CITY LOGISTICS IN THE CENTRE OF THE SLOVAK COUNTY TOWN

Karol HRUDKAY, Lucia MADLEŇÁKOVÁ, Kristián ČULÍK, Ján MORGOŠ

University of Žilina, University Science Park, Žilina, Slovak Republic, EU,
karol.hrudkay@uniza.sk, *lucia.madlenakova@uniza.sk*, *kristian.culik@uniza.sk*, *jan.morgos@uniza.sk*

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Abstract

With the rising living standard, traffic in city centres has been becoming more congested and more and more cities have to adapt different measures and regulations of traffic in their centres. In order to be these measures effective, they should be data-based, and moreover the data must be likelihood.

In the framework of international project Clevernet - Implementation of innovative sensor networks in cross - border regions, a network of traffic sensors was deployed in the centre of Žilina in mid-2021. The network covers all 9 entrances / exits, i.e. total of 26 lanes. These sensors in operation mode 24/7 not only detect passing vehicles but also classify them according to size and speed. Traffic sensors are complemented by microclimatic units and surface frost sensors to study wider climatic aspects.

Thus, a database has been continuously being created, which has a diverse application for expertly based political decisions of authorities. Areas of application are various issues related to transport and climate change as well (static transport, traffic safety, pedestrian safety, transport emissions, public space heating, phenomena affecting transport such as anti-pandemic measures, ...).

The fact that the traffic situation in the centre is serious also represents fact that the city with approximately 81.5 thousand inhabitants generates approximately 54 thousand vehicle entrances to the city centre on a working day. Typically, it is 300 to 335 thousand a week and almost 1.5 million a month. The data is open and available to the professional and scientific community.

Keywords: city logistics, sensor network, traffic data, intensity, road safety

1. INTRODUCTION

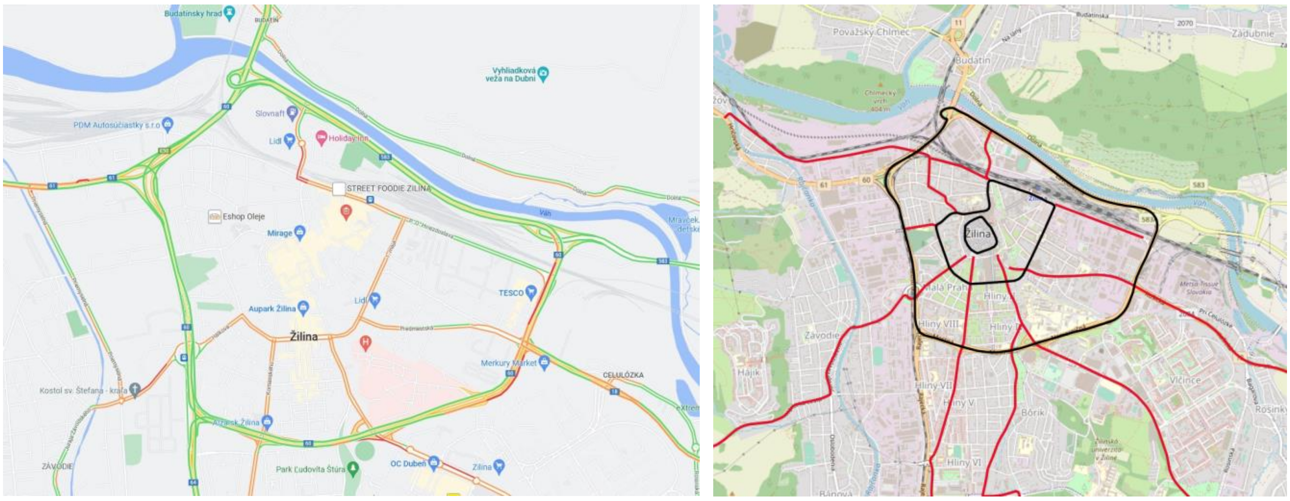
Economic changes in recent decades have had a negative impact on the environment and society, which is increasingly affecting cities and agglomerations. In recent years, several concepts have been developed aimed at the sustainable development of urban agglomerations. The main elements of these concepts are ecological [1,2] and safety transport [3], safety and resilience of cities [4] and reduction of energy intensity of cities [5].

With the rising living standard, traffic in Žilina centre has been becoming more congested as it is illustrated on the **Figure 1a** for the case of traffic during Friday´s noon but some problems with the intensity of traffic persist throughout most of the days. So, some measures and regulations have to be adopted to minimise the negative impact of traffic. To be these measures effective, they should be data-based, and moreover the data must be likelihood. Unfortunately, accurate, reliable and continuous traffic data was lacking (traffic data has even stopped to publish National Traffic Information System [6]).

The aim of the paper is to present first results following from data collected almost one year. Data analysis can show were and when the traffic is a serious problem in centre of Žilina and then already known statistics help the municipality to better understand the problem and identify appropriate measures and solutions to mitigate the negative impacts.

1.1. Transport system in Žilina

In terms of traffic services, Žilina has a historically established ring-radial transport system (**Figure 1b**), which forms the backbone of the area and creates a framework for individual functional components. This system is followed by and the system of main pedestrian routes with public spaces and cycle paths follows from it [7].



a) b)

Figure 1 a) Typical working day traffic in Žilina (Google Maps, typical traffic on a Friday at 12:00), **b)** Ring-radial transport system in Žilina

2. ON THE PROJECT

The project Clevernet (Implementation of innovative sensor networks in cross - border regions) has been realised in the framework of Interreg V-A SK – CZ 2014-2020 programme since beginning of 2021. The consortium consists of two research institution (University of Žilina as the leading partner and Transport research centre as the leading cross-border partner) and three small and medium enterprises (Citiq, Cityone, UNITI) [8].

2.1. Project motivation

Motivation and the project starting points follows from the situation in the middle of 2019 when the concept of Smart City was widely known and popular subject, but the small and medium-sized municipalities (SMMs) had the problems to grasp such complex issue, problems with insufficient staff and financial capacities [9]. Despite the fact that the concepts or methodologies existed, SMMs had problem to cover the deployment of such projects and vice versa it could be seen promoting of technology companies what was in most cases ineffective for SMMs.

SMMs particularly perceived the potential of obtained data mainly for increasing of effectiveness and quality of life. For example, district cities in Czech Republic did not work with data systematically (40% of them the data utilised only in partial areas, 55% sporadically and randomly, others did not work with data at all). It was also recognised key steps of successful projects: data processing and application in the decision-making process. And on the other hand, the main factors that negatively affected the projects were unmanageable processes, focusing on technical solutions and financing.

2.2. Project aims

The aim is to aid small and middle-sized municipalities with systematic data collection and utilisation and, on the other side, help target SME producing solutions for Smart City to be familiar with environment of small and medium-sized municipalities and better establish themselves on the market of smart solutions. The basic and key step for the implementation of the Smart City concept is the processing of the obtained (measured) data and their subsequent application in the city's decision-making processes and thus increase municipality preparedness for the upcoming challenges.

The most extensive activity in the project is research of deployment of sensor networks in municipality conditions and research of efficient work with data and their productive use. The implementation of the activity is divided into two interconnected areas:

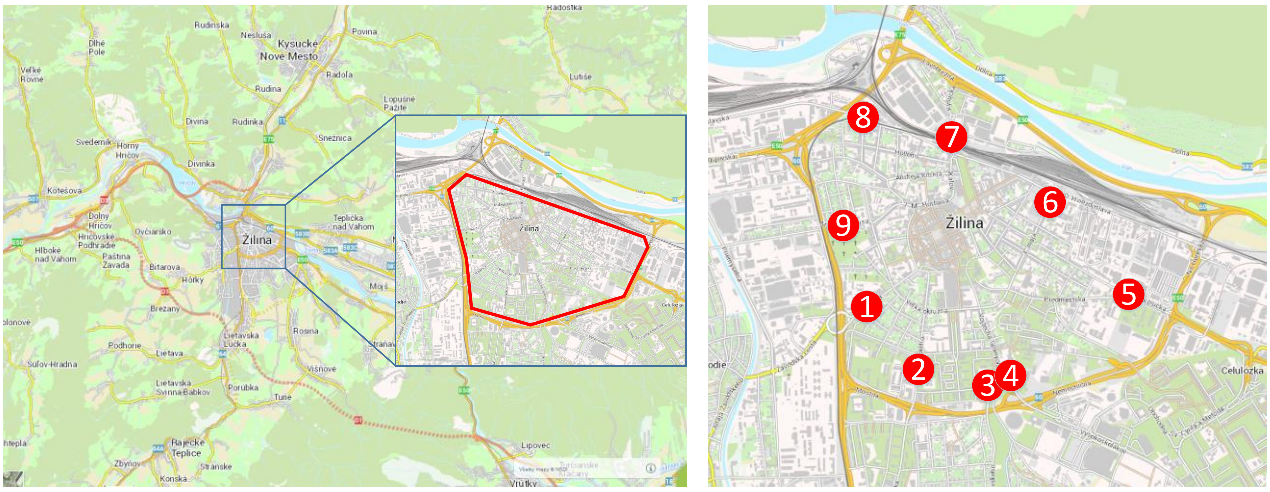
I. Market analysis for detectors and sensor networks for the Smart City area

II. Living laboratory

3. LIVING LABORATORY

3.1. The concerned area

Žilina was chosen as the area of deployment of the Living laboratory because of experience from previous projects and good cooperation with the municipality. The area of the city centre of Žilina was identified for the study of transport because of the lack of traffic data, minimal influence of transit traffic and maximum capture of originating and destination traffic.



a) b)

Figure 2 a) The concerned area of Living laboratory, **b)** Locations (gates) of deployment of traffic sensors in the centre of Žilina

The population of Žilina as of 30.04.2022 is 81,480, the area of the city is 80.03 km^2 and therefore the population density is 1,018 inhabitants per km^2. The concerned area (**Figure 2a**) has circumference of 6.5 km and an area of 2.65 km^2. 16,458 inhabitants live in the affected city districts, of which "only Žilina" is 2,283 inhabitants (i.e., inhabitants without permanent residence), which is approximately 6,200 inhabitants per km^2. Of course, there are many schools, shops and two shopping centres, companies, offices and small businesses in the affected area.

3.2. Living laboratory subsystems

The Living laboratory was deployed during June and July 2021. Clevernet urban Living laboratory consists of several subsystems (**Table 1**):

- radiocommunication network – LoRa network with 2 sites and 8 gateways,

- traffic sensors – 26 magnetometers able to count and classify traffic flow,
- microclimatic units – monitor climate characteristics (air temperature at high 80 cm and 200 cm, humidity, barometric pressure, wind speed and direction) at three different environments (city centre – "concrete jungle", city park – aprox. 9200m^2, mixed zone – university campus),
- surface frost sensors – help increase safety on the roads and pavements in winter times (2 sites),
- parking sensors - 2 magnetometers for counting of incoming and outgoing vehicles (incremental parking system).

The traffic sensors are complemented by microclimatic units and surface frost sensors to study wider climatic and safety aspects. So, the unique laboratory is primarily focused on the research of traffic and environment.

An urban lab concept is widely used tool for innovation support in Europe. It usually relies on a strong community of people from different professions who want to move their city forward with the help of available technological tools. This creates new services for citizens that support better neighbourly relations, local business or a healthier environment, and increase digital literacy. The city's laboratory is designed as a playground for everyone who wants to learn something new about their city and new technologies. Initially, specific sensor networks were deployed that measure traffic or overheating of public spaces, so that various information is already available that can be used not only in further research, but also in creating innovations in the business sector or in the local government environment.

Table 1 Living laboratory subsystems

LoRa network	Traffic sensors	Microclim. units	Frost sensors	Parking sensors
				

3.3. Traffic sensor network

The most technologically advanced part of the sensor network is a low-cost traffic counter that can also count vehicles or measure their length and speed from a simple change in the Earth's magnetic field. From the existing financially costly technologies measuring traffic on major lines, this system shifts research into a low-cost sensor network that allows traffic to be monitored across the board and to show the impact of the city measures in numbers. It is the technology that can be used by any municipality, regardless of size. In addition to the money spent, the speed of deployment without the need to deal with a building permit, connection to the electricity network or GDPR is a great benefit.

The city laboratory in the conditions of Žilina represents a virtual traffic fence around the city centre consisting of 9 gates (**Figure 2b, Table 2**), which monitor all lanes and thus create a unique complex monitoring the traffic flow of the city centre. It also provides information on the number, length and speed of vehicles every 5 minutes, thanks to which the municipality has comprehensive continuous data on the traffic situation in Žilina. These can be used, for example, for parking policy, infrastructure planning, public transport optimisation or road safety investments.

The sensor network covers all 9 gates (entrances/exits), i.e. a total of 26 lanes. These sensors in operation mode 24/7 not only detect passing vehicles but also classify them according to length (car: 3-7m, van: 7-14m, truck/bus: 14-30m) and speed (<30 km/h, 30-60 km/h, >60 km/h).

Table 2 Deployed traffic sensors

Gate	Profile	Sensor names	Comment
1	Hálkova	Hálkova IN left, Hálkova IN right, Hálkova OUT left, Hálkova OUT right	
2	Komenského	Komenského IN, Komenského OUT	
3	Tajovského	Tajovského IN, Tajovského OUT, Tajovského/Vysokoškolákov OUT	Tajovského/Vysokoškolákov = turning lane
4	Vysokoškolákov	Vysokoškolákov IN left, Vysokoškolákov IN right, Vysokoškolákov OUT left, Vysokoškolákov OUT right	
5	Košická	Košická IN left, Košická IN right, Košická OUT left, Košická OUT right, Košická/Štefánika IN	Košická/Štefánika = turning lane and entrance to a one-way street
6	1.mája	1.mája IN, 1. mája OUT	
7	Kysucká	Kysucká IN, Kysucká OUT	
8	Bratislavská	Bratislavská IN, Bratislavská OUT	
9	Rázusa	Rázusa IN, Rázusa OUT	

4. DISCUSSION

After verification operation, sensor network has been working in continuous operation since September 2021. The data are open, can be filtered and visualised according to a number of criteria [8]. An example (week 25.-31.10.2021) of published dashboard is as follows (**Figure 3**).

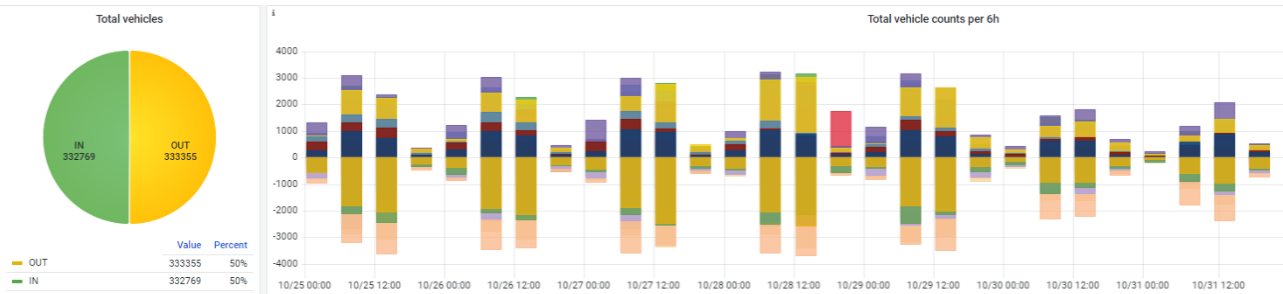


Figure 3 Traffic during the week 25.-31.10.2021 – total vehicles

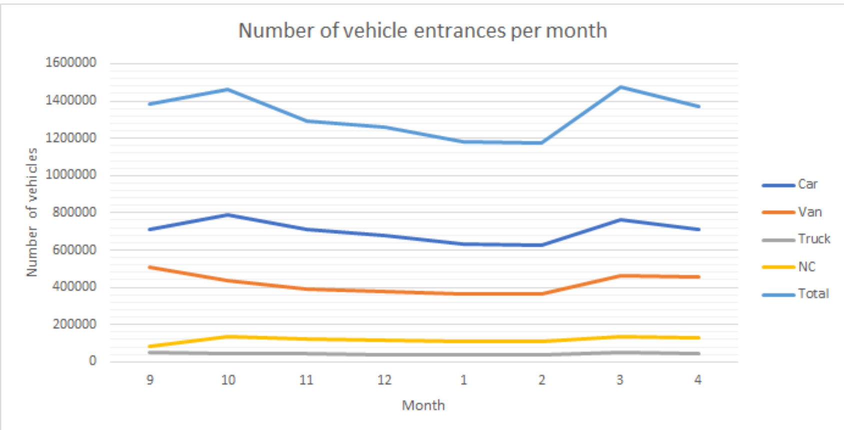


Figure 4 The number of vehicle entrances per month to the concerned area (NC - not categorised)

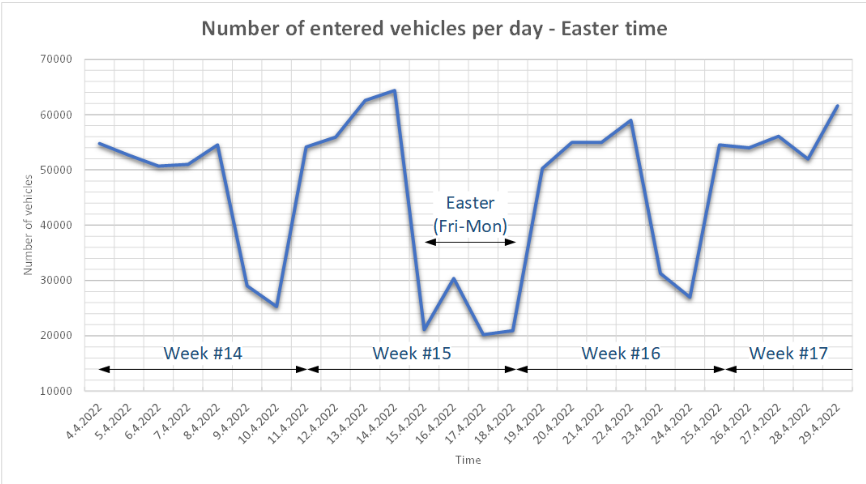


Figure 5 The number of vehicle entrances per day during Easter 2022 on Komenského street

In the period from September 2021 to the end of April 2022, an average of 43,814 vehicles daily entered to the concerned area. If these entries were to be made only by residents of the area concerned, they would realise average 2.66 entries per resident. The most extreme values fall on the New Year - minimum: 10,339 vehicle entries per day, and the Thursday before Easter - maximum: 64,359 entries per day.

From the **Figure 4** follows that the traffic was significantly affected by anti-pandemic measures. In addition, of course, traffic copies the working week and is also heavily influenced by the holidays. Typically working day enter to the area approx. 54 thousand vehicles, on weekend it is only 50 %. During the holidays with the middle of the week, traffic drops to 40 %. Paradoxically, traffic on a weekly basis during the week with a holiday will fall by only 8 %, as it will mostly move to other working days. Special cases are periods with several holidays, such as Christmas and Easter (**Figure 5**).

5. CONCLUSION

The paper describes Living laboratory focused on study transport and climatic issues in city conditions. The results of the logistics analysis based on the time database representing the real traffic of the Slovak regional city Žilina are presented. It is possible to see that the traffic is a significant burden for the area.

A database has been continuously being created, which has a diverse application for expertly based political decisions of authorities. Areas of application are various issues related to transport and climate change as well e.g. static transport, traffic safety, pedestrian safety, transport emissions, public space heating, phenomena affecting transport such as anti-pandemic measures what are typical competences of municipalities related to transport and public space.

The data presented in this article also encouraged the municipality of Žilina to continue cooperation with the project researchers in most of the mentioned areas.

ACKNOWLEDGEMENTS

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REFERENCES

[1] HUK, K., AGATA, G. Impact of private transport on the environment and society in the concept of city logistics and life cycle assessment. *Acta Logistica*. 2021, vol. 8, no. 3, pp. 287–295.

[2] JAROŠ, J., HRUDKAY, K., VALÁŠKOVÁ, K., KUDELA, P. Mitigating of negative environmental impact of transport on the level of smaller municipalities. In: *Transport Means - Proceedings of the International Conference.* Kauno Technologijos Universitetas, 2020, pp. 386–391.

[3] HUDÁK, M., MADLEŇÁK, R. The research of driver's gaze at the traffic signs. In: *CBU International Conference Proceedings*, ISE Research Institute, 2016, vol. 4, pp. 896-899.

[4] MASŁOWSKI, D., KULIŃSKA, E. Preventing urban transport problems through the use of sustainable and smart logistics. In: *Proceedings CLC 2019*. Tanger Ltd., 2019, pp. 264-269.

[5] RISTVEJ, J., LACINÁK, M., ONDREJKA, R. On Smart City and Safe City Concepts. *Mobile Networks and Applications*. 2020, vol. 25, no. 3, pp. 836–845.

[6] Available from: https://odoprave.info. [viewed: 2022-05-24].

[7] ČELKO, J. et al. *Transport masterplan with sustainable urban mobility plan*. [online]. 2016. [viewed: 2022-05-24]. Available from: https://www.zilina.sk/wp-content/uploads/2021/03/UGD_ZILINA_PUM.pdf (in Slovak)

[8] Available from: www.clevernet.uniza.sk. [viewed: 2022-05-24].

[9] Implementation of innovative sensor networks in cross - border regions. Application for a non - repayable financial contribution. University of Žilina. 2019