opportunities and challenges of automated metro systems in the selected projects based on three pre-determined factors. The projects are being selected based on the size of the city in combination with the capacity of the metro system.

Analysis and selection criteria

For the analysis, existing fully automated metro systems in European, as well as worldwide cities were selected. The final selection was carried out according to two criteria: First, the size of the city and its respective metropolitan area. Metropolitan area is hereby defined as a city and its surrounding area including daily commuting areas [18]. Only cities well below one million of inhabitants were considered. Second, by the capacity of the metro system, only considering low to medium metro capacities. The latter defined by passenger capacity per train, according to the criteria by UITP [32]. Moreover, the selection was further narrowed down by geography, given the European focus of this paper. However, data from global metro systems was considered given the comparability of the metro systems in question. Figure 1 presents existing metro systems in Europe and in the US with low to medium capacity. The selected cases are shown in the right-hand side of the figure [32].

For the purpose of this analysis, another selection was conducted to enable the authors to fully apply the identified criteria to the selected metro systems and spark discussion. Three metro systems were selected: Copenhagen Metro because of it being the first driverless metro in Europe, designed as a fully automated system from the start [27]. Brescia metro system was selected because of its medium city size and its success connecting a second-tier city within its city limits [24]. Nuremberg metro, Germany's first driverless metro, was selected being the pioneer project for rolling stock companies going driverless in Europe [12]. The selection criteria described allowed the authors to access a vast supply of available data points.

Figure 2. Selection criteria and results

	Population (City)	Population (Urban Area)	Metro Capacity
Lausanne	139,000	449,000	<300
Rennes	209,000	359,000	<300
Lille	228,000	1,069,000	<300
Toulouse	433,000	1,039,000	<300
Miami	470,000	470,000	<300
Brescia	184,000	487,000	300 to 700
Lyon	472,000	1,736,000	300 to 700
Nuremberg	499,000	512,000	300 to 700
Copenhagen	548,000	1,361,000	300 to 700
Vancouver	600,000	2,610,000	300 to 700

	Population (City)	Population (Urban Area)	Metro Capacity
Brescia	184,000	487,000	300 to 700
Nuremberg	499,000	512,000	300 to 700
Copenhagen	548,000	1,361,000	300 to 700

Source: [5], [8], [20], [35].

Data collection

The authors collected secondary data from various industry sources including reports from consultancies, governments, advisors, industry journals, as well as directly from the operating entities and manufacturers. One of the unique advantages of secondary data is that it is available in great amounts [22].

Data analysis

In the data analysis part of this research, the authors first analysed each selected metro system on an individual basis using the three key factors for interpretation. Consequently, the authors conducted an analysis of cross-case patterns among the selected metro systems. The identified commonalities represent the overarching challenges and advantages. Finally, the key factors provide a foundation for assessing future implications for the relevant stakeholders.

RESULTS

The data analysis showed overarching commonalities across the various metro systems analysed.

In Copenhagen, the automated metro enabled the city to run 24/7 operation and to quickly adapt to changes in capacity due to exceptional events [21]. Like comparable metro systems, Copenhagen runs shorter trains. In addition, a dual-track system allows maintenance while service is being continued [11]. The first driverless metro system in Northern Europe was a success and led to more driverless metro lines in the city [31]. The latest driverless metro line, called Cityringen, is about to reach ca. 25 % of people who are currently not users of the public transport system. Upon completion, 85 % of places in the centre and its neighbourhoods will make up less than a 10min from a metro station [28]. Platforms have been designed to be smaller to fit into the overall urban architecture. Moreover, stations have been designed with a focus on natural light getting through [27]. According to Wavestone, the service reliability was at 98,7 % in 2017. Both lines offer 3G to its passengers on the entire metro network [37]. Sustainability has been an important part for the metro system from the early planning periods in the 90s. A rising sea level and an increasing number of extreme weather events led to operational adaptations over time [3].

The Italian city of Brescia opened its fully automated metro system, the Brescia Metrobus, in 2013. The length of the trains was tailored to the demand and planned short frequencies. Stations were designed in shorter distances to lower the hurdle of shifting transport modes for its users. The installed screen doors also help to avoid strong winds from the tunnel. The system enables quick changes in the number of trains in line with fluctuating passenger numbers. It further allows its staff to assist passengers and take care of service-related issues [26]. The metro system was designed with a several factors in mind. First, the metro in general provides users with short transit times and it integrates and improves the interchanges between different transport modes. These factors were considered essential to incentivize a modal shift towards public transport. In addition, an increase in the use of public transport away from private vehicles supports a reduction in air and noise pollution. Brescia metro is further an example of lower capital and operational expenditures, as well as operating flexibility [24]. The success in terms of ridership after its first year showed the importance of a long-term urban vision. Not only with regards to the adapted infrastructure, but also the inter-modularity including a bike sharing scheme, but also the expansion into the city surroundings with other modes of transport [23].

In Nuremberg, Germany's first driverless metro line, service intervals were down to 100 seconds, compared to 200 seconds with a driver. Trains can quickly get automatically introduced into the current operation in case of higher passenger numbers or events. A 15 % reduction in energy consumption due to automatic adjustment of speed was achieved [12]. Although capital expenditures were higher back at the time, especially for automation technology, which was new for metro systems, operational costs are lower [29]. Furthermore, the German Aerospace Center (DLR) found that automation led to a 99 % reliability figure and to 800,000 produced km less per year, resulting in € 38 m savings in operational costs due to lower vehicle demand [7]. Distance between stations is less than on conventional metro systems with 880 m and the operator is offering a route planner app and WIFI in all stations and on trains [37]. In contrary to most of the existing fully automated metro systems, Nuremberg's metro lines are not equipped with platform doors, mainly due to the conversion requirements of the old infrastructure [25]. Figure 3 highlights and summarizes the main characteristics of the selected European metro systems based on the identified three key factors.

Figure 3. Main characteristics of the selected metro systems

Cities / Factors	**Factor 1: Flexibility** (Capital and Operational expenditures, Design)
Copenhagen	□ Smaller platforms □ Shorter trains □ Platforms integrated in urban architecture □ Ongoing climate conscious adaptations
Brescia	□ Lower capital expenditures □ Lower operational expenditures □ Shorter trains □ Shorter distances between stations
Nuremberg	□ Higher capital expenditures □ Reduced operational expenditures □ 15% reduced energy consumption □ 800,000 produced km less per year

Cities / Factors	**Factor 2: Sustainability** (Availability, Reliability, Safety)
Copenhagen	□ Success initiated 2nd metro line □ High acceptance by users □ 85% of places are less than 10min walk from any station □ 98.7% reliability
Brescia	□ Higher number of stations to encourage modal shift □ Short transit times □ Safety screen doors □ Inter-modularity with other transport modes
Nuremberg	□ 100s service intervals □ Shorter distances between stations □ No platform safety doors □ 99% reliability

Cities / Factors	**Factor 3: Quality of Life** (Additional services, 24/7 operation, Real-time adaptation)
Copenhagen	□ 24/7 operation □ Higher number of trains in exceptional events □ Natural light at stations □ 3G on entire metro network
Brescia	□ Adapted frequency □ 24/7 monitoring □ Assistance by staff members □ Bike sharing scheme
Nuremberg	□ Automatic introduction of new trains for events □ Route planner app □ WIFI in all stations and on trains

DISCUSSION

The obtained results provide great insight and significance in answering the research questions laid out earlier. In particular, the analysis of factor 1: flexibility showed similarities across the analysed metro systems. However, Nuremberg metro system proved to be an outlier. This is mainly due to the old infrastructure being upgraded for automated operation. An interesting aspect in the analysis was found in the difference between academic papers and industry journals. The latter often have a key focus on capital and operational expenditures, while academic papers often put the emphasis on the impact of sustainability and user acceptance. The analysis of factor 2: sustainability showed that automation consistently provides for high reliability figures. Safety measures are higher than on conventional metro systems. One exception is Nuremberg metro system again because of the missing platform doors, which are typical for automated metro systems. In addition, shorter distances between stations and transit times in general seem to be of high importance for users to switch to public transport. By analysing factor 3: quality of life, the authors found that thanks to automation, an immediate introduction or reduction of the number of trains, as well as real-time adaptation of frequencies help to avoid crowded platforms. This also ties in with factor 1 as adjusted train numbers and frequencies help to reduce the overall energy consumption and consequently operational expenditures. These features are directly linked to the technology of automation and are not available on conventional metro systems. Hence, it can be said that automation helps to better project operational expenditures in the future, an important factor for smaller or second-tier cities. This information can already be used in the planning and design phase of the metro system. Linking back to factor 1, the analysis has shown that the metro design differs if metro system has been designed as fully automated system from the start. In general, the analysis provided insight into the success factors of fully automated metro systems presented through factor 2 and 3. Inter-modularity and the integration with transport modes is key for user acceptance and growth in passenger numbers. Furthermore, a metro system designed to fit the existing urban architecture plays an important role.

CONCLUSION

The aim of this paper was to define and understand the challenges and opportunities of automated metro systems in smaller or second-tier cites in Europe. Three key factors were identified that can affect the decision of smaller or second-tier cities to consider a fully automated metro system. The authors adopted a qualitative approach using secondary data from three existing fully automated metro systems in Europe. The characteristics of the selected metro systems were consequently analysed in line with the three identified factors: flexibility, sustainability and quality of life. The results show that automation indeed offers an opportunity for smaller or second-tier cities to build a metro system as part of their sustainable public transport offering. In particular, the results show that adaptation to the specific urban city architecture plays a key role for the metro system's success with users. Moreover, one of the key findings is that despite high capital expenditures, operational expenditures are reduced through automation. In addition, high frequencies, real-time adaptation and additional services seem to improve the living standard of the users. However, these findings need to be viewed in the light of their limitations. Thus, the authors invite future researchers to examine more European data points, i.e. metro systems, to fully understand the potential of driverless metro systems for second-tier or smaller cities. Moreover, three existing fully automated metro systems have been discussed, but the authors have been relatively silent on the topic of conversion of a conventional metro system to a fully automated one. Future research may examine the extent to, which these conversions do or do not offer an opportunity for the adaptation of automation for smaller or second-tier cities. It can be concluded that research into the opportunities and challenges of automated metro systems for smaller or second-tier cities is still in its infancy. The authors have taken first steps toward a better understanding of the potential of said systems for cities in Europe. We hope that both the findings and implications presented in this piece of research will help steer the discussion and support future research, as well as projects in the urban mobility and digitalization field.

REFERENCES

[1] Canavan, S., Barron, A., Cohen, J., Graham, D. J., and Anderson, R. J. (2019). Best Practices in Operating High Frequency Metro Services. In Transportation Research Record 2019 (Vol. 2673(9) 491–501).

[2] Canavan, S., Graham, D. J., Melo, P. C., Anderson, R. J. (2012). Identifying the Main Drivers of Technical Efficiency of Urban Metro Systems using Stochastic Frontier Techniques. 1st European Symposium on Quantitative Methods in Transportation Systems (4-8th September 2012). Lausanne, Switzerland.

[3] Climate ADAPT (2021). Case Study: Integrating adaptation in the design of the metro of Copenhagen. Available at: https://climate-adapt.eea.europa.eu/metadata/case-studies/integrating-adaptation-in-the-design-of-the-metro-of-copenhagen.

[4] Cohen, J.M., Barron A. S., Anderson, R. J., Graham, D. J. (2015). Impacts of Unattended Train Operations on Productivity and Efficiency in Metropolitan Railways. In Transportation Research Record 2534.

[5] Council of Europe (2021). Intercultural cities programme. Available at: https://www.coe.int/en/web/interculturalcities/copenhagen.

[6] Cui, J., Nelson, J. D. (2019). Underground transport: An overview. Tunnelling and Underground Space Technology (Vol. 87, pp. 122-126).

[7] Deutsches Zentrum für Luft- und Raumfahrt - DLR (2018). Bahnautomatisierung aus verschiedenen Blickwinkeln. Vorlesung am 6.11.2018. Institut für Verkehrssystemtechnik. Available at https://elib.dlr.de/122050/1/PR_TS_VDI_AK_Bahn_Automatisierung_DLR_181106_final.pdf.

[8] European Commission (2016). A European strategy for low-emission mobility. Available at: https://ec.europa.eu/clima/policies/transport_en.

[9] European Parliament (2020). Policy Department for Structural and Cohesion Policies Directorate-General for Internal Policies. PE 652.211. Sustainable and smart urban transport. Available at: https://www.europarl.europa.eu/RegData/etudes/STUD/2020/652211/IPOL_STU(2020)652211_EN.pdf.

[10] Fürst, E. (2014). Making the way to the university environmentally sustainable: A segmentation aproach. In Transportation Research Part D: Transport and Environment (Vol. 31, pp. 1-12).

[11] Intelligent Transport (2009). The Copenhagen Metro: a 24/7 system. Available at:

https://www.intelligenttransport.com/transport-articles/568/the-copenhagen-metro-a-247-system/.

[12] Intelligent Transport (2013). Nuremberg: Germany's first driverless metro systems celebrates its fifth birthday. Available at: https://www.intelligenttransport.com/transport-news/11410/nuremberg-germanys-first-driverless-metro-system-celebrates-its-fifth-birthday/.

[13] J. Siroky, J., Nachtigall, P., Tischer, E., Magdechova, K. (2018). Possibilities of Introduction of Automated Operation on the Prague Metro. In Proceedings of 22st International Scientific Conference. Transport Means 2018. Trakai, Lithuania.

[14] Jochem, P., Rothengatter, W., Schade, W. (2016). Climate change and transport. In Transportation Research Part D: Transport and Environment (Vol. 45, pp. 1-3).

[15] Knupfer, M. S., Pokotilo, V., Woetzel, J. (2018). McKinsey&Company. Elements of success: urban transportation systems of 24 global cities. Available at: https://www.mckinsey.com/~/media/McKinsey/Business %20Functions/Sustainability/Our %20Insights/Elements %20of %20success %20Urban %20transportation %20 systems %20of %2024 %20global %20cities/Urban-transportation-systems_e-versions.ashx.

[16] Moccia, L., Allen, D.W., Laporte, G., Spinosa, A. (2020). Mode Boundaries of Automated Metro and Semirapid Rail in Urban Transit.

[17] Nakache, F. (1984). Lille metro: Description of the VAL control system. 34th IEEE Vehicular Technology Conference 1984 (pp. 249-254). Pittsburgh, Pennsylvania.

[18] OECD/European Commission (2020). Cities in the World: A New Perspective on Urbanisation. OECD Urban Studies. OECD Publishing. Paris.

[19] Pakusch, C., Bossauer, P. (2017). User Acceptance of Fully Autonomous Public Transport. 14th International Joint Conference on e-Business and Telecommunications (ICETE 2017). (Vol. 2: ICE-B, pp. 52-60).

[20] PopulationStat (2021). World statistical data. Available at: https://populationstat.com.

[21] PTI (2011). Automated metro operation: greater capacity and safer, more efficient transport. Available at: https://metroautomation.org/wp-content/uploads/2012/12/PTI_2011_6.pdf.

[22] Rabinovich, E. and Cheon, S. (2011). Expanding horizons and deepending understanding via the use of secondary data sources. Journal of Business Logistics (Vol. 32, No. 4, pp. 303-316).

[23] Railway Engineering (2014). The Brescia Metro: pride of the city. Available at: http://railwayengineering.it/the-brescia-metro-pride-of-the-city/.

[24] Railway Gazette (2008). Automation in a medium-sized city. Available at: https://www.railwaygazette.com/automation-in-a-medium-sized-city/32869.article.

[25] Railway Technology (2008). Nuremberg Automatic U-Bahn. Available at: https://www.railway-technology.com/projects/neuremburgautobahn/.

[26] Railway Technology (2013). Available at: https://www.railway-technology.com/projects/brescia-driverless-metro-system/.

[27] Railway Technology (2018). Around the world: 1 000km of fully automated metros. Available at: https://www.railway-technology.com/features/around-world-driverless-metro-lines/.

[28] Ramboll (2019). The Copenhagen Metro. Available at: https://ramboll.com/projects/rdk/copenhagen%20metro.

[29] Schmidt, K. (2007). Economic Aspects of Metro Automation in Nuremberg. In Public Transport International. International Association of Public Transport. (Vol. 56, Issue 2, pp. 28-30).

[30] Sobrino, N., Monzon, A. (2013). Management of Urban Mobility to Control Climate Change in Cities in Spain. In Transportation Research Record: Journal of the Transportation Research Board No. 2375 (p. 55-61). Transportation Research Board of the National Academies. Washington, D.C.

[31] UITP (2012). Observatory of Automated Metros. Available at: https://metroautomation.org/copenhagen-metro-celebrating-10-years-of-successful-operation/.

[32] UITP (2018). Observatory of Automated Metros. World Report on Metro Automation. Statistics Brief. Available at: https://www.uitp.org/publications/world-report-on-metro-automation/.

[33] UITP (2019). The Benefits of Full Metro Automation. Knowledge Brief. Available at: https://www.uitp.org/publications/the-benefits-of-full-metro-automation/.

[34] UITP 2012. What is Metro Automation? Metro Automation Facts, Figures and Trends. Available at: https://metroautomation.org/wp-content/uploads/2012/12/Automated_metros_Atlas_General_Public_2012.pdf.

[35] Unites States Census Bureau (2021). QuickFacts. Available at: https://www.census.gov.

[36] Wang, Y., Zhang, M., Ma, J., Zhou, X. (2016). Survey on Driverless Train Operation for Urban Rail Transit Systems. In: Urban Rail Transit (2 (3-4), pp. 106-113).

[37] Wavestone (2017). World's Best Driverless Metro Lines 2017. Market Study on Driverless Metro Lines and Benchmark of Network Performance. Available at: https://www.wavestone.com/en/insight/best-driverless-metro-lines-world-2017/.

[38] Zhao, F., Cao, H., Lu, T. (2021). What Impact Will the New-Built Metro Bring to the Transportation of Second-Tier Cities? From the Perspective of a Multilayer Complex Network. In Urban Rail Transit (7, pp. 117-127).

Synthetic Population Generator for Activity-Based Travel Demand Models

ANDRÉ MAIA PEREIRA, JAKUB VOREL, ONDŘEJ PŘIBYL, VOJTĚCH MYŠKA, MILAN KŘÍŽ

Abstract The traditional transport models, such as the well-known four-step model have certain limitations especially with respect to modelling changes in travel behaviour due to certain policies. This has been recently proven during home-office work due to COVID-19 pandemic. The traditional models were not able to cope with that and the need for new approaches able to understand the motivation for travel are needed. The primary motivation to travel is to participate on certain activities. If we understand where and when (optimally also why) a person participates on certain activity, we can rather easily derive the need to travel. This is the basic principle of so-called Activity-based approach to travel demand analysis. The activity-based models (e.g., the tool MATSim - Multi-Agent Transport Simulation) have, however, high demand on data. Each person in the (typically large-scale) study area must be assigned to daily activity plans and derived travel attributes. On this way, it is necessary to have the knowledge of the socio-demographics, activity chains, and travel behaviour of the study area. As we cannot collect data about everybody, a synthetic population needs to be generated. In this paper, we present a methodology that is used to generate a synthetic population and another one for the travel demand of this population. It is applied to a case study in the catchment area of Ústí nad Labem (Czech Republic). We identify data needs for the approach, as well as the data available in the Czech Republic. Based on the gaps between requirements and available data, as well as the accuracy of each methodology, results of the proposed approach covering demographic transition allowing merging of the data, and travel demand generation using the Eqasim framework (developed by the team of MATSim) is presented.

Keywords: • Activity-Based Models • Synthetic Population • Travel Behaviour

---

CORRESPONDENCE ADDRESS: André Maia Pereira[1], Jakub Vorel[2], Ondřej Přibyl[1], Vojtěch Myška[2], Milan Kříž[1]; [1] Czech Technical University in Prague, Faculty of Transportation Sciences, [2] Czech Technical University in Prague, Faculty of Architecture, e-mail: eng.andremaia@gmail.com

 ISBN 978-961-95633-0-4

INTRODUCTION

Transportation engineers have been for decades using various simulation models to measure impact of changes in infrastructure, improvements in control algorithms, but also influences of new technologies, such as cooperative vehicles or new travel modes. Traditional transport models have only limited capabilities in this respect as they are focusing exclusively on travel activities ignoring distribution of non-travel activities in space and time. Recently, this was proven by the sudden and drastic changes of travel behaviour due to COVID-19 restrictions [1]. New approaches in transport modelling are Therefore, reflecting the non-transportation activities and socio-demographic characteristics of people with the aim to reflect the behaviour of people.

The most widely used type of travel demand models in current practice is the macroscopic transport model. Here, the typical approach is to divide study area into zones and centroids of these zones represent origin and destination of all trips from and to the zones. The demand is usually represented by matrices among these zones. The focus of macroscopic travel demand models lies in aggregated modelling of travel demand. The best-known principle used within the trip-based approach is the four-stage (or four-step) model [2].

They were established already in the 1950s and were aimed at measuring impact of major building projects and on a very aggregated level. These motivations result in the inability of traditional models to adequately perform in complex policy applications [3]. One fundamental limitation of the traditional trip-based models: they ignore the fact that travel as a demand is derived from activity participation decisions. People travel to participate activities [4, 5]. All this together led to creation of new modelling approach – so called Activity-based approach to travel demand analysis [6, 7].

Activity-based models work at a disaggregate level of persons and households [8]. Travel is considered to be one of many attributes of an activity. The origins and destinations of trip are usually not the zone centroids, but rather precise coordinates in space. The principle of derivation of demand from activities distributed in space and time enables new dimensions of transport modelling. Activity-based models also can incorporate detailed person-level and household-level attributes, and produce detailed information across a broader set of performance metrics. Activity-based models are considering sequences or patterns of behaviour, and not individual trips, as the relevant unit of analysis. The activity participation is influenced by spatial, temporal, transportation, and interpersonal interdependencies. Typical activity-based models focus on task of scheduling and rescheduling of activities. All these characteristics make it a very strong tool for modelling impact of new policies or travel modes [9] or already above-mentioned unexpected situations, such as COVID-19 pandemic [10, 11].

An example of an activity-based model is MATSim (Multi-Agent Transport Simulation). MATSim is an open-source framework for implementing large-scale agent-based transport simulations [6, 12]. MATSim is based on the co-evolutionary principle. Every agent (modelled person) repeatedly optimizes its daily activity schedule while in competition for space-time slots with all other agents on the transportation infrastructure. Each cycle starts with an initial demand arising from the study area population's daily activity chains. During iterations, this initial demand is optimized individually by each agent. Daily plans are composed of a daily activity chain and an associated score. The score can be interpreted as an econometric utility [12] and is the main tool for optimization.

Nevertheless, it is not always possible to conduct a nation-wide census survey of activity plans. For this reason, the focus lies on the so-called synthetic population, which mimic real population parameters on aggregated level and not necessarily on the level of individuals [13]. This approach also brings several limitations and challenges, which we will address and discuss within this paper. The synthetic population can be used for various purposes: generated trips can be inputted into transportation models, while occupation of buildings can be useful for energy demand modelling or for analysing how the visitors of places are moving during the day.

The need for an activity-based-analysis of travel behaviour was identified within a project Smart City – Smart Region – Smart Community[2]. It is a Czech national project focusing on travel behaviour research of citizens of the Ústí and Labem catchment area. First, a series of surveys was conducted to collect data among others about the potential and limitations for using car sharing or ride sharing, as well as people's reasons to use individual cars [14, 15]. The resulting mathematical models will be used to provide reasonable scenarios demonstrating effects of changes of travel behaviour on traffic and environmental indicators.

The rest of this paper has the following structure: The section Methodology focuses on how the available data for the case study in the Czech Republic was used by the Eqasim framework [16], in order to generate necessary files for a MATSim model. In fact, two methodologies will be presented – A demographic transition to get comparable data for the year 2016, and the generation of a synthetic population and corresponding travel demand. Then, we present and discuss the resulting model. Conclusions of the paper cover overview and discussion of the main findings,

2 http://smart-mateq.cz/projekty/projekty-smart/smart-iti/

followed by a short insight of the next steps in the project.

METHODOLOGY

Synthetic populations are typically generated from census data combined with other data on buildings, facilities, and land use. Other sources of information, such as Household Travel Surveys (HTS), can enrich the synthetic population by a synthetic travel demand.

Census surveys often provide a number of characteristics of persons, especially their demographics, place of employment, education, data on commuting to work and schools and their housing conditions. Land and buildings registers may offer detailed technical attributes that allow more precise location of people activities. Regarding travel surveys, they reveal the patterns of transport behaviour per groups of people, such as, which transport modes were used, trip distance and duration, trip purposes, origin and destination of trips, and even other characteristics of relevance.

The synthetic population by combining the various data sources and by disaggregating characteristics and activities on individual level provides an excellent opportunity for detailed and comprehensive modelling of urban processes. When combined with the samples of travel surveys synthetic populations can become very powerful tool for modelling of urban mobility.

Creating the synthetic population in the Czech Republic is not an easy task. Census data are collected every ten years with the latest available one being conducted in 2011[3]. On the other hand, the latest Household Travel Surveys (HTS) considering the Ústí and Labem catchment area were procured around 2016. Therefore, for the use of the Census data within the inter-census period they need to be updated based on other annual statistics. Therefore, the population of the study area - capital Ústí nad Labem and its catchment area (22 municipalities) - must be updated. In the following paragraphs we present the steps undertaken to generate the synthetic population (update of Census 2011 to the year of 2016) and travel demand (using the Eqasim framework).

Synthetic Population and Travel Demand

The generation of the synthetic population and its travel demand is based on the Eqasim framework and source code files for the São Paulo scenario[4]. The framework is based on the synpp package[5] to chain different algorithms in Python scripts (stages)

3 https://www.czso.cz/csu/czso/scitani-lidu-domu-a-bytu-2011
4 https://github.com/eqasim-org/sao_paulo
5 https://github.com/eqasim-org/synpp

used to a larger pipeline setup that then generates MATSim [6, 12] input files. In general, as every input data is different, every algorithm requires specific solutions. However, we will use the São Paulo case as the standard procedure to compare how we contribute to the research area.

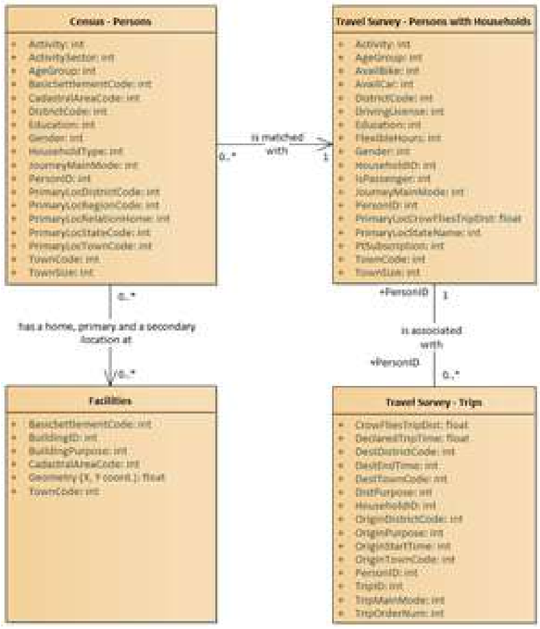
A typical Eqasim's chain (sequence) of stages follows the following steps:

1. (Z1): load zoning data.
2. (C1): load raw census data.
3. (C2): clean and update raw census data (C1).
4. (H1): load raw household travel survey data.
5. (H2): clean and update travel survey data (H1).
6. (P1): merge census (C2) and travel survey (H2) data, and generate a synthetic population.
7. (F1): load facilities/buildings data.
8. (F2): assign facilities to zones (Z1) and classify them according to trip purposes.
9. (P2): define home and primary locations, and generate the travel demand of the synthetic population, corresponding to the Origin-Destination (OD) pairs from merged data (P1) based on availability of the facilities (F2) within the zones area of each trip's OD pair.
10. (P3): define secondary locations, and generate the activity patterns, based on distance and mode distributions from merged data (P1), and based on availability of the facilities (F2) within the zone area of the primary location.

Fig. 1 shows the Entity-Relationship diagram representing the data model utilized during the process for synthetic population of persons based on an update of Census 2011 data, data on facilities[6], and travel demand resulting from two household travel surveys. One at national level (Česko v pohybu[7], referred as National HTS) and another at city level (City HTS) [17]. Aggregations and generalization of attributes was necessary for both travel surveys, Census 2011 and facilities data to transform the attributes to common metrics. Because the City HTS only provides information on trips having origin or destination in the city of Ústí nad Labem, the National HTS was used to cover travel demand of the rest of municipalities in the study area, in spite of providing only small sample for the study area.

6 https://www.czso.cz/csu/rso/registr_scitacich_obvodu
7 https://www.ceskovpohybu.cz/

Figure 1. E-R diagram for the data model used in the Eqasim framework



Multiple zones had to be loaded in step Z1: municipalities (town on Fig. 1) for the National HTS, basic settlement units for Census 2011 and city districts (cadastral area on Fig. 1) for the City HTS).

Raw Census 2011 data (step C1) is loaded. Then, step C2 deals with the synthetic population that represents real population of persons living in the study area in 2016;, which was generated by stochastic simulation of several demographic transition processes that update Census 2011 data. The natural change is based on natality and mortality rates, otherwise by the residential mobility.

First, the deaths of persons are simulated for each year by converting the death rates[2] to death probabilities attributed to individual persons based on their age and gender. Died persons are removed from synthetic population in each year. The newly born persons are simulated by using the natality rates[3] that are converted to probability of a new child being born based on women age. The gender of newly born children is probabilistically attributed based on general proportion of 100 females per 105 males. Newly born persons are added to the synthetic population in each year. The relocation of persons in the municipality is done by simply adding persons from a demographic database that have the municipality as new residence. The location of residence is provided only on the level of municipalities. This demographic database:

2 https://www.czso.cz/csu/czso/umrtnostni-tabulky-metodika
3 https://www.czso.cz/csu/czso/porodnost-a-plodnost-2011-2015

inner and outer migration[4], includes: age, gender, previous and new residence. The relocation of persons out of municipalities is based on the distribution of age and gender of persons in the demographic database. The sampled persons are consequently erased from synthetic population.

The transition processes are based exclusively on age, gender and location data with other characteristics not entering the simulation. Moreover, the aging is simulated by simply increasing the person's age by one in each simulation cycle.

The missing values of persons' characteristics of economic activity, the sector of economic activity, zone location, education, the type of housing and family status are completed in each cycle by sampling from the records of persons with known values in each subgroup defined by combination of characteristics of gender and age. If the subgroups have no filled values, then only two age subgroups: 0-14 and 65 and older are used for sampling of missing values.

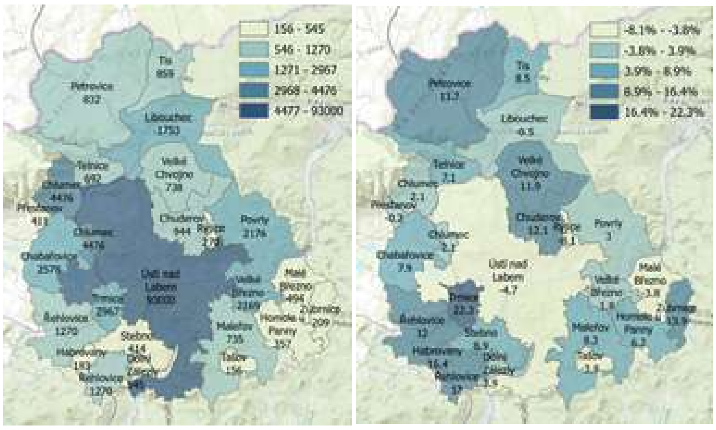
Fig. 2 describes changes of population in the municipalities of the study area between 2011 and 2016 as result of the demographic transition procedure. The decrease of population of the biggest municipality, Ústí nad Labem, and increase of population in small municipalities in its hinterland indicates the suburbanization process and resulting changes in commuting pattern in the study area.

Next steps enrich the synthetic population by travel demand data. Steps H1 and H2 remove trips that have inconsistent data, as in the São Paulo scenario. The following trips are removed: a) first and last trips not at home, b) moving from one place to another without a reported trip. In a different way, we also removed trips with repeating purpose (for instance going from work to work) as they seem to be wrong answers accounting every change of vehicle as a trip, and trips with unknown distances and times.

One key feature of our algorithm is that as we are defining the study area to only the catchment area of Ústí nad Labem, any trip from or going out of the area will start/end at the "city gates" (entry/leaving points of the road crossing the border of the study are). We calculated the shortest path (and consequently the likely gate) from any town in the Czech Republic to the district, and manually for neighbouring countries. In the case of unknown destination municipality (though known the region) code in the National HTS, we select the gate of the study area, where the probability of each "gate" is given by the proportion of inhabitants of each municipality served by the gate. Moreover, attributes and values of each data source are defined or recategorized into a common categorization amongst the data sources.

4 https://www.czso.cz/csu/czso/cenik-informacnich-sluzeb-a-produktu-bwut?skupina=13

Figure 2. Population of municipalities in 2011 (left) and % changes of population between 2011 and 2016 (right)



- These kinds of common attributes are necessary for matching socio-demographic data with travel behaviour data on step P1. Eqasim matches the synthetic population with the National HTS and City HTS samples by a set of user-defined attributes, using an algorithm called Hot-deck matching [18]. In our case as we use two different HTS and the synthetic population data, we selected the attributes based on living place of individual persons. If living in the municipality of Ústí nad Labem, then the following attributes were used for matching:Mandatory: "AgeGroup"
- Preferential: "Gender", "Education", "Activity", "CadastralAreaCode", "JourneyMainMode", and "PrimaryLocRelationHome".

Meanwhile, for people living in the rest of municipalities in the study area, the following attributes were used:

- Mandatory: "AgeGroup".
- Preferential:"Gender","Education","Activity","TownSize","JourneyMainMode", and "PrimaryLocRelationHome".

The difference between mandatory and preferential attributes is that for the first one, every match must be the same on each data source (Census or HTS), while the latter will try to match as much as possible. This configuration of few attributes as mandatories and many as preferential was necessary because, especially for the City HTS, the inclusion of the person's Activity (representing if the person is employed or employer, working or non-working either student and pensioner, etc.) would result in removal of about 10~25 % of the synthetic population that could not be matched with HTS. We opted to retain all people but lose a bit the control to ensure some attributes are always matching.

In steps F1 and F2 of the "BuildingPurpose" of Facilities and buildings data is classified according to a classification that would be comparable between National and City HTS, considering the trip purposes: home, free time, shopping, work, education, and errands. This classification of buildings and facilities is a standard procedure for any activity-based model. However, we improved this filtering by establishing another level to connect the "BuildingPurpose" attribute of building data and "ActivitySector" attribute of the synthetic population: Households, Industry, Agriculture, Forestry, Transportation, Utilities, Hospitality, Administrative, Public Services, Commercial and Private Services . Based on the activity sector that the person works, we try to make the work location more accurate. One last aspect we deviate from the reference São Paulo case is the inclusion of one artificial facility (with all possible "BuildingPurpose") to the "gate" locations (the entry/leaving points of the study area). On this way, inbound or outbound trips of the study area start or end at the "gates". That enable us to model visitors of the study area and residents that travel outside, though transit (trips that only cross the district) traffic is still not considered.

In P2, the procedure is very similar to the reference São Paulo case: trip attributes are associated with synthetic population, departure times are diversified based on the distribution of the departure times, and the proportion of OD trips between zones for work and education is estimated from step P1. After it, we define the specific place of:

- Home location: randomly in the zone (Basic Settlement) of the residence.
- Education: chosen locations classified for "education" trip purposes that matches with "PrimaryLocCrowFliesDist" in the zone stated in the Census (if stated).
- Work locations: like educational places but selecting all purposes and filtering them also by using same "ActivitySector" associated to "BuildingPurpose".

Further information related to the algorithm for assigning primary locations, called Hot-deck matching, can be found here [18]. We complement the model (compared to the reference São Paulo scenario) by changing the trip duration or departure time, so it accounts to only the time to/from the gate to the location within the study area (if home or primary location is not within the district).

Finally, in line with the standard procedure, P3 resample distance distributions for calibration of travel modes. Additionally, it assigns the secondary location by the distance of facilities from the primary location, according to the relaxation-discretization algorithm [19].

RESULTING MODEL

The model described above provides outputs covering the synthetic population including for each generated person information about home, primary and secondary locations, age, gender, economic activity, and ownership of driving license and/or public transport subscription. This is used to generate other output, travel demand including attributes, such as the location coordinates, departure and arrival times, travel mode and purpose of each activity along a chain of trips. Another set may output facility (building) locations and what they offer (regarding trip purposes), and household data can also be provided stating the car availability.

Figure 3. Resulting Origin-Destination (OD) pairs for work-related and education-related trips

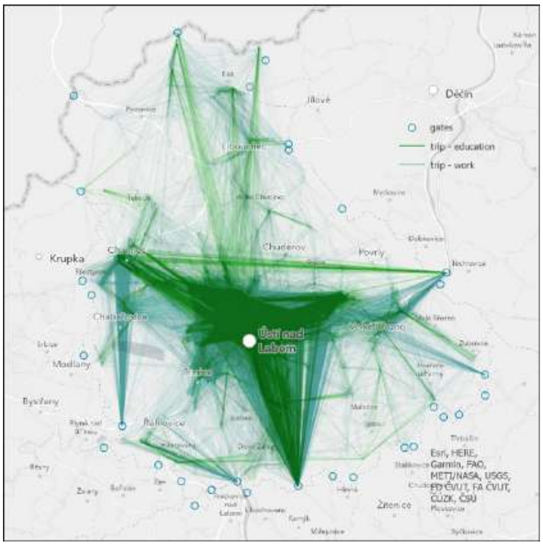
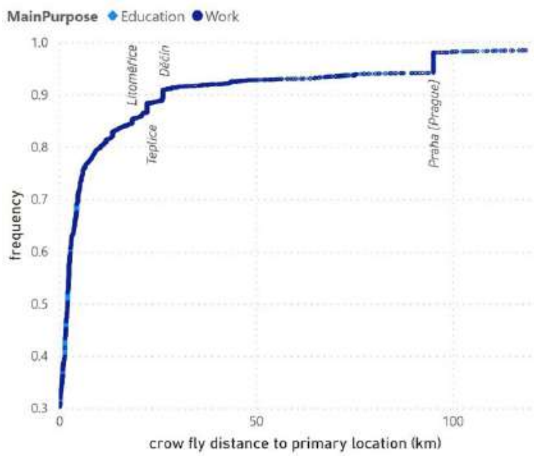


Fig. 3 presents the generated travel demand (Origin-Destination pairs) for work-related and education-related trips within the study area (inside the dotted line) of the study area for each person. The figure shows many trips originating and ending on the "gates" (located at motorways and highways entering and leaving the study area) and alongside them through the city centre. The idea to create artificial buildings (on step C2 and F2) for all trip purposes at the gates of the study area and estimate, which gate would be used turned out to be useful. However, the southern gate with the biggest demand is indeed not so busy. This is a limitation of using shortest-path instead of least-travel path. Therefore, average speed data is required for a more accurate algorithm. Another aspect is that while workplaces are distributed along the main roads of the study area and bigger municipalities, the educational trips are concentrated in the city of Ústí nad Labem, which is the only municipality having the university facilities and most of higher school facilities in the study area.

The cumulative frequency distribution of the crow flies' distance (direct distance between points on Earth) for each trip purpose to primary locations can be seen on Fig. 4. There are few outliers that have been cut out of the figure to better show the variations within the interval up to 120 km. Fig. 4 reveals that most of the trips (around 80 %) are under 20 km. In fact, the average distance of people for work trips is 15,9 km and for education is 13,49 km (the outliers increase these values quite a lot as some trips goes as far as to neighbouring countries, such as Germany and Slovakia). There are clear steep increases at certain distances. Partly, these increases are explained by trips between the municipality of Ústí nad Labem and nearby cities surrounding it (Litoměřice, Teplice, and Děčín), in addition to the capital of the Czech Republic, Prague.

Figure 4. Crow fly distances for education and work trips



DISCUSSION AND CONCLUSIONS

In this paper we applied and improved an already existing methodology [16] for the generation of synthetic population and travel demand for the catchment area of Ústí nad Labem in the Czech Republic. Primarily, we solved the issue regarding the necessary demographic transition of Census data for properly matching with household travel survey data. Secondarily, we propose a procedure to consider trips originating or destinating outside the analysis study area by concentrating trips on the gates of the study area, which was left out in previous applications of the framework [16, 19, 20]. Finally, given the fact that the procedures depend heavily on the available data, several modifications from the reference source code[2] were

2 https://github.com/eqasim-org/sao_paulo

proposed. One major change refers to the use of two different household travel surveys at the same time, one local (City HTS) for residents of the city Ústí nad Labem and another, national (National HTS) for trips of other municipalities. Other improvements refer to unique connections from the available databases in the Czech Republic, such as reliable building purposes from building register (opposed to the limitations of facilities from OpenStreetMaps in [16, 19, 20]) with trip purposes and economic activity sector.

However, other relevant data, such as income is not available in the Czech Census. As stated in [20], the assignment of secondary location does not consider the attractiveness of the locations, and neither assignment of primary and secondary locations takes into account number of working positions, studying seats, or visitors' capacity. Although we were able to model traffic going into or leaving the study area, through (transit) traffic, as well as freight, private transport (for example factories not served by public transport), and tourism are yet to be somehow considered.

Other already applied possibilities can be used as inspirations for future work. For example, in [16], data regarding the type of educational places (e.g., kindergartens, primary, high schools and universities) was not available, but a simple classification by age groups ensured that the distributions respected the attributes per age only, and not explicitly per several common attributes. The categorization of educational facilities, likely also by age groups is the mostly likely improvement to be achieved on future research.

Other aspects that will also require adjustments are the definition of the likely gate by considering average speed or travel time, instead of only the shortest path. The grouping of people of the Census into households is useful because household travel surveys have data regarding the household, such as number of members, number of dependents and income.

As policy makers and city administrators are coping with the growing complexity of urban processes, effective policies depend on their ability to understand how the patterns emerge from bottom-up. The synthetic population enriched by travel demand data allows to test various behavioural assumptions related to the urban population.

ACKNOWLEDGEMENTS

This paper was supported by the project "Smart City – Smart Region – Smart Community" (CZ.02.1.01/0.0/0.0/17_048/0007435) financed by the Operational Programme Research, Development and Education of the Czech Ministry of

Education, Youth and Sports, supported by EU funds.

REFERENCES

[1] Abdullah, M. & Dias, Ch. & Muley, D. & Shahin, M. (2020). Exploring the Impacts of COVID-19 on Travel Behavior and Mode Preferences. Transportation Research Interdisciplinary Perspectives. 8. 100255. 10.1016/j.trip.2020.100255.

[2] Piątkowski, B. & Maciejewski, M. (2013). Comparison of traffic assignment in visum and transport simulation in MATSim. Transport Problems, 8(2), 113–120.

[3] McNally, M. G., & Rindt, C. R. (2007). The Activity-Based Approach. In D. A. Hensher & K. J. Button (Eds.), Handbooks in Transport. Handbook of Transport Modelling (pp. 55–73). Emerald Group Publishing Limited.

[4] Manoj, M. & Ashish V. (2013) Activity based travel demand models as a tool for evaluating sustainable transportation policies, Research in Transportation Economics, Volume 38, Issue 1, Pages 45-66.

[5] Přibyl, O. & Goulias, K.G. (2005) Simulation of Daily Activity Patterns Incorporating Interactions within Households: Algorithm Overview and Performance. Transportation Research Record. 1926(1):135-141. doi:10.1177/0361198105192600116.

[6] Tajaddini, A. & Rose, G. & Kockelman, K. & Vu, H. (2020). Recent Progress in Activity-Based Travel Demand Modeling: Rising Data and Applicability. 10.5772/intechopen.93827.

[7] Chu, Z. & Cheng, L. & Chen, H. (2012). A Review of Activity-Based Travel Demand Modeling. 48-59. 10.1061/9780784412442.006.

[8] Delhoum, Y. & Belaroussi, R. & Dupin, F. & Zargayouna, M. (2020). Activity-Based Demand Modeling for a Future Urban District. Sustainability, 12(14), 5821.

[9] Ortega J. & Hamadneh J. & Esztergár-Kiss D. & Tóth J. (2020) Simulation of the Daily Activity Plans of Travelers Using the Park-and-Ride System and Autonomous Vehicles: Work and Shopping Trip Purposes. Applied Sciences. 10(8):2912. https://doi.org/10.3390/app10082912.

[10] Müller, S. & Balmer, M. & Charlton, W. & Ewert, R. & Neumann, A. & Rakow, C. & Schlenther, T. & Nagel, K. (2021). Predicting the effects of COVID-19 related interventions in urban settings by combining activity-based modelling, agent-based simulation, and mobile phone data. 10.1101/2021.02.27.21252583. Preprint.

[11] Wang, D. & Yueshuai He, B. & Gao, J. & Chow, J.Y.J. Ozbay, K. & Iyer, S. (2021)

Impact of COVID-19 behavioral inertia on reopening strategies for New York City transit, International Journal of Transportation Science and Technology, Volume 10, Issue 2, Pages 197-211.

[12] Horni, A. & Nagel, K. & Axhausen, K.W. (eds.) (2016) The Multi-Agent Transport Simulation MATSim. London: Ubiquity Press. DOI: http://dx.doi.org/10.5334/baw. License: CC-BY 4.0 https://matsim.org/the-book.

[13] Cho, S. & Bellemans, T. & Creemers, L. & Knapen, L. & Janssens, D. & Wets, G. (2014). Synthetic Population Techniques in Activity-Based Research. 10.4018/978-1-4666-4920-0.ch003.

[14] Matowicki, M. & Přibyl, O.; Pecherková, P. (2021) Carsharing in the Czech Republic: Understanding why users chose this mode of travel for different purposes. Case Studies on Transport Policy. 9(2), 842-850. ISSN 2213-624X.

[15] Brög, W. & Erl, E. & Ker, I. & Ryle, J. & Wall, R. (2009). Evaluation of voluntary travel behaviour change: Experiences from three continents. Transport Policy. 16. 281-292. 10.1016/j.tranpol.2009.10.003.

[16] Sallard, A. & Balać, M. & Hörl, S. (2020). A synthetic population for the greater São Paulo metropolitan region. Arbeitsberichte Verkehrs-und Raumplanung, 1545.

[17] NMS Market Research (2018). Plán Udržitelné Městské Mobility Města Ústí Nad Labem: B1 -Sociodopravní Průzkumy. Unpublished raw data.

[18] D'Orazio, M. & Di Zio, M. & Scanu, M. (2012, May). Statistical matching of data from complex sample surveys. In Proceedings of the European Conference on Quality in Official Statistics-Q2012 (Vol. 29).

[19] Hörl, S. & Axhausen, K. W. (2020). Relaxation-discretization algorithm for spatially constrained secondary location assignment. In 99th Annual Meeting of the Transportation Research Board: New Mobility and Transportation Technology Takeaways (TRB 2020) (pp. 20-01108). IVT, ETH Zurich.

[20] Balac, M. & Hörl, S. (2021). Synthetic population for the state of California based on open-data: examples of San Francisco Bay area and San Diego County. In 100th Annual Meeting of the Transportation Research Board (TRB).

Correlation Analysis Method of Customization and Semi Personalization in Mobility as a Service

YINYING HE, CSABA CSISZÁR

Abstract The Mobility as a Service (MaaS) has been proposed as a user-centric, data-driven, and personalized service. However, at current development stage, the full personalization is still not available. Customization settings are available in most mobile applications, several semi personalized functions are also involved in. The quantitative analysis of relations between these two are missing, which could be the reference for further development tendency of interface functions on mobile application. Thus, the research objective is identified as: the quantitative correlation analysis between semi personalization and customization settings. The multi-criteria qualitative analysis method is applied to identify the assessment aspects of semi personalized functions and customization settings regarding MaaS applications. The scoring method is also introduced. Then the correlation quantitative analysis method is applied to calculate the correlation coefficient. We have assessed 25 MaaS applications regarding determined aspects. The correlation coefficients for each application and together with the overall value are calculated, the assessment results are summarized, as well as the correlation tendency is interpreted. The obtained numerical values of coefficient are small, thus the correlation between customization settings and semi personalization is not strong. And most of the selected mobile applications are customization setting oriented. During the recent development phase, detailed customization settings are needed to collect data, but fewer manual selection from options are expected in further personalized services. Our results facilitate the planning of personalized functions and development of MaaS applications.

Keywords: • Mobility as a Service • Mobile Application • Customization • Semi Personalization • Correlation Analysis

CORRESPONDENCE ADDRESS: Yinying He, PhD student, Csaba Csiszár, PhD habil. associate professor, Budapest University of Technology and Economics, Faculty of Transportation Engineering and Vehicle Engineering, Department of Transport Technology and Economics, Műegyetem rkp. 3, Budapest, Hungary, e-mail: he.yinying@edu.bme.hu, e-mail: csiszar.csaba@kjk.bme.hu

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

The smart city is defined as a digitalized livable environment. To distinguish from the traditional cities, it provides cyber-physical systems and subsystems, which means, systems and sub-systems are available to be interconnected and interacted with each other, by physical connection and virtual information flow [1]. Smart mobility or transportation is considered as a subsystem, it has the property of a cyber-physical system too [2]. Physical vehicle movements remain but more comfortable for travelling supported by technologies, real-time information flow and management become more and more important. The Mobility as a Service (MaaS) is one of representatives of digitalized mobility service provided by the smart mobility system, which aims to 'deliver' the integrated service via a single platform.

The using of smartphone has changed the lifestyle of people a lot, e.g., mobile payment, social life, fragmented reading. Various aspects of daily life have been influenced or depended on the smartphones, as well as with mobility and travel behavior [3]. Travellers are available to interact with connected environment by smartphones. Thus, travellers not only participate in the physical movement of vehicles, but they are also available to be involved actively in information flows via mobile application (MA), e.g., online service demand announcement, real-time network condition sharing. The 'citizens as sensors' becomes possible because of the smartphone use.

MaaS is promoted as one MA based new mobility service [4]. The development of interface functions and their providing are critical questions, not only for software developers, for mobility service researchers as well. The applications on smartphones are the tendency to be the intelligent assistant of travel, especially considering the future autonomous vehicle based mobility services. In addition, mobile phone data have been used extensively in research recent years [5].

MaaS is also considered with probability to decrease private car use, how the private vehicles could be decreased or replaced? Customization and personalization of provided service are the key: to provide service to users at least equal convenient and cheap as owning their own cars. Only mobile application on smartphones can provide such quick real-time information interactions.

Customization and personalization of services are discussed in customer relationship management focusing on big data [6], in a book are presented as the information customization and personalization [7], however the exact definitions of customization and personalization are not presented. The authors of [6] have concluded that big data could facilitate services more customized and personalized, but they do not present that a service is 'customized or personalized' from, which aspects and how. Customization and personalization as setting options are discussed in [8] systematic analysis of MaaS services, the differences between them are not distinguished. The results of these two may appear similar- to optimize user experiences, but different input data require different function design purpose. In most papers these two terms are used in a mixed way, but they are different: customization is not personalization. They may not contradict with each other, they may overlap with each other in several aspects, but they are far more than the same. Thus, to define the customization, semi personalization and personalization, to identify the correlation intensity between customization and semi personalization in a MaaS service are identified as the research niche of this paper.

Accordingly, the research questions are as follows:

- What are the aspects to be assessed regarding customization and semi-personalization in a MaaS MA?
- How to obtain the correlation coefficient?
- What is the applicability of the method?

To answer research questions, the remainder of the paper is structured as follows. Literature review is summarized in Section II. In Section III, the research methodology is described by the proposed evaluation aspects and the applied calculation method of coefficient. In Section IV, the assessment results are presented and discussed. We have accessed 25 MA according to the introduced method, the coefficients as results are obtained and interpreted. The paper is completed by the concluding remarks including future research directions.

LITERATURE REVIEW

The literature is reviewed involving the scientific results of MaaS trials along with the MA in these trials, the MA in a MaaS service and the correlation analysis.

MaaS has been implemented for at least 6 years [9], [10], but it is not enough for a technology-enabled service to assess its impacts. The trial studies of real MaaS implementation are still very limited. Only Ubigo from Sweden and the MaaS trial in Australia has provided research results that MaaS has possibility to decrease private car use [11], [12]. The change of travel behavior requires long time and widely user acceptance. Whim is regarded as a successful MaaS application, but no scientific analysis paper about Whim smartphone application is available. The MA is not developed in Ubigo trial, but a modified MA was provided in Australian trail. Ubigo is the earliest trial focusing on mobility modes combination-the monthly packages. At some extent, Australian one is a more complete trail compared with Ubigo. The Smile project from Austria is also based on a MA, unfortunately, no scientific papers about results are presented either [13].

The mobile Internet and mobile cloud as the two most significant technologies facilitate the MA based mobility services [14]. The journey planning is still one of important functions in a MaaS MA [15], however, the service alters, the transfer convenience, the tracking, etc., which tightly related with real-time information are to be put in the focus. Especially autonomous vehicle based MaaS services are taken into consideration [16].

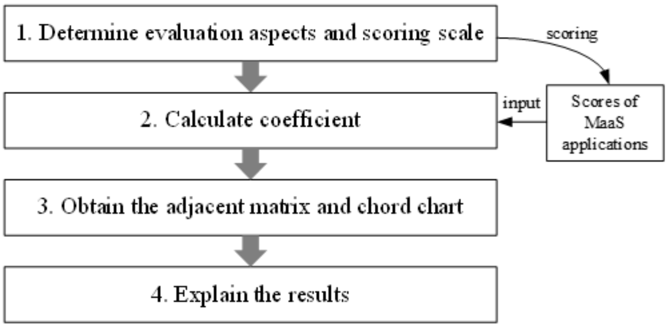
The correlation coefficient is used to describe the statistical characteristics of two random variables. Typically, the scatter diagrams are presented first to observe the tendency of data, then the coefficient r is calculated to show the correlation intensity in numerical values. In case of strong linear correlation, mostly the regression model is applied for further demonstration purpose [17]. The correlation analysis has been widely applied in various science and technology fields, especially the regression model. A literature overview and evaluation has been presented to summarize the correlation between the analytical measurement of diesels winter qualities and in real world operability, the conclusion of this descriptive study is that the correlation between theoretical and real practice is getting weaker [18]. The correlation coefficients are used in one fuzzy set study to measure the similarity instead of distance functions too [19]. In order to find a substitution parameter to represent the transportation economy, the coefficients between several parameters are calculated and presented in scatter diagrams [20]. They found that the introduced parameter 'the order of the settlement' better to represents the correlation between public transportation lines and transportation economy within their research limitations.

METHODOLOGY

The correlation analysis in this context is not limited to statistical analysis, because the 'customization' and 'semi-personalization' cannot be regarded as strict random variables. Similar to [21] correlation exists between 'land use' and 'urban public transport', we quantify the correlation intensity between customization and semi-personalization these two variables regarding same evaluation aspects of the MA.

The steps of method are summarized in Figure 1.

Figure 1. Steps of method



The core of the method is to use numerical values to 'describe' the qualitative aspects, in order to use values to show the correlation intensity. Accordingly, the following definitions are identified first.

The common objective of customization, semi personalization, and personalization in mobile applications is to provide additional input data to functions considering traveller's expectations and/or behavior. ***Customization*** is achieved by manual selection from lists of options according to travellers' preferences. The traveller provides data. ***Personalization*** is achieved automatically by system cognitive capability and advanced data processes using passively collected, historical personal travel related data. ***Semi personalization*** is achieved by less manual input and more automatic, simple data processes using historical data from other database if needed (e.g., the crowdsourced travellers: waze application). No passively collected personal travel related data is used.

The personalized mobility application is not available yet. Data privacy is one concern. Another drawback is that even individual mobility data is quite large, the optimization ability is still limited. Thus, the correlation between customization and semi-personalization is analysed in our work.

The Person coefficient and Spearman rank coefficient are both widely used in correlation analysis. Instead of the exact values or sample data, the ranks of sample data are applied in Spearman method, the base formula is the same [22] and presented in Equation (1).

$$r_{XY} = \frac{cov(X,Y)}{\sigma_X \cdot \sigma_Y} \tag{1}$$

Regarding the sample data, the equation is expressed in Equation (2) and (3). The uper '-'stands for the average values.

$$r_{XY} = \frac{Cov(X,Y)}{\sqrt{Var(X) \cdot Var(Y)}} = \frac{\frac{\sum_{i=1}^{n}(X_i - \bar{X}) \cdot (Y_i - \bar{Y})}{n-1}}{\sqrt{\frac{\sum(X_i - \bar{X})^2}{n-1}} \cdot \sqrt{\frac{\sum(Y_i - \bar{Y})^2}{n-1}}} \quad (2)$$

$$r_{XY} = \frac{\sum_{i=1}^{n}(X_i - \bar{X}) \cdot (Y_i - \bar{Y})}{\sqrt{\sum(X_i - \bar{X})^2 \cdot \sum(Y_i - \bar{Y})^2}} \quad (3)$$

From the statistics point of view, the coefficient r reflects the differences between sample data and average values. The equation (3) is applied in further calculation. Considering the main functions, such as route planning, booking, ticketing and payment, i.e., functions I-VII, the assessment aspects of a MA regarding customization (X) and semi personalization (Y) are summarized in Table 1 first as ***step 1***.

Table 1. Aspects

	Aspects (Ai)	**Customization (X)**	**Semi personalization (Y)**
		I. Base	
A1	Service usage area	manual selection	automatic detection based on GPS location
A2	Message notification	manual selection	automatic message sending, e.g., delay, alters.
		II. Route Planning	
A3	Favorite location saving	manual selection	frequently used ones are automatically saved
A4	Preferred mode choice	selectable. e.g., bus, tram	providing multimodal route planning options
A5	Preferred route choice	selectable. e.g., best/fast/without transfer	optimal one based on current network condition
A6	Mobility-impaired information	manual selection	providing wheelchair or relevant information
A7	Preferred walking speed	setting is available	applying average speed
A8	Preferred waiting time	setting is available	applying average acceptance time window
		III. Booking Availability	
A9	Public transport service	separate booking is available in the same app (1); separate booking turns to specific app (0,5)	needed modes in a travel chain are booked by once button push
A10	Taxi		
A11	Car-sharing/rental		
A12	Bike-sharing		
A13	Scooter-sharing		
A14	Ride-sourcing		

Table 1. Aspects (cont.)

Aspects (Ai)		Customization (X)	Semi personalization (Y)
		IV. Ticketing	
A15	Electronic ticket	separate tickets for different modes	one ticket is available for a travel chain, e.g.,QR code
A16	Monthly package	selectable	discussion with operator, tailored package is available based on individual real needs.
		V. Payment	
A17	Pay per trip in a travel chain	in the same application (1); not the same (0,5)	credit card automatic payment
A18	Monthly subscription	pay per month manually	
		VI. Feedback	
A19	Feedback opportunity	manual selection and input	automatic question before each payment
A20	Statistics report	manual selection to display	automatic relevant reports sending (e.g., weekly/monthly mobility data, CO_2 footprints)
		VII. Added value	
A21	Navigation opportunity	selectable for different modes	automatic update according to involved modes in a travel chain (e.g., find booked vehicles)
A22	Incentive mechanism	manual adding and management	automatic mechanism. e.g., Bonus: green modes use, walking more.

The scoring method is objective: except additional scale '0,5' is applied for A9-A14 and A17, others are '1' for each Ai when checking the functionality availability of each MA (*step 1*). Then the selected applications are evaluated (input data), the scores are shown first in the scatter diagram and then, the coefficients are calculated (*step 2*). The adjacent matrix R is obtained, and the chord diagram is presented (*step 3*). Finally, the results are explained (*step 4*).

$$R = \begin{bmatrix} r_1 & 0 & 0 & \cdots & 0 \\ 0 & r_2 & 0 & \cdots & 0 \\ 0 & 0 & r_3 & \cdots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \cdots & r_{25} \end{bmatrix}$$

RESULT AND DISCUSSION

The applicability of the method is demonstrated in this section. The assessment results of 25 MaaS MA are summarized and discussed.

Selected MaaS applications and scoring

The major of selected MaaS MAs are available in Europe (18), most worldwide operation (7) are founded in America, which are summarized in Table 2.

Table 2. Information of selected MAs

j	Name	Main operational area	Website link
1	Combitrip	Netherland	https://www.combitrip.com/en
2	DiDi	worldwide	https://www.didiglobal.com/
3	Hely	Netherland	https://hely.com/
4	HVV	Germany	https://www.hvv.de/
5	Jelbi	Germany	https://www.jelbi.de/
6	Kyyti	Finland	https://www.kyyti.com/
7	Leipzig Move	Germany	https://leipzig-move.de/
8	MyCicero	Italy	http://www.mycicero.eu/
9	Mobility Stuttgart	Germany	https://www.s-bahn-stuttgart.de/
10	Mozio	worldwide	https://www.mozio.com/en-us/
11	Moovit	worldwide	https://moovit.com/
12	Mein GVH	Germany	https://www.gvh.de/home/
13	MVG	Germany	https://www.mvg.de/
14	Optymo	France	https://www.optymo.fr/
15	Omio	worldwide	https://www.omio.com/
16	PubliCar	Swiss	https://www.postauto.ch/
17	ReachNow	Germany	https://www.reach-now.com/
18	Transit	worldwide	https://transitapp.com/
19	Trip	worldwide	https://www.trip.com/
20	TripGo	worldwide	https://skedgo.com/tripgo/
21	UbiGo	Sweden	https://www.ubigo.me/en/home
22	Urbi	Europe	https://en.urbi.co/
23	Whim App	Finland	https://whimapp.com/
24	Wegfinder	Austria	https://wegfinder.at/
25	Wien Mobil	Austria	https://www.wienerlinien.at/

The selected MAs have been downloaded from Google Play, tested, and scored by the authors according to aspects table and scoring method, to obtain the input data of ***step 2***. The structure of scoring data set is presented in Figure 2.

Figure 2. The structure of scoring table

Aspect / MA	A1	A2	...	A*i*	...	A22
1	$(X_{1,1},Y_{1,1})$	$(X_{2,1},Y_{2,1})$	(...)	$(X_{i,1},Y_{i,1})$	(...)	$(X_{22,1},Y_{22,1})$
2	$(X_{1,2},Y_{1,2})$	$(X_{2,2},Y_{2,2})$	(...)	$(X_{i,2},Y_{i,2})$	(...)	$(X_{22,2},Y_{22,2})$
...	(...)	(...)	(...)	(...)	(...)	(...)
j	$(X_{1,j},Y_{1,j})$	$(X_{2,j},Y_{2,j})$	(...)	$(X_{i,j},Y_{i,j})$	(...)	$(X_{22,j},Y_{22,j})$
...	(...)	(...)	(...)	(...)	(...)	(...)
25	$(X_{1,25},Y_{1,25})$	$(X_{2,25},Y_{2,25})$	(...)	$(X_{i,25},Y_{i,25})$	(...)	$(X_{22,25},Y_{22,25})$

The scores of the selected MA regarding customization X and semi personalization Y are presented in Table 3.

Table 3. The obtained score of MA

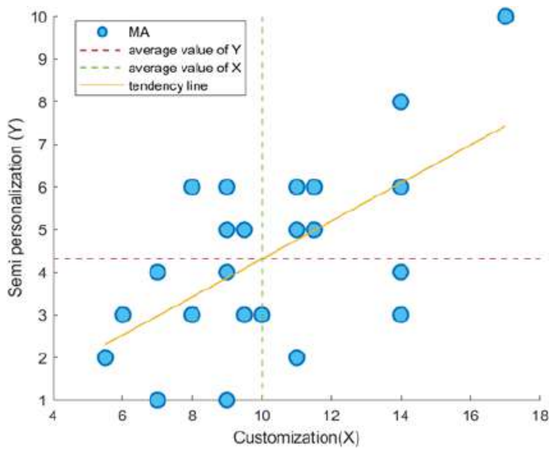
MA, *j*	**1**	**2**	**3**	**4**	**5**
X_j	5,5	9	9	11,5	14
Y_j	2	5	1	5	4
MA, *j*	**6**	**7**	**8**	**9**	**10**
X_j	17	11	9	11	7
Y_j	10	6	4	5	4
MA, *j*	**11**	**12**	**13**	**14**	**15**
X_j	14	9,5	9	11	7
Y_j	3	3	6	2	1
MA, *j*	**16**	**17**	**18**	**19**	**20**
X_j	10	9,5	8	8	7
Y_j	3	5	6	3	4
MA, *j*	**21**	**22**	**23**	**24**	**25**
X_j	6	8	14	14	11,5
Y_j	3	3	8	6	6

The scores of X_j and Yj are calculated as Equation (4).

$$X_j = \sum_{i=1}^{22} X_{i,j}, Y_j = \sum_{i=1}^{22} Y_{i,j} \quad (4)$$

The scores of customizations (X_j) and semi personalization (Y_j) of each MA j as (X_j, Y_j) are presented in the scatter diagram (Figure 3). Typically, the scatter diagram is used for data visualization, in order to determine whether the correlation relation exists, and whether the further analysis is needed.

Figure 3. The scatter diagram



Two dashed lines on the diagram: X = 10,02 and Y = 4,32 are to show the average value of Xj and Yj, respectively. The overall tendency shown by the trendline is almost positive linear correlation, but both the correlation and linear tendency are not strong, as the MAs are scattered on both sides of the trendline. According to the diagram, the correlation exists between X and Y. The coefficients r_j between X_j and Y_j can be calculated to continue analysis, to determine what kinds of correlation (positive or negative) and the intensity of correlation (strong or weak).

Correlation coefficient

The correlation coefficient is the ratio of covariance and variance of two variables, which indicates the relative difference compared with average value. As only the correlation direction is shown in the scatter diagram, the coefficient is a supplement to show the intensity of correlation. The calculated coefficients r_j: (X_j, Y_j) regarding each MA according to equation (3) are presented in Table 4.

Table 4. The value of coefficient *r*

MA, *j*	**1**	**2**	**3**	**4**	**5**
r_j	-0,219	-0,451	0,262	-0,359	-0,379
MA, *j*	**6**	**7**	**8**	**9**	**10**
r_j	-0,376	-0,408	-0,153	-0,325	-0,281
MA, *j*	**11**	**12**	**13**	**14**	**15**
r_j	-0,25	-0,085	0,113	-0,316	-0,149
MA, *j*	**16**	**17**	**18**	**19**	**20**
r_j	-0,363	-0,484	-0,463	-0,3	0,437
MA, *j*	**21**	**22**	**23**	**24**	**25**
r_j	0,054	0,028	-0,411	-0,386	0,19

Where the $\overline{X}_j$ and $\overline{Y}_j$ are calculated as Equation (5).

$$\overline{X}_j = \frac{1}{22} \times \sum_{i=1}^{22} X_{i,j}\,,\ \overline{Y}_j = \frac{1}{22} \times \sum_{i=1}^{22} Y_{i,j} \tag{5}$$

The r_j for each MA *j* is calculated as Equation (6) regarding data table as ***step 2***.

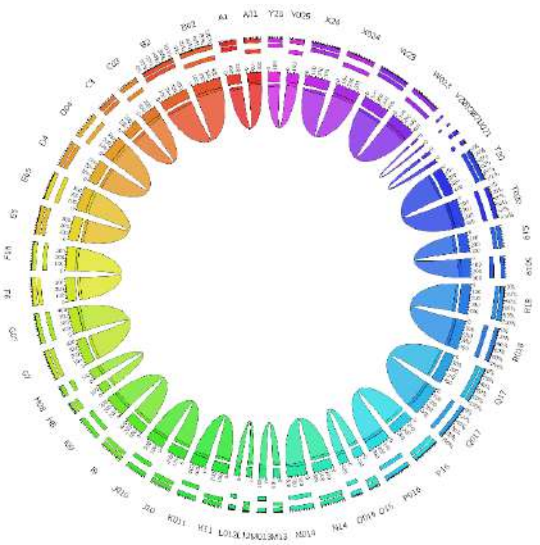
$$r_{X_jY_j} = \frac{\sum_{i=1}^{22}\left(X_{i,j}-\overline{X}_j\right)\cdot\left(Y_{i,j}-\overline{Y}_j\right)}{\sqrt{\sum_{i=1}^{22}\left(X_{i,j}-\overline{X}_j\right)^2\cdot\sum_{i=1}^{22}\left(Y_{i,j}-\overline{Y}_j\right)^2}} \tag{6}$$

Considering the requirement of the software to generate the diagram: the name of the row and the column of input matrix should be different. Thus, both in the following matrix and the chord diagram, the capital letter '*A, B, …, Y*' is used to stand for each MA '1, 2, …, 25'. '*A*01, *B*02, …, *Y*025' is to show the row name of R, and 'A1, B2, …, Y25' is to show the column name of R. The obtained adjacent matrix R is:

$$R=\begin{bmatrix} & A1\,B2\,Ci\cdots Y25 & & & \\ A01 & r_1 & & & \\ B02 & & r_2 & & \\ C0i & & & r_j & \\ \cdots & & & & \ddots \\ Y025 & & & & & r_{25} \end{bmatrix}$$

(***step 3***) Since X_j and Y_j are refer to each MA *j*, the coefficients r_j only exist on the diagonal of R. Accordingly, the obtained chord diagram is presented in Figure 4.

Figure 4. The chord diagram



(***step 4***) The absolute values of rj are used in chord diagram to show the results of correlation analysis. The correlation intensity is shown by the width of the ribbon. The different colours are applied to distinguish the elements (MAs in this context), which is the default setting of software. As the matrix is a diagonal matrix, no crossing ribbon exists. From the diagram, four r_j of MA are very weak (L, M, U, V: 12 Mein GVH, 13 MVG, 21 Ubigo, 22 Urbi), six are relatively strong (B, G, Q, R, T, W: 2 DiDi, 7 Leipzig Move, 17 ReachNow, 18 Transit, 20 TripGo, 23 Whim App). The comparison among values or 'ribbon width' is not needed, each value rj only reflect the correlation between X_j and Y_j of that corresponding MA j. For example, the r_{23} of Whim is '-0,411', which shows, the X_{23} and Y_{23} is negative correlation regarding each $X_{Ai,23}$ and $Y_{Ai,23}$, the tendency is: customization setting obtains the higher scores, the semi personalization obtains lower, and vice versa. The r_{21} of Ubigo is '0,054', the correlation is positive, which shows that customization and semi personalization together obtain higher or lower scores. Regarding aspects Ai, the aggregated scores are presented in Table 5.

Table 5. The score of aspects

Ai	**1**	**2**	**3**	**4**	**5**
X_i	13	13	16	18	8
Y_i	6	10	2	13	13
Ai	**6**	**7**	**8**	**9**	**10**
X_i	9	5	1	21	11,5
Y_i	5	15	15	1	1
Ai	**11**	**12**	**13**	**14**	**15**
X_i	15	13,5	7,5	4	19
Y_i	1	1	1	0	3
Ai	**16**	**17**	**18**	**19**	**20**
X_i	10	19	4	23	2
Y_i	3	0	5	1	0
Ai	**21**	**22**			
X_i	9	9			
Y_i	5	7			

Where the X_i and Y_i are calculated as Equation (7).

$$X_i = \sum_{j=1}^{25} X_{i,j}\, , Y_i = \sum_{j=1}^{25} Y_{i,j} \qquad (7)$$

The overall result of r is r = 0,313 calculated according to Equation (3), where $\bar{X}$ and $\bar{Y}$ are calculated as equation (8) and (9).

$$\bar{X} = \frac{1}{22} \times \left[\sum_{i=1}^{22} \left(\sum_{j=1}^{25} X_{i,j}\right)\right] \qquad (8)$$

$$\bar{Y} = \frac{1}{22} \times \left[\sum_{i=1}^{22} \left(\sum_{j=1}^{25} Y_{i,j}\right)\right] \qquad (9)$$

The scores regarding main functions are also summarized in Table 6.

Table 6. The score of main functions

F	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**
Xi	26	57	72,5	29	23	25	18
Yi	16	63	5	6	5	1	12

Regarding 25 selected MAs, the scores of semi-personalization are relatively low compared with customization. The selected MAs are customization setting oriented applications.

Discussion

The obtained coefficients r_j are to present the descriptive correlation in numerical values, which is a quantitative method to show the correlation intensity. From the results, all obtained r_j < 0,5, which means, the correlation between customization and semi personalization is not strong, whatever in each MA or from an overall point of view. Positive values are obtained by 6 MA, the others are negative values. The positive correlation indicates that functionalities of X and Y are together developed. The negative correlation indicates that the availability of X and Y are in opposite direction. The absolute values show the intensity: strong/large or weak/small.

The availability of customization setting options are developed well among selected MAs, the availability of semi-personalization is to be improved. During the recent development phase, detailed customization settings are needed to collect data, but fewer manual selection from options are expected in further personalized service.

Compared with the work of other authors [7, 8], we have distinguished customization and semi personalization of a MA in a quantitative way. We have assessed the selected MAs regarding customization and semi personalization. Furthermore, the correlation intensity r is presented and interpreted too.

CONCLUSION

In a MaaS service, the perceived results provided to travellers are displaying customized or personalized information on a MA. The differences of these two distinguished in this work are the information providing processes: what kind of input activities from traveller' side. The virtual information management and physical vehicle movement together of an entire travel are experienced by travellers as the customized and/or personalized services.

The main contributions of our work are:

- The definitions of customization and semi personalization regarding the MA.
- The determined assessment aspects and the objective scoring.
- The correlation between customization and semi personalization is quantitatively analyzed.

The key findings regarding assessed 25 MAs are:

- The values of coefficient are small (r < 0,5), the correlation between customization and semi personalization are not strong.
- The selected MAs are customization setting oriented applications.
- The aspects obtained lower scores regarding Y semi-personalization could be further developed in a MA, e.g., sending feedback demand and statistics report more actively.

The purpose of customization and personalization is to actively or passively input additional data to optimize functions. The continuous development of personalization supported functionalities are recommended, as the tendency of MA is to provide information aiding personalized services. Fewer manual inputs are needed in the future.

What we faced, as the lesson learnt is that definitions of terms are changing along with development. For example, customization and personalization are different in a traditional mobility service and a digitalized service. We have defined them regarding the data input process in a MA.

The further research direction is to introduce a mobile application concept for autonomous vehicle based MaaS service. The backend functions and the frontend interface functions are analyzed and distinguished, the information flows regarding travel phases are presented. In addition, the input data, which connect frontend and backend functions are summarized.

ACKNOWLEDGEMENT

This work was supported by EFOP-3.6.3-VEKOP-16-2017-00001: Talent management in autonomous vehicle control technologies. The Project is supported by the Hungarian Government and co-financed by the European Social Fund. The research was also supported by the Ministry of Innovation and Technology NRDI Office within the framework of the Autonomous Systems National Laboratory Program.

REFERENCES

[1] Lom, M., & Pribyl, O. (2021). Smart city model based on systems theory. International Journal of Information Management, 56, 102092. Doi: 10.1016/j.ijinfomgt.2020.102092.

[2] Ismagilova, E., Hughes, L., Dwivedi, Y. K., & Raman, K. R. (2019). Smart cities: Advances in research—An information systems perspective. International Journal of Information Management, 47, 88-100. Doi: 10.1016/j.

ijinfomgt.2019.01.004.

[3] Aguiléra, A. (2018). Smartphone and individual travel behavior. Urban Mobility and the Smartphone: Transportation, Travel Behavior and Public Policy, 1. Doi: 10.1016/B978-0-12-812647-9.00001-9.

[4] Boutueil, V. (2018). New mobility services. Chapter, 2, 39-78. Doi: 10.1016/B978-0-12-812647-9.00002-0.

[5] Chrétien, J., Le Néchet, F., Leurent, F., & Yin, B. (2018). Using Mobile Phone Data to Observe and Understand Mobility Behavior, Territories, and Transport Usage. Urban Mobility and the Smartphone: Transportation, Travel Behavior and Public Policy, 79. Doi: 10.1016/B978-0-12-812647-9.00003-2.

[6] Anshari, M., Almunawar, M. N., Lim, S. A., & Al-Mudimigh, A. (2019). Customer relationship management and big data enabled: Personalization & customization of services. Applied Computing and Informatics, 15(2), 94-101. Doi: 10.1016/j.aci.2018.05.004.

[7] Schofer, J. L., & Mahmassani, H. S. (2016). Mobility 2050. A Vision for Transportation Infrastructure.

[8] Esztergár-Kiss, D., Kerényi, T., Mátrai, T., & Aba, A. (2020). Exploring the MaaS market with systematic analysis. European Transport Research Review, 12(1), 1-16. Doi: 10.1186/s12544-020-00465-z.

[9] A Brief History of MaaS Global, the company behind the Whim app, https://whimapp.com/helsinki/en/history-of-maas-global/ (access on 8th July, 2021).

[10] About UbiGo, https://www.ubigo.me/en/about-ubigo (access on 8th July, 2021).

[11] Sochor, J., Karlsson, I. M., & Strömberg, H. (2016). Trying out mobility as a service: Experiences from a field trial and implications for understanding demand. Transportation Research Record, 2542(1), 57-64. Doi: 10.3141/2542-07.

[12] Hensher, D. A., Ho, C. Q., & Reck, D. J. (2021). Mobility as a Service and private car use: evidence from the Sydney MaaS trial. Transportation Research Part A: Policy and Practice, 145, 17-33. Doi: 10.1016/j.tra.2020.12.015.

[13] The mobility platform of the future, https://smartcity.wien.gv.at/en/smile-2/, (access on 9th July, 2021).

[14] Junior, W., Silva, B., & Dias, K. (2018). A systematic mapping study on mobility mechanisms for cloud service provisioning in mobile cloud ecosystems. Computers & Electrical Engineering, 69, 256-273. Doi: 10.1016/j.compeleceng.2018.01.030.

[15] Georgakis, P., Almohammad, A., Bothos, E., Magoutas, B., Arnaoutaki, K., & Mentzas, G. (2020). Heuristic-Based Journey Planner for Mobility as a Service (MaaS). Sustainability, 12(23), 10140. Doi:10.3390/su122310140.

[16] Pethő, Z., Török, Á., & Szalay, Z. A survey of new orientations in the field of vehicular cybersecurity, applying artificial intelligence based methods. Transactions on Emerging Telecommunications Technologies, e4325. DOI: 10.1002/ett.4325.

[17] Botzoris, V. A. P. a. G. N. (2019). Chapter 5 - Statistical Methods for Transport Demand Modeling. 163-224. Doi: 10.1016/B978-0-12-811513-8.00005-4.

[18] Zöldy, M. (2021). Investigation of correlation between Diesel fuel cold operability and standardized cold flow properties. Periodica Polytechnica Transportation Engineering, 49(2), 120-125. Doi: 10.3311/PPtr.14148.

[19] Peng, Y., Xiaohe, L., & Jianbo, S. (2021). A multi-attribute group decision making method considering both the correlation coefficient and hesitancy degrees under interval-valued intuitionistic fuzzy environment. Applied Soft Computing, 104, 107187. Doi: 10.1016/j.asoc.2021.107187.

[20] Szabó, Z., Török, Á., & Sipos, T. (2021). Order of the cities: Usage as a transportation economic parameter. Periodica Polytechnica Transportation Engineering, 49(2), 164-169. Doi: 10.3311/PPtr.13786.

[21] Štefančić, G., Šarić, S., & Spudić, R. (2014). Correlation between land use and urban public transport: Case study of Zagreb. Promet-Traffic&Transportation, 26(2), 179-184. Doi: 10.7307/ptt.v26i2.1471.

[22] 3 - Descriptive Methods. (2007). 21-69. Doi: 10.1016/B978-0-12-369492-8.50008-X.

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

Automated People Counting Systems – Usability Analysis

LUKÁŠ HRDINA, ONDŘEJ PŘIBYL, MICHAL MATOWICKI AND ANDRZEJ TORUN

Abstract In the last years, with new topics, such as smart cities emerging, there is a lot of progress with respect to gathering new data, transforming them into information and knowledge and to share and enhance such knowledge among different fields. This is true also for traditionally closed environments, such as railway stations. We can see many new sensors emerging. They do not monitor only the movement of the trains. A lot of attention is newly paid to the movement of people. For this different video detection systems, ultrasonic technologies, even weight sensors installed in vehicles are often used to learn more about travelers' behavior. Such data can be used for many different aspects, such as safety, security or even control and optimization. In this paper, we do not look primarily at the different technologies used in sensors to monitor presence and movement of travelers (automated people counting – APC systems). Our aim is to define the possible usage of such data. System engineering approach is used to utilize the findings from literature and project review. Based on a state-of-the-art analysis, we identify the major actors and prepare use cases defining the way how they can use and benefit from the data. A classification of the technology is provided to better explain the needs of particular use cases. The use cases are also further classified according to strategic, tactical, and operational control level.

Keywords: • Automated People Counting • Usability Analysis • Public Transport • Railways

---

CORRESPONDENCE ADDRESS: Lukáš Hrdina, Ondrej Pribyl, PhD, Michal Matowicki, PhD, Faculty of Transportation Sciences, Czech Technical University in Prague, Na Florenci 25, Praha 1, Czech Republic e-mail: pribylo@fd.cvut.cz, Andrzej Torun, PhD, D.Sc., Instytut Kolejnictwa (Railway Research Institute), Warszawa, Chłopickiego 50, Poland

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

Problem formulation and motivation

It is a common problem in many aspects of smart cities that technological companies offer and sell certain technologies (sensors, dashboards, algorithms, and others) as the solution that solves all problems and creates a smart city [1]. The decision makers, typically municipalities or technological agencies cannot see the whole picture and selecting an optimal solution is a major challenge. The solutions often have limited interfaces or their technology does not allow for proper integration into a holistic solution [2].

This is true also for the field of public transport operations. Lately, several commercial companies or even research projects have been developing so-called automated people counting (APC) systems. These systems are using various technologies including, among else, video detection, infrared sensors and weighting systems. A short overview is provided in the State-of-the-art assessment of APC technology within this paper.

This paper focuses on APC systems at public transport stations and related facilities like service centers or waiting rooms.

APC systems are a useful tool to get insight on the number and behavioral patterns of customers, but to have an effective APC system, it is important to know what the overall goals are and what do I expect from implementing APC.

Various research projects in EU, such as INSTEMPO [3] and Fair Stations [4], are incorporating APC as a means of innovating railway stations.

The link between customer satisfaction and crowd monitoring and management is confirmed by several studies. For example [5] presented results of an online survey showing that for effective management, planning and reconstruction of stations, the forecasting and management of passenger flow and time control of the entrance groups of the station become a necessary factor for assessing satisfaction with the services of the stations.

Objectives

In this paper, we want to help decision makers in the public transport sector to understand the advantages that such technology brings to them. To do that we classify the APC systems to be able to demonstrate their suitability for different tasks in their daily business. These tasks are captured using use cases [6].

The use case analysis starts with the definition of so-called actors. Actors, according to definition (uml.org), are "*external entities that interact with the system in scope*". This is important, as we can identify the use cases offered to each of the actors. The decision makers can thus see the impact not only on their business, but also on other players (actors) and thus address also the long-term strategic impact on society [7].

To provide a clear picture, we look at different dimensions of the problem. The use cases are linked not only to various actors, but they are also considered according to their impact in the strategical, tactical, as well as operational level [8].

Maslow, in his 1943 paper [9] provided a pyramid identifying the hierarchy of needs. This is important, especially when looking at the needs of passengers at railway stations. In this paper, we classify the use cases with respect to this pyramid, as it provides another important touch to a better understanding of the implications and advantages of APC technology.

Crowd monitoring and management are not only needed with respect to the passengers, even though they are one of the key players. Already in 1974, in the US, Federal Transit Administration (FTA) set up the FTA's National Transit Database (NTD) to be the repository of data on financial, operating, and asset conditions of American transit systems. They need data from APC critically.

The purpose of this paper is to show the different perspectives and views on APC data. We demonstrate its impact on different actors. The paper helps the different stakeholders to understand the reasons why they might consider APC in their stations.

Technological overview

An APC system consists of 3 components: the sensors, sensor controller, and back-office that processes the data.

The sensors themselves collect data and can do some basic preprocessing (, such as data binning or adding metadata). The recorded values are passed to the controller, which receives signals from one or multiple detectors. The controller can do further data processing and then sends the data to the back-office.

The back-office is a software that collects and processes measured values and stores them in a database. The data can be processed and visualized in the back-office or sent to third party software in the form of raw data exports or via direct database access. In that case, it is important that the data is transferred in a well-defined format to ensure smooth processing.

Anonymization of the data is a crucial step in this process. In general, the entire data collection process is very sensitive and must meet the General Data Protection Regulation (GDPR) specifications.

The APC system provider can offer its own back-office but large entities may have a custom solution for data processing implemented and so would prefer direct access to the data.

Classification of APC technology

There is a large number of different technologies that are used for collecting data in APC systems. Each technology has certain advantages and disadvantages and is suitable for different applications (use cases). The spectrum is very broad. To define the requirements for particular use cases, a classification of the APC technology according to complexity with respect to the data collected is provided here:

Level I

- Detector ID
- Timestamp
- Direction of passage
- Simple data aggregation (count of people during a period, count of people present in an area at the moment)

Level II

- Object classification (adult, child, bicycle, pram, wheelchair, luggage, dog…)

Level III

- Movement trajectories
- Dwell time
- Occupation heat map

While this is a certain simplification, it is used in the following sections to classify the use cases.

Sensor technology

There are several detecting technologies used in APC systems [10]. "Automatic" in APC expects no cooperation from counted subjects, so tap-in tap-out gates and sensors based on receiving Bluetooth or Wi-fi signals from people's personal devices are out of the scope of this paper.

Optical gates are a simple technology that is used for counting passengers without any classification. By doubling the sensors, it is possible to infer the direction of movement, however it can capture only one passing person at once. These detectors return typically Level I data.

State-of-the-art IR sensors use both active and passive components in one housing, mounted above the passageway [11]. These detectors can count two persons passing through the door at once while heading the opposite direction. It can also classify the measured object by size to determine its category. Careful installation and calibration of the sensors is needed to provide satisfactory results. Level II data can be obtained from these detectors.

Video camera imagery is processed by image recognition software to obtain not only the passenger count but can also track their movement. Cameras can offer wide-angle coverage and allow to cover a larger area, thus being able to provide Level III data.

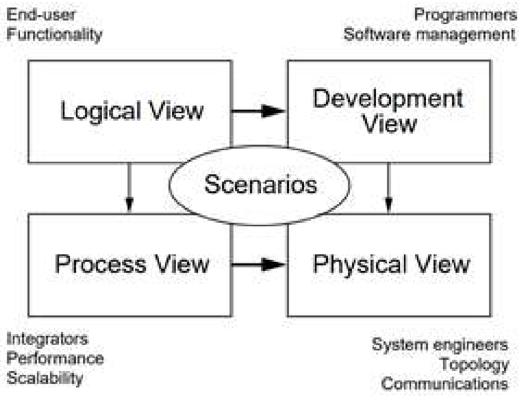
When using cameras, there is a reasonable concern of privacy violation, which can be mitigated by installing cameras on the ceiling facing downwards so that only the top of the person's head is visible. When implementing tracking, personal data must be anonymized according to legal requirements, such as GDPR mentioned above.

METHODOLOGY

In many real-world projects, technology is used without thinking about its actual impact. To understand this impact, we follow a standardized methodological approach called "4+1 View Approach" [12] using Unified modeling language, particularly the use case diagram as a suitable tool [6]. This classical approach is originated within the field of software engineering but offers so-called use cases (from UML's Use Case diagram) as a central point of any analysis. Use case describes "*a set of actions that some system should or can perform in collaboration with one or more external users of the system (actors). Each use case should provide some observable and valuable result to the actors or other stakeholders of the system*" (uml.org).

This use-case centric approach (see Figure 1) is advantageous in the way that even though it is suitable for software developers as it provides sufficient details, use cases, i.e., the high-level functionality is at a central point.

Figure 1. Principle of the 4+1 view model



Source: Kruchten, 1995.

To collect the content of this analysis, we used several mechanisms. First and most important was an extensive state-of-the-art analysis. The existing scientific papers, research projects, but also reports from technological companies or governmental agencies were identified and analyzed. Additionally, interviews with various stakeholders were conducted and the results incorporated into the use case analysis.

The use case analysis [13] starts by defining the system in scope. In our case, we are focusing on the system: an automated people counting system in railway stations.

Next methodological step consists in the identification of actors. An actor is "an external entity that interacts with the system in scope" (adopted from uml.org). It is a role played by a person or other external system that uses the high level functionality of the system. A use case diagram depicts actors, use cases and the interactions between them.

The actors identified for the APC system at railway stations include bodies listed below. The colored boxes correspond to the marks that represent the actors in Figures 3–5.

1. National and international regulatory and standardization bodies – are responsible for setting standards that the APC systems adhere to and for collecting nation-wide statistical data (e.g., Ministry of Transport and others).

2. Infrastructure manager – is responsible for the construction and maintenance of railway tracks and related infrastructure.

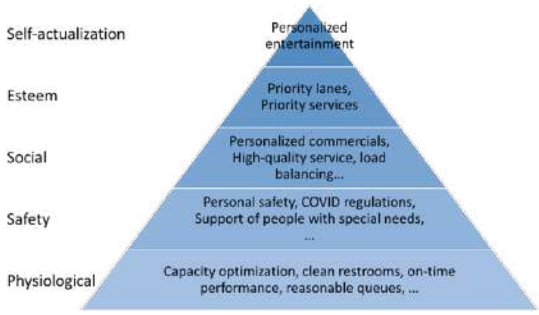
3. Railway station operator – is responsible for operation and maintenance related to railway stations, including platforms, waiting rooms, or customer service centers. The operator may be identical to the infrastructure operator.

4. Transport service provider – are responsi¬ble for carriage and train operations and provide direct service to passengers.

5. Passengers – are the customers of the transport service.

While the passenger is listed last, being the customer of the public transport system, they are its central point. At the same time, the requirements (mainly the economical) of the passenger can often contradict those of the infrastructure manager or railway station operator. For this reason, an additional analysis is provided here. In order to understand the needs of the passenger, a Maslow's pyramid was adopted with respect to the passenger needs in railway stations.

Figure 2. Passenger needs according to Maslow's hierarchy



This pyramid provides another dimension to the use cases provided in the following chapter. It has 5 levels. At the bottom, there are physiological needs, such as capacity restrains, expectations about cleanliness of bathrooms, etc. Next level is dealing with the personal security and safety. This topic became lately, during the COVID-19 pandemic, even more important. The third level focuses mainly on the main services and their quality. Here we are looking at ticketing services, etc. The fourth level covers esteem, such as priority lanes, VIP services, and others. The last, fifth level deals with self-actualization and covers also personal growth, including reading or personalized entertainment.

RESULTS OF USE CASE ANALYSIS

The main contribution of this paper is, next to the theoretical and methodological background, a collection of use cases relevant for APC. The use cases were collected based on personal interviews with relevant stakeholders (mainly infrastructure operators and technology providers in the Czech Republic), as well as literature review. Apart from the above-mentioned literature, we focused on papers and projects related to the passenger's movement [14, 15, 16, 17, 18], technology [10, 19, 20, 21] and general system approach, and usability studies [5, 22, 23, 24, 25, 26, 27].

We use different classifications:

1. According to the actors
2. According to control levels
3. According to requirements on technology

The particular identified actors were defined and described in the Methodological section. Different control levels [28] are defined as following:

Strategic level – is linked to the strategic planning of the organization and marks the future that is expected for the company.

Tactical level – describes the tactics the organization plans to use to achieve the ambitions outlined in the strategic plan. It usually has a scope of a year or less and breaks down the strategic plan into smaller tasks.

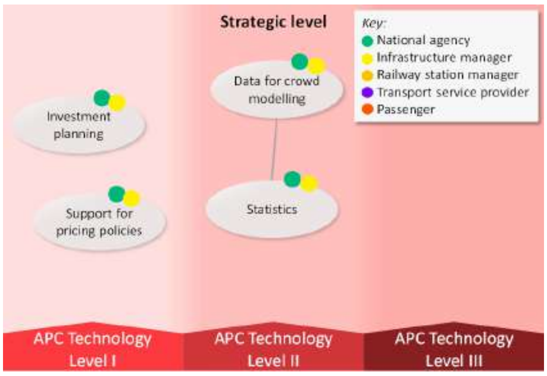
Operational level – describes the day-to-day railway station operations.

The classification of technology is described in section *Classification of APC technology*.

The following sections provide an overview of the Use cases, which are classified into three control levels as presented in diagrams. In each control level, the use cases are ordered by the required APC technological complexity level. Every use case is labeled with colored circles representing relevant actors. The key to the colors is presented in the diagram in Fig. 3. Lines connecting the use cases represent strong relations between them.

Strategic Use Cases

Figure 3. Diagram of the required APC technology level of strategic level use cases and their relevant actors



Investment planning

Based on the actual number of passengers in the railway station, it is possible to identify bottlenecks and thus plan for needed investments into the infrastructure. This covers also all buildings.

Support for pricing policies

On the strategic level, it is possible to set, for example, particular contracts and pricing levels based on actual passenger data. This can be used, for example, to define the pricing policies of:

- long-term and short-term Park & Ride,
- renting commercial estate and advertising space,
- rush-hour ticketing surcharge.

Data for crowd modelling

Different scenarios can be virtually tested in order to assess the people flow when subjected to different conditions. Crowd modelling can be a very useful tool in the design phase, to test the efficiency of possible solutions (including technologies, procedures, layouts, etc.). Furthermore, it can be used also to test station retrofitting solutions (e.g., new stairs/escalators; smart signaling systems).

Crowd models can also be created to monitor the behavior of people in a given environment in real time thanks to the integration of virtual doors and cameras that can be used to count people in the area continuously and in real time. These models can be used to generate what-if scenarios in order to apply different people management strategies to optimize the flow of people (both in normal conditions and in the event of emergency/evacuation).

Calibration is a crucial step and APC plays a key role in this step.

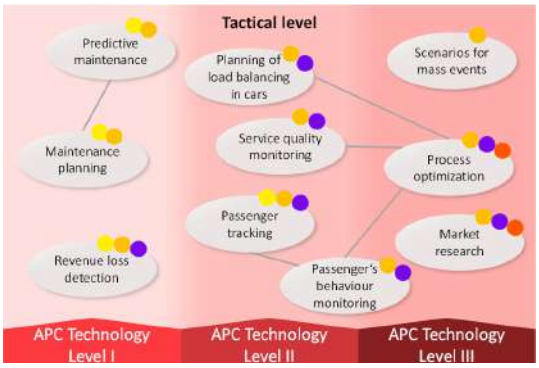
Statistics

Manual passenger counting campaigns can be replaced by automated people counting systems on platforms or even train doors when coupled with platform screen doors.

Furthermore, APC data can and shall be used for reporting to a National Transit Database (NTD).

Tactical Use Cases

Figure 4. Diagram of the required APC technology level of tactical level use cases and their relevant actors (key to actors is in Fig. 3)



Predictive maintenance

Predictive maintenance based on actual usage of certain components increases the effectivity of maintenance. This is meaningful, for example, for escalators, ticket boxes, but even for light bulbs located in less frequent places that are triggered by motion sensors.

Maintenance planning

The actual time of maintenance can be scheduled for the time of low demand based on the historical or actual occupancy of the railway station or its parts. This significantly improves the passengers' comfort.

Revenue loss detection

Discrepancies between the number of sold tickets and the count of passengers on board can be detected and used for tactical planning and corrective measures.

Planning of load balancing in cars

The knowledge of passenger movement throughout the station on the platform can be used to stop short trains closer to the points of largest demand.

By knowing the ridership of trains, the train length can be modified to accommodate changing passenger numbers when scheduling the trains.

Service quality monitoring

Knowledge gained from monitoring the usage of services (shopping, ticketing, information handling, etc.) can be used to improve staffing, optimize opening hours, or decide better point of service layout in hallways and product displays in shops.

Passenger tracking

By automatically tracing the boarding and alighting stops of individual passengers, more data about travel habits can be acquired without the need of passenger's cooperation when compared to tap-in tap-out fare systems. However, personal data protection must be assured, as it is prescribed in regulations, such as GDPR.

Passengers' behavior monitoring

On the tactical level, the movement of passengers within the railway station and on platforms can be tracked. This must be done anonymously and on an aggregated level (for example using heat maps). The understanding of passenger behavior may be used for optimization of passenger movements or service quality.

Scenarios for mass events

Fully calibrated crowd models can help in the preparation of scenarios for special mass events, such as concerts, football games, and others. The data needed can be collected using APC systems.

Process optimization

All railway station processes can be optimized if we know passengers' presence and movement patterns, as well as the provided services. It is possible to compare the real usage (demand) with the supply based on train schedules, i.e., its dynamic characteristics and changes during the day. This can be used primarily for optimizing the number of ticket counters, as well as ticket boxes in relation to queues, etc.

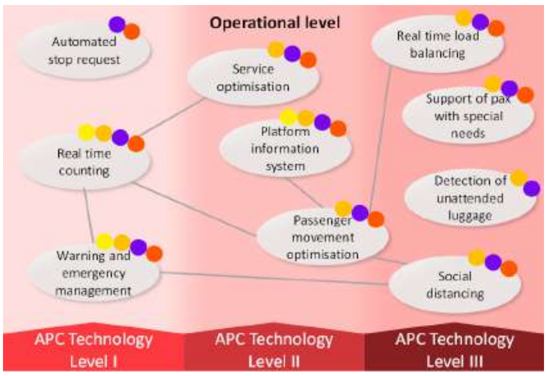
Additionally, platform technicians can plan their activities based on actual demand.

Market research

Nowadays, there is a massive application of these technologies for market research. Measurements of transits and of densities in specific areas can be interesting for a market investigation, which aims to increase the number of sales in the shops, for instance, giving more visibility to certain products.

Operational Use Cases

Figure 5. Diagram of the required APC technology level of operational level use cases and their relevant actors (key to actors is in Fig. 3)



Automated stop request

This use case can be applied at less frequently used railway stations. If passengers waiting on the platform are detected, a stop of a train arriving on the platform is requested.

Real time counting

The real-time occupancy of a railway station, or certain areas inside thereof (, such as waiting rooms) can be determined. This is important for example with respect to dedicated use cases, such as Emergency management.

Warning and emergency management

The collection of data on the number of users in the station can be also used to design efficient evacuation strategies and plans, increasing the level of reliability of the station. It can be used in real time to provide information for emergency management units, for example, about the number of people in danger and thus determining the needed number of ambulances etc.

Service optimization

The knowledge of the actual number of passengers in dedicated parts of the railway station can be used to optimize the building operations based on actual occupancy, for example:

- toggling on heating or lightning,
- staffing ticketing services,
- customizing information displayed on panels,
- optimization of advertisement display

and others.

Platform information system

In cooperation with other use cases (for example, Load balancing), the occupancy of individual cars can be displayed at the stop prior to the train's arrival so passengers can distribute themselves more efficiently, allowing for more even utilization of train capacity and higher comfort.

Trespassing into the platform edge safety zone can trigger a warning announcement.

Passenger movement optimization

This use case provides optimization of the route for passengers changing trains (or in general moving within the railway station). The objective is to decrease the journey time, decrease crowding and queues. This is possible through providing timely and accurate information on the platform or in digital devices, changing the direction of escalators to support higher demand, directing the platform personnel to further support passengers, increasing localized and timely ticketing etc.

Real time load balancing

The knowledge of the number of people in certain segments of the railway station and their movement, as well as information about the actual load of the incoming trains allows an optimal distribution of passengers on the platforms to avoid crowds and queues.

Support of passengers with special needs

In case the system detects passengers with special needs (for example, handicapped, cyclists, passengers with baby carriages, passengers with animals, and others), the railway operators can support them, for example, by:

- prolonging the boarding times,
- providing personalized navigation,
- providing personal support, or
- providing extra supporting tools and gadgets.

Detection of unattended luggage

The detection of unattended luggage may trigger an alarm and dispatch a security officer to investigate.

Social distancing

Knowledge of real-time heat maps with passengers in certain parts or segments of the platforms or within the railway station building can be used to address social distancing. A warning (information) system is established to suggest changes in passengers' movement patterns and travel behavior. This significantly increases the safety of passengers in the short term (e.g., limiting bumping into each other), but also in the long term (e.g., by decreasing the probability of spread of diseases, such as COVID-19).

CONCLUSION

The main objective of this paper is to provide different stakeholders an overview of the use cases related to the usage of APC technology on railway station platforms (but it can be applied with only slight modifications to other public transport modes as well). The aim is to help to understand how to use the technology and how to have the most benefit.

To do that, we introduced a 4+1 approach to use case analysis and followed it through the paper as follows. We provided an overview of the technology by itself and classified it into three main levels. These different levels are assigned to various use cases and help to determine the requirements on the data that need to be fulfilled.

Next, we provide an analysis of actors relevant for the system in scope. We identified 5 actors. They are also assigned to particular use cases.

The main contribution of this paper is however, in capturing and organizing the actual use cases. They were collected using interviews with different stakeholders and an extensive literature review. For better clarity, we classify them into three control levels: strategic, tactical, and operational.

The use cases are useful for all actors described within this paper. They should be mainly studied and understood by infrastructure providers and railway station operators before they consider the implementation of APC. We believe this might protect them from "assertive" sale practices of some technology providers and increase the overall benefits of APC technology. It might also help in better marketing and thus better acceptance of the technology by the passengers. This is the best way to increase the overall benefits of the technology.

REFERENCES

[1] H. M. Kim, S. Sabri and A. Kent, "Smart cities as a platform for technological and social innovation in productivity, sustainability, and livability: A conceptual framework," Smart Cities for Technological and Social Innovation, p. 9–28, 2021.

[2] O. Přibyl and M. Svítek, "System-oriented Approach to Smart Cities," in Proceedings of the First IEEE International Smart Cities Conference, New

York, 2015.

[3] "Project Instempo: Innovative Solutions in Future Stations, Energy Metering and Power Supply," [Online]. Available: https://cordis.europa.eu/project/id/777515.

[4] "Project Fair Stations," [Online]. Available: http://www.fairstations.eu/.

[5] R. Sidorchuk, A. Lukina, I. Markin and S. Korobkov, "Influence of Passenger Flow at the Station Entrances on Passenger Satisfaction Amid COVID-19," Journal of Open Innovation: Technology, Market, and Complexity, pp. 1-26, 16 November 2020.

[6] M. Clausen, R. Apel, M. Dorchain, M. Postina and M. Uslar, "Use Case methodology: a progress report," Energy Informatics, 2018.

[7] M. Trkman and P. Trkman, "Actors' misaligned interests to explain the low impact of an information system – A case study," International Journal of Information Management, no. 34, 2013.

[8] M. Bertoni, "Introducing Sustainability in Value Models to Support Design Decision Making: A Systematic Review," Sustainability, no. 9, 2017.

[9] A. H. Maslow, "A theory of human motivation," Psychological Review, no. 50, p. 370–396, 1943.

[10] D. C. Duives, T. van Oijen and S. P. Hoogendoorn, "Enhancing Crowd Monitoring System Functionality through Data Fusion: Estimating Flow Rate from Wi-Fi Traces and Automated Counting System Data," Sensors, vol. 20, 2020.

[11] I. Pinna and B. Dalla Chiara, "Automatic passenger counting and vehicle load monitoring," Ingegneria Ferroviaria, vol. 65, pp. 101-138, 2010.

[12] P. Kruchten, "The 4+1 View Model of architecture," IEEE Software, vol. 12, p. 45–50, 1995.

[13] S. Tiwari and A. Gupta, "A Systematic Literature Review of Use Case Specifications Research," Information and Software Technology, vol. 67, 2015.

[14] M. Küpper and A. Seyfried, "Analysis of Space Usage on Train Station Platforms Based on Trajectory Data," Sustainability, vol. 12, no. 20, 2020.

[15] E. Jenelius, "Data-Driven Metro Train Crowding Prediction Based on Real-Time Load Data," IEEE Transactions on Intelligent Transportation Systems, vol. 21, no. 6, 2020.

[16] S. Peftitsi, E. Jenelius and O. Cats, "Determinants of passengers' metro car choice revealed through automated data sources: a Stockholm case study," Transportmetrica A: Transport Science, vol. 16, no. 3, pp. 529-549, 2020.

[17] J. Capalar, A. Nemec, C. Zahradnik and C. Olaverri Monreal, "Optimization of Passenger Distribution at Metro Stations Through a Guidance System," in Computer Aided Systems Theory, 2018, p. 397–404.

[18] F. Hänseler, J. van den Heuvel, O. Cats, W. Daamen and S. Hoogendoorn, "A passenger-pedestrian model to assess platform and train usage from automated data," Transportation Research Part A Policy and Practice, vol. 132, p. 948–968, 2020.

[19] P. Fraga-Lamas, T. Fernández-Caramés and L. Castedo, "Towards the Internet of Smart Trains: A Review on Industrial IoT-Connected Railways," Sensors, vol. 17, 2017.

[20] K. A. Nguyen, Y. Wang, G. Li, Z. Luo and C. Watkins, "Realtime Tracking of Passengers on the London Underground Transport by Matching Smartphone Accelerometer Footprints," Sensors, vol. 19, no. 19, 2019.

[21] S. Velastin, R. Fernandez, J. Espinosa Oviedo a A. Bay, "Detecting, Tracking and Counting People Getting On/Off a Metropolitan Train Using a Standard Video Camera," Sensors, sv. 20, č. 21, 2020.

[22] E. Matsika, "DELIVERABLE D6.3: Exploitation plan, including recommendations for future standards and guidelines, and concept development," EU FAIR Stations Project, 2019.

[23] E. Matsika, "DELIVERABLE D6.2.: Validation: Stakeholder Feedback and Experimental and virtual testing of the developed concept," EU FAIR Stations Project, 2019.

[24] H. Lemmerer, "User Needs and Expectations of the General Public and PRMs. EU FAIR Stations Project," EU FAIR Stations Project, 2018.

[25] M. Plaud (ed.), Smart stations in Smart Cities. Intelligent and Resilient., International Union of Railways, 2017.

[26] Siemens, "Digital Station Solutions and Railway Communication. Flyer.," [Online]. Available: www.mobility.siemens.com. [Accessed August 2021].

[27] X. Chu, A Guidebook for Using Automatic Passenger Counter Data for National Transit Database (NTD), Tampa: National Center for Transit Research at CUTR, University of South Florida, 2010.

[28] R. Petrevska Nechkoska, G. Poels and G. Mancheski, "Bridging operational, strategic and project management information systems for tactical management information provision," Electronic Journal of Information Systems Evaluation, vol. 18, no. 2, p. 146–158, 2015.

19TH EUROPEAN TRANSPORT CONGRESS
EUROPEAN GREEN DEAL CHALLENGES AND SOLUTIONS FOR MOBILITY AND LOGISTICS IN CITIES
OCTOBER 7 – 8, 2021, MARIBOR, SLOVENIA, CONFERENCE PROCEEDINGS

The Development of Safety Control System for Autonomous Train Operation – Lessons Learned

JAN PRIKRYL, MICHAL MATOWICKI, BOHUMIL KOVAR, TOMAS BRANDEJSKY, VIT FABERA, ADAM HLUBUCEK, ONDREJ PRIBYL, VITEZSLAV LANDSFELD, MICHAL NOVAK

Abstract The paper provides an overview of the ongoing development process of the safety control system for autonomous train operation. In the provided work authors cooperate with a leading signaling systems supplier to apply their knowledge of semi-automated train operation and to analyze and synthesize possibilities and techniques for development and implementation of a system able of substituting necessary train driver activities and responsibilities. A brief overview of the feasible control systems for this task is provided, and challenges in implementation of such a system to provide autonomous operation of trains on grade-of automation levels 3 (driverless, with a train attendant) and 4 (unattended) are analyzed. Finally, the essential building blocks of the proposed safety control system are outlined, and their functionality and related data flow is briefly discussed.

Keywords: • Autonomous Train Operation • Grade Of Automation • Control System • Decision-Making • Digital Map

---

CORRESPONDENCE ADDRESS: Jan Prikryl, Dr.-techn., Michal Matowicki, PhD, Bohumil Kovar, PhD, Tomas Brandejsky, PhD, Vit Fabera, PhD, Adam Hlubucek, Ing., Ondrej Pribyl, PhD, Czech Technical University in Prague, Konviktska 2, Prague, Czechia, e-mail: prikryl@fd.cvut.cz, Vitezslav Landsfeld, Ing. Michal Novak, Ing., AZD Praha s.r.o., Zirovnicka 3146/2, Prague, Czechia, e-mail: landsfeld.vitezslav@azd.cz

Accessible at: www.fgpa.um.si/etc ISBN 978-961-95633-0-4

INTRODUCTION

Although autonomous transportation is not a new concept, its significance and application capabilities grew rapidly thanks to the technologies available in the 21st century. After first implementations in autonomous metro trains and monorail applications, autonomous shuttle buses have followed. Finally, autonomous cars appeared with individual brands claiming millions of miles driven without accident [1]. Thanks to growing popularity and interest in automotive sector, open environment railways[2] might remain the last branch of transportation to become driverless. Although both automotive and railway sections are struggling with proper legislation regulations in Europe, road vehicles tend to be further ahead in people consciousness thanks to technological advancement and better advertisement. This is caused by numerous difficulties connected with automatization of the train driving process, which at this point means transition from the semi-automatic operation at GoA2 mode (automated start/stop, a driver operates the doors, drives the train if needed and handles emergencies) to fully automated operation. Driverless and unattended operation requires additional functionalities, e.g., concerning perception and localization of autonomous trains. While these specific issues have been already studied [2, 3], a lot of other functions remains unaddressed, e.g., robust decision-making or learning. Moreover, the safety levels for these additional functions remain to be established [4], and also the certification process and legislation have to be revised for these new technologies.

From the technological perspective, the Rio Tinto company has led a recent breakthrough in an open environment operation by completing a first fully autonomous freight rail journey of 100 kilometres in the Pilbara region of Western Australia. However, their trains operate on a separated track and not as a part of a complex railway network, and the operational environment is a wide desert, which, while open, retains a low level of possible surroundings interactions, and also low risk in case of failure or accident. Autonomous rail freight transportation [5] seems then to be an interesting intermediary step before autonomous passenger trains. A complex overview of this topic has been already provided by D. Trentesaux et al. in [6].

In Europe, the issue of autonomous train operation is further complicated by the heterogeneous nature of individual national railway conditions, regulations and rules or habits. The coordinated and unified approach for this problem has been established relatively recently and thus the operational and engineering rules, signaling technology and technological readiness still differ among national rail networks all over Europe. Specifically in Czechia, a GoA2 solution named AVV, an

2 For purpose of this paper, railways will refer to the open environment network e.g., mainlines and regional lines. Other systems like metro or shuttle trains at airpoirts will not be reffered to as railways.

ATO (Automatic Train Operation [7, 8]) system responsible for control of dynamic properties of rolling stock, is in commercial use for more than 30 years with hundreds of trains equipped. This is a significant achievement and enabler for fully autonomous train operation.

In this paper, we summarize experience and lessons learned by a multidisciplinary team of scientists and field experts in their effort to develop a safety decision-making control system for autonomous train operation called VEXA. The project started in 2020 with the aim to deliver by 2023 a proof of concept for a safety system, which, based on input from onboard systems, such as Object Detection, Automatic Train Operation, Digital Trackside Map and others, decides whether it is safe to start or continue the train cruise in a given moment in time. The following Sections of this paper includes description of the state-of-the-art, overview of the considered control systems for VEXA, estimated environment and surrounding systems for VEXA operation, as well as challenges and issues solved while designing the system.

STATE-OF-THE-ART IN AUTONOMOUS TRAIN OPERATION

Although autonomous transportation systems have been developed for decades, the most significant advances have only recently been made. When we are talking about autonomous vehicles, we most often imagine systems from companies, such as Tesla and Google, which allow the car to be driven without driver intervention under certain conditions.

Interestingly, one of the first semi-autonomous transportation systems was the London Underground, where the first ATO system was successfully implemented on the London Victoria Line in the early 1970s [9]. A similar ATO system was operated in the Prague metro since 1978. Although the driver was still present and, for example, was responsible for closing the doors or giving the command to departure, this can be considered a great success. Since then, thanks to the advances in computing, electronics, telecommuni-cations and sophisticated machine learning algorithms, significant progress has been made and as a result, in 2018 there were 64 fully automated underground lines in 42 cities, with a total length of over 1000km [10]. It is important to note that these systems are operated in a secured environment and are Therefore, easier to implement than similar systems targeted at the mainlines.

In the Austrian autoBAHN 2020 project [11], a prototype drives autonomously on an existing railroad with an adapted car-based obstacle recognition system, detecting objects and sorting them according to risk classes before deciding on the train behavior given the context. The French ATO Plug-and-Play [12] aims to not only avoid obstacles but also recognize signals, activate passenger alarms, and to detect intrusion and level crossings.

Autonomous trains constantly perceive and evaluate the environment before reacting to obstacles. The perception of the onboard autonomous control system can be divided into rail track detection, obstacle detection, and obstacle classification, while the reaction can be separated into obstacle trajectory prediction and threat assessment. Most of the literature solving the whole process of perception first detects the rail tracks and then, if rail lines are not clearly visible, the occluded areas around the rail lines are investigated for obstacles [13, 14, 15].

As the railway transport is highly proliferated by European Union bodies thanks to the fact that rail is the most "green" transport mode, a Join Undertaking organization called Shift2Rail (https://shift2rail.org/), established in 2015 by EU and European leading railway suppliers, infrastructure managers and railway undertakings and funded under Horizon 2020 program, is highly focused to the development of ATO up to grade of automation GoA4. Hence noticeable achievements including real operation demonstrations of ATO are brought to life within its program. The results will be included in gradual standardization steps in the near future.

Most ATO development activities and demonstrations are carried out in a Shift2Rail Innovation Program IP2 "Advanced Traffic Management & Control Systems" and also in IP 5 "Technologies for Sustainable & Attractive European Freight". A successful Technology demonstrator of GoA2 was showcased in 2020 and work on GoA3/4 development is ongoing. As the program of Shift2Rail will be finished soon, the activities for preparing the Shit2Rail’s successor entitled Europe’s Rail Joint Undertaking have already started. So, the work in the ATO field will continue.

CONTROL SYSTEMS OVERVIEW

Requirements of rail vehicle onto control system solved within VEXA project are analogical to ones solved in the area of mobile robots, autonomous vehicles and especially autonomous trains on dedicated tracks (e.g., metro) etc. with respect to detail described below. Mobile robotics solves artificial creatures in common, real or virtual. It originated especially by works of Moravec [17], Nils [18], and Giralt et al. [19] and spread onto wide area of real creatures modelling, anthropomorphic robotics, robotic swarms, etc. That research also brought abstraction in the form of agent idea and its specific case – mobile agent model.

The term agent denotes humans, software entities (bots) and intelligent, autonomous, and mobile agents in robotics and artificial intelligence especially in the sense of systems interacting and acting in the given environment. Thus, mobile agents must be able to move in the space and have some sensors to observe the environment and actuators to influence it. For our research of an autonomous train control system, the mobile agents are the most interesting.

In the work of Russel and Norvig [20] the following basic agent types are recognized:

1. simple reflex agents, which are the simplest possible agent entities, which only react to external inputs, typically using a set of pre-determined rules;
2. model-based reflex agents, which maintain an internal model of their environment, and, which are also able to store some historical data; the decision-making is then performed based on the data and the internal model;
3. goal-based agents build on the model-based reflex agents by adding a binary "goal", a target setpoint that they try to reach; however, they are only able to decide if they reached the goal or not;
4. utility-based agents are equipped with a model, a setpoint, and a utility function, which tells the agent how far it its internal state from the envisioned goal state;
5. learning agents are the most complex and truly autonomous entities: they retain the performance element of their simpler counterparts, and add a learning element, which modifies agent's performance according to the feedback on agents results; a learning agent may also include a subsystem that suggests alternatives to the already attained decisions.

Later, Weiss [21] defined different four classes of agents. This taxonomy is more suitable to our application:

I. Logic-based agents – where the decision about what action to perform is made via logical deduction;

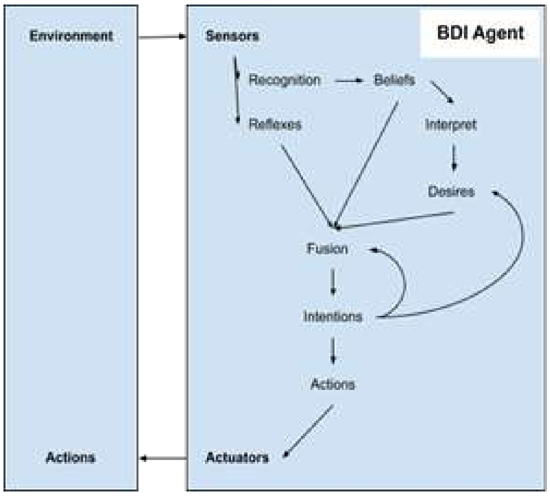
II. Reactive agents – here, the decision-making is implemented in some form of direct mapping from situation to action;

III. Belief-desire-intention agents – their decision-making depends upon the manipulation of data structures representing the beliefs, desires, and intentions of the agent;

IV. Layered architectures – the decision making is realized via various software layers, each of, which is more or less explicitly reasoning about the environment at different levels of abstraction.

Within the VEXA project, BDI (Belief-Desire-Intention) was chosen for the need to solve both strategic (especially safety related) and tactical (route schedule related) activities of variable priority and level of nesting. The BDI agents [22] were originally developed for software agents in agent-based simulations of complex social interactions but they are also applicable for mobile robot (e.g., automatic train) control [23]. They are based on the idea of beliefs representing information about agent state, desires representing a dynamic set of agent aims and tasks, and intentions representing actual focus of agent activity, its plans. Desires and intentions might be dynamically prioritized and changed on the basis of agent state development and environment observation.

Figure 1. BDI Agent structure



VEXA train vehicle in its first variant implements reactive reasoning immediately mapping safety related observation (sensor inputs) like obstacle recognition (from perception system), fire alarm signal etc. onto intentions and information about train route schedule (from ATO), movement permitting signals etc. onto desires to be processed in the suitable time and order.

CHALLENGES AND SOLUTIONS

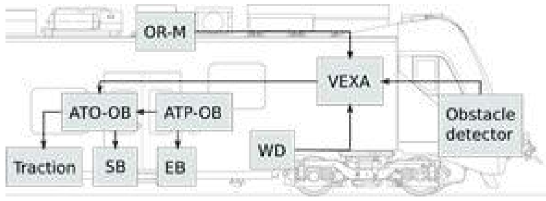
An autonomous train control system should replace the human operator – driver. Such a system must undertake driver's tasks, mainly to check conditions before leaving the station (check if doors are closed, if people are not pushed by doors, if people are not present near the rail in the area of station) and permit the movement from the station. On the track, during the run, it must detect anomalies. In case that the track is equipped with a high-level ATP (Automatic Train Protection system) like ERTMS/Etc.S, the autonomous system does not need to detect, identify and follow light signals. Naturally, the system should monitor various detectors in the train like fire detectors, emergency break, emergency buttons controlled by passengers, and evaluate dangerous situations and treats. The autonomous system must also cooperate with the ATO part and the diagnostic system of the train.

These systems have already been deployed widely at metro (underground) transport (e.g., Lille in France, Dubai). The main difference between the autonomous metro and rail is that autonomous metro is a closed system. Metro trains run through tunnels, overground rails are isolated from the surroundings by barriers, stations are also equipped by barriers (with automatic doors) separating the rail-space from the rest of the platform. This setup minimizes undesirable occurrences of persons, animals and other things in the runway of the train. On the other hand, a traditional rail is an open environment: there are crossings, people or animals can occur in the railway space, the rail track may become blocked by trees, rocks, or vehicles. As a consequence, the GoA3/4 ATO must employ a perception system that is significantly more complex than its counterpart deployed in metro. This system must reliably detect obstacles, especially persons/animals in rail, and cars at railway crossings in a distance comparable to the detection distance of the original human driver.

One of the key components of an autonomous control system is the location subsystem. Although the localization of the train can be provided by some of the GNS technologies, the precision of localization is not sufficient in this case. Hence, the exact position of the train must be determined based on pre-defined waypoints (balises) and odometry, in collaboration with the ATO/ATP systems. With respect to complicated surroundings of the railway (in contrast to metro) it is desirable to store a digital map on board of the train, which contains information about objects surrounding the railway track (e.g., trees, houses, walls, slopes, railway crossings). The system can compare recognized object by perception system with objects stored in maps to better identify abnormalities – for example if the perception system recognizes a silhouette of a person near the rail in some distance, the decision-making system may find out from the map data that a statue is placed in that position, so the probability of undesirable person existence is low.

So, main components of autonomous train control systems are perception system (obstacle detector) and map management system, and the core – the decision-making system based on agent approach.

Figure 2. Position of VEXA in the context of autonomous train systems (GoA4)



From the left:
ATO-OB – Automatic Train Operation On-Board,
ATP-OB – Automatic Train Protection On-Board,
SB – Service Brake,
EB – Emergency Brake,
OR-M – Operation Rule-Module,
WD – Watchdog Module.

Given the current advances in artificial intelligence, a tempting approach to implementation of the VEXA system would be to use some kind of statistical learning to devise a system that replicates the decisions of a human operator under observed sensory inputs. However popular this approach may be in other autonomous driving or in sensor data pre-processing tasks, a decision-making system for a GoA3/4 train operation needs to undergo a very detailed certification process, which requires – among others – a guarantee of a stable system response to given inputs. Unfortunately, known property of AI systems is, that they cannot guarantee stable decisions in cases where an unknown (or even a slightly altered) input has been observed, and Therefore, artificial intelligence cannot be currently used in our decision-making system, as such a system will likely fail the certification process.

If the software should be really deployed, the development of the whole system must fulfill European standards EN 50126-1, EN 50126-2 (RAMS life cycle), EN 50129, and especially the development of the software must satisfy EN 50657. The software / system must be assessed by the independent safety assessor.

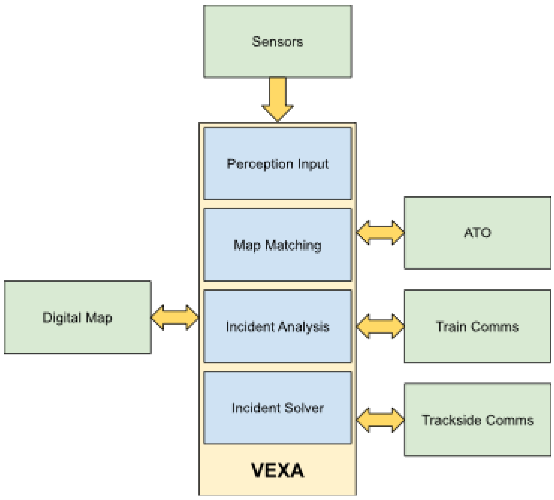
Firstly, the software must be developed to meet the requirements of the highest Safety Integrity Level (SIL) – SIL4. The structure of the team must satisfy the standard from the point of independency of roles related to SIL4 (e.g., an independent verifier and validator). The software life cycle must be introduced, and the development documentation must be kept according to the EN 50657 standard. Above all, the lifecycle must begin with hazard analysis, followed by the requirements specification phase; safety-related requirements must be extra labeled. Test specifications must be created against requirements, and each phase of the life cycle must be verified. The development is finished by an overall/integration testing and validation phase.

VEXA SYSTEM PROPOSAL

The VEXA system has a modular structure. The key input for VEXA are various sensors that replace the sensory perception of the train driver. This set may be different for each implementation of an autonomous train. Therefore, a (dynamic) configuration of all modules used in a particular train set is possible. The data from the sensors monitoring the outside field of interest for the train operation are preprocessed and delivered to VEXA using the *Perception Input* (PER) module.

The *Map Matching module* of VEXA is responsible for evaluation of objects identified by PER. The module receives detailed information about train position and speed from the *ATO*, e.g., as reported by the ECTS equipment. Based on this information it calculates the predicted position of moving objects and identifies future objects in the field of interest[2]. The most important and main function of the *Map Matching* module is the comparison and evaluation of overlap between known objects stored within the digital map and objects reported by PER. Based on these results, a list of unexpected objects is sent for further investigation and incident analysis.

Figure 3. Components of the VEXA system (blue)



The *Incident Analysis* Module regularly analyses the list of unexpected objects to determine possible threats. It also aggregates, maps and monitors events reported by the train and trackside systems. The incidents are classified using deterministic rules that mimic the decision-making process of a train operator. If an incident must be prevented, this module decides, which reflexive reaction is required to prevent or mitigate its impact.

2 The field of interest is in our case a strip in Field of View of pre-defined width from railway center. This strip is further divided into different danger zones, where potential obstacles are detected and reported.

Finally, the *Incident Solver* module is responsible for executing the reaction decided by its parent module. If necessary, it also contacts the supervisor, e.g., with a request to take over the train operation.

An important component of the system is represented by the *Digital Map* environment, providing VEXA with the map data describing the railway infrastructure and its surroundings. Even though the map is not a part of VEXA itself (as VEXA concentrates on the driver decision-making tasks), it must be developed in close collaboration with this system as it represents a vital information source for the analysis of the objects detected in the field-of-interest of the train. The environment consists of two subsystems: *Digital Map Trackside* and *Digital Map Onboard*.

Digital Map Trackside describes the whole railway line or network intended to be operated by VEXA-supervised vehicles. The infrastructure data are tied to the map objects that are grouped into individual tiles according to their geographical location. Based on the VEXA equipped railway vehicle location, the appropriate data tiles are sequentially loaded to the *Digital Map Onboard* subsystem providing the data to the VEXA *Map Matching* module.

The structure of the Digital Track Map is designed to reflect the principles of the International Railway Solution IRS 30100 UIC RailTopoModel. Therefore, the railway network is to be expressed using so-called net elements connected by so-called net relations. The net elements represent the basis for locating so-called net entities, which are various data-describable objects and properties of the railway transport route [16]. This solution allows us to localize the entities using spot, linear or area type of functional location. In terms of the substantive content, such entities as horizontal curves, vertical curves, signals, platform edges, level crossings, non-stopping areas and so on can be included to the Digital Track Map.

The first instance of the Digital Track Map is being created based on the Čížkovice – Obrnice railway line.

CONCLUSIONS

Although autonomous metro trains and monorail vehicles are becoming common applications of unattended operation in closed-access railway environment, autonomous operation of trains in the open environment still faces many challenges, e.g., concerning perception and localization of autonomous trains or appropriate reactions to many different situations and/or safety certification process of the new generation systems like the internal decision-making system, and missing legislation and rules for an autonomous train operation.

We have described basic challenges faced by a GoA3/4 ATO system, a part of, which is currently being developed as a proof-of-concept under the name VEXA. The developed system is supposed to take over the decision-making responsibilities of the original train driver. It merges into the current context of an GaA4 ATO system and relies on input from the various onboard sensors/detectors and other ATO/ATP components, as well as on reliable and detailed digital map data. Based on information provided, it analyses the possible threats for the train operation and chooses the appropriate behavior. The core of the developed decision-making system is based on belief-desire-intention (BDI) software agent paradigm.

ACKNOWLEDGEMENTS

The research presented in this paper is supported by the Technology Agency of the Czech Republic (TA ČR) under project number CK01000111 "Development of a train expert system for autonomous train behaviour".

REFERENCES

[1] Teoh, E. R., & Kidd, D. G. (2017). Rage against the machine? Google's self-driving cars versus human drivers. Journal of safety research, 63, 57-60.

[2] J. Wang, X.-H. Yan, B.-G. Cai, and W. Shangguan, "Research on deeply integrated GPS/INS for autonomous train positioning," presented at the 4th IEEE International Symposium on Microwave, Antenna, Propagation, and EMC Technologies for Wireless Communications, 2012.

[3] M. Gschwandtner, W. Pree, and A. Uhl, "Track Detection for Autonomous Trains," in Advances in Visual Computing, 2010, pp. 19–28.

[4] R. Jenkins, Autonomous vehicle ethics and laws: toward an overlapping consensus. New america, 2016.

[5] H. Flämig, "Autonomous Vehicles and Autonomous Driving in Freight Transport," in Autonomous Driving, Springer, Berlin, Heidelberg, 2016, pp. 365–385.

[6] D. Trentesaux et al., "The Autonomous Train," 2018 13th Annual Conference on System of Systems Engineering (SoSE), 2018, pp. 514-520, doi: 10.1109/SYSOSE.2018.8428771.

[7] Lieskovský, A., Myslivec, I., Šula, B. Moderní řídicí systémy hnacích vozidel Českých drah. Automatizace č.8, 1996.

[8] Lieskovský, A., Myslivec, I.: ATO and Etc.S can work together, Railway Gazette International, March 2011.

[9] Day, John R.; Reed, John (2008) [1963]. The Story of London's Underground (edisi 10th). Harrow: Capital Transport. ISBN 978-1-85414-316-7.

[10] UITP - Annual World Report 2018, https://metroautomation.org/.

[11] Gebauer, Oliver, W. Pree, G. Hanis and B. Stadlmann. "Towards Autonomously Driving Trains on Tracks With Open Access.", 19th ITS World Congress, 2012.

[12] Lagay, R., Adell, G. M. "The autonomous train: A game changer for the railways industry.", 16th international conference on intelligent transportation systems telecommunications (ITST) (pp. 1-5), IEEE, 2018.

[13] Kano, G., Andrade, T., & Moutinho, A. "Automatic Detection of Obstacles in Railway Tracks Using Monocular Camera." In International Conference on Computer Vision Systems (pp. 284-294). Springer, Cham, 2019.

[14] Fioretti, F., Ruffaldi, E., & Avizzano, C. A. A single camera inspection system to detect and localize obstacles on railways based on manifold Kalman filtering. In 2018 IEEE 23rd International Conference on Emerging Technologies and Factory Automation (ETFA) (Vol. 1, pp. 768-775). IEEE. 2018.

[15] Berg, A., Öfjäll, K., Ahlberg, J., & Felsberg, M. "Detecting rails and obstacles using a train-mounted thermal camera." In Scandinavian Conference on Image Analysis (pp. 492-503). Springer, Cham. 2015.

[16] UIC. RailTopoModel v1.1 [online], 2017. https://uic.org/rail-system/railtopomodel.

[17] Moravec H. P. "The Stanford Cart and the CMU Rover", Proceedings of the IEEE, 71(7), 1982, 872-884.

[18] Nils J. Nilsson (ed), "Shakey the Robot", SRI A.I. Center Technical Note 323, April, 1984.

[19] Giralt G., Chatila R., and Vaisset M. "An Integrated Navigation and Motion Control System for Multisensory Robots", Robotics Research 1, Brady and Paul (eds), MIT Press, Cambridge, MA, 191-214.

[20] Russell S. J., Norvig P. "Artificial Intelligence: A Modern Approach (2nd ed.)". Upper Saddle River, New Jersey: Prentice Hall. Ch. 2., 2003.

[21] Weiss G., "Multiagent Systems (2nd ed.)", MIT Press, 2013.

[22] Bratman, M. E. "Intention, Plans, and Practical Reason." CSLI Publications. ISBN1-57586-192-5, 1999.

[23] Darryl N. Davis; Shylaja Kanaganapalli Ramulu "Reasoning with BDI Robots: From simulation to physical environment – Implementations and Limitation.", 2017.

Sponsors, Co-organizers and Supporters