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Research Article

Mobility Data for a Safer and Greener Transport

Tamás Attila Tomaschek[1,*], András Mihály Selmeczy[2]

[1]Department of Automotive Technologies, Faculty of Transportation Engineering and Vehicle Engineering, Budapest University of Technology and Economics, Műegyetem rkp. 3., H-1111 Budapest, Hungary
[2]Hungarian Public Roads/Magyar Közút Nonprofit Zrt.
Fényes Elek utca 7-13, H-1024 Budapest, Hungary
*e-mail: tomaschek.tamas@kjk.bme.hu

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Abstract: Traffic network operators are using several channels to share their traffic related data, on one hand because of legal obligation, on the other hand to ensure a higher level of service for their customers. Of course, the value chain, and the provided content will change a lot with the emerge of connected and automated driving, or with the spread of Mobility-as-a-Service solutions and Alternative Fuel Infrastructure Regulation (AFIR) related data sharing in the near future. This paper gives a comprehensive overview of the current practice in Hungary, introducing the ways of distributing multimodal traffic related information, some existing services that were implemented based on these automatic data channels. The paper also gives an overview on the ongoing transition towards automatic data provision and how the regular road operators' role change to digital road operators, furthermore the European harmonisation process that was started in the framework of the Napcore project.

Keywords: Mobility data; Automatic Data exchange; Multimodal travel information; National Access Point; EU Green Deal; MaaS

I. INTRODUCTION

Recently a wide range of Traffic and Travel Information Services (TTIS) are available for travellers. The Reference Handbook for harmonized ITS Core Service Deployment in Europe [1] defined the following five different core services of TTIS:

- Forecast and Real-time Event Information (information about both expected and unexpected events, incidents),
- Traffic Condition and Travel Time Information (information on the traffic conditions – Level of Service, and travel times on identified road segments of the network),
- Speed limit information (static and dynamic speed limits),
- Road Weather Information (road surface condition, visibility, exceptional weather conditions),
- Multimodal Travel Information (comparative information of different modes/means of transport, and/or combination of different modes/means of transport with the same route).

Services and applications available on the market are made up by the combination of these core elements. The main mission of TTISs is to inform travellers about planned, e.g. road works, major (sports) events, closures; or unplanned events e.g. accidents, obstacle on road, bad visibility, slippery road, etc. in order to support them in reaching their destination in a calm and safe way and to provide reliable, and up-to-date information on traffic conditions and estimated travel times to support their decisions on the go. It is also important to mention the differences between traffic and travel information. Traffic information concerns the conditions of traffic, or the state of the road, containing forecast and/or real-time information. Detailed forms of this type are danger or incident waring, and control support information. Travel information is a kind of information or advice e.g. route guidance derived from the actual state of the transport system. End users can decide whether they use the information or advice, or not. Travel information can be used before and on-trip to facilitate planning, booking, and to adapt to disturbances, service changes or any other types of events. Having the proper information, the traveller can even alter departure time, mode choice, take alternative routes, or reconsider the decision to travel.

There are several studies about the positive effects of TTIS. These impacts are related to safety, network efficiency, and environment, however in most cases these are theoretical and difficult to quantify e.g. the provision of travel information on the go has positive impact on road safety because on the one hand drivers will be informed, and aware of the hazards along their journey; and on the other hand well informed drivers are calmer, and refrain from risky driving behaviour.

TTISs are aiming to meet the different needs of the end users. User needs depend on several circumstances, like the nature of travel, or personal preferences, disabilities, etc. Current information needs may also depend on the stage of the journey, the position, or the way one is willing to consume the information. There are several ways to categorize end users, the easiest way is to distinguish private and business/commercial travellers. Private travellers might be commuters, or leisure travellers. Other key actors of the Traffic and Travel Information value chain according to the TISA Value Chain model [2] are the content owners/providers, the service operator (who uses content to generate information with added value), and the service provider (the interface to the costumer).

II. Provision of TTIS in Hungary

Hungarian Public Roads is responsible for the operation and maintenance of more than 32 000 km of national public roads. With regards to its 6000 employees and its economic indicators the company stays within the first ten state owned enterprise in Hungary. Activities of the Hungarian Public Roads consist of operation, as well as the routine and preventive maintenance of the national public road network including expressways and motorways. In addition to that, the Company is responsible for the issue of route permits for oversized vehicles, the control of these vehicles at weight control stations, the provision of trainings for professionals within the entire road sector and the operation of the Road Information Services ("Útinform"), the National Road Databank and the Road Museum in the town of Kiskőrös [3].

Útinform department of the Hungarian Public Roads collects essential information on the circumstances, events and incidents affecting the traffic flow and safety on the national public road network. Based on the collected information, the road users are informed through various channels on every issue that affects the traffic flow and safety on the national public roads, including accidents, road closures and weather-related obstacles. Útinform is not only a division of the company, but it is also the Main Responsible Body for Transport of the Ministry for Construction and Transport, and responsible for the operation of the National Access Point (NAP) in Hungary. Information flow within the territory of Hungary is managed by the Útinform department, but in the Central South Eastern European (CSEE) region, corridors are passing through many different countries, and after a couple of hours driven one can get from Vienna to Belgrade via Budapest. Traffic incidents can have impacts far beyond the territory of a country. Many drivers are foreigners, and major part of the trips start/end in a third country. In this environment only cross border thinking works, and solutions based on cooperation are effective. Standards and corridor projects are really boosting the elaboration of common solutions, and services along the TEN-T corridors as an outstanding European added value of an initiative like the CROCODILE (Cooperation of Road Operators for COnsistent and Dynamic Information Levels) corridor project [4]. Recognising this fact, countries of the region have been working together for more than a decade, in the field of traffic management.

There were several milestones of the co-operation, like the MoU signed in Opatija (Croatia), in 2014. that was signed by the neighbouring road/motorway operator companies in Austria, Croatia, Hungary, Italy and Slovenia. Since then several bilateral and multilateral agreements were signed for specific issues (e.g. exchange of camera images). Since 2014, Hungarian Public Roads together with its partners is continuously working to fill the signed cooperation agreements, and made a huge step forward from keeping in touch via e-mail to implement automatic data exchange and launch an Application Programming Interface (API) developed for DARS, Slovenia to initiate cross-border traffic management measures. There are bilateral agreements on the exchange of webcam images and automatic data exchange based on DATEX II signed with the ASFINAG and DARS, and in December 2022, an agreement of similar content was also signed with the Croatian partner (HAC). The results are already tangible: the webcams of the partner companies are now available via the Útinform website, and vice versa.

Meanwhile a system based on dynamic and static network models (PTV Optima) were introduced on both the Slovenian and Hungarian sides. This system provides reliable traffic forecasts, with or without specific traffic management measures, which might be a higher level in elaborating, and executing cross-border traffic management plans. The technical preparation of linking the two models is currently underway.

III. Objectives

The European data strategy aims the European Union to become a leading player in a data-driven society. Establishing a single market for data could allow the free movement of data within the EU and it should also enable the European Union and its Member States to chart a data economy where public and private interests are balanced. By 2025, the value of the data economy in the European Union will be close to 830 billion euros, compared to 300 billion euros in 2018. Thus, the data-based economy is a lever to foster the emergence of a 3.0 mobility industry, based on intermodality and diversification of services to citizens. Data-based technologies will also make it possible to limit the impact of the transport sector on the environment. Indeed, data is the fuel for technological development in the transport sector and the digital transformation of infrastructure.

Consequently, access to a volume of quality data and the value it generates are essential for innovation in transportation: traffic regulation, improved safety, and supply chain optimization. For example, road transport navigation using real-time traffic avoidance devices can save up to 730 million hours. This represents up to 20 billion euros in labour costs. [5]

Even in Hungary we are witnessing a permanent development of the technology, and an environment where user expectations are constantly changing, where all road operators have to adapt to these changes. The aim of this paper is to provide a comprehensive overview of the ways of distributing traffic related information, by introducing the platforms and operation of a key traffic data provider in Hungary, and the ongoing transition towards automatic data provision, and Digital Infrastructure [6]. Sharing traffic related data facilitates the implementation of comprehensive information services to all EU citizens regarding interconnections, interoperability and multimodality and as a result also contributes to reducing external costs, such as congestion, damage to health and pollution of any kind including noise and emissions. A good example of socio-economic benefits of Intelligent Transport Systems (ITS) is given by the French part of the Arc Atlantique Corridor project. Over a 5-year period of ITS services deployment, the calculated minimum savings on French conceded motorways were:

- 7 fatalities, 17 seriously injured and 143 slightly injured,
- 136 000 vehicle hours lost,
- 565 000 litres of fuel,
- 1,524 tons CO2 emission for the congestion volumes.

The socio-economic benefits corresponding to these savings, amount to 5,2 M€ per year, giving a return on the investment programme of French motorway companies of approximately 3 years. Similar results can be seen by the ITS Corridor projects URSA MAJOR Neo, Next-ITS and MedTIS. [7]

IV. Types and characteristics of direct information channels

1. Website/call centre

Hungarian Public Roads operates two different websites for the costumers, one for the company (kozut.hu) and one dedicated for Road Information Services. The general website is the portal for publishing legally binding data and information of public interest [8]. The Útinform website (www.utinform.hu) provides information about events occurred along the national road network that affect the continuity and safety of traffic flow.

Information about these kind of incidents is made available to road users by the Road Information department via the available service channels (website, Interactive Voice Response – IVR system). On the interactive map, colours are helping in expressing the severity of an incident (from green – no impact on traffic, to red – blocked lanes/carriageway). The Útinform website has been using a so called responsive web design, in order to have a web page that looks good on all devices for a long while. Statistic data based on Google Analytics clearly shows, that more than 80% of visitors are using smartphones or tablets, and only a 16% of costumers use desktops. The share of smartphones has risen around 3% compared to the same period of the previous year, meanwhile there is a drop in the number of tablets (0.5%), and desktops (2.5-3.0%). Útinform has registered altogether 1.78 million (different) active users visiting the website (around 55% of the visitors are returning to the site). The number of visitors correlate with measured road traffic volumes in general, with a significant rising trend (around 10% per year). The average traffic of the website was more than 10,000 visitors per day in 2022 (varies within the range from 3,131 to 34,395), but the figures rise sharply when one or more incident(s) with higher impact occur(s). The Information service operates an IVR system for handling incoming telephone calls. The Infoline is available 0-24 h, anybody can call it from Hungary or abroad without extra charges (+36-1-336-2400). The options for each button are the following in the IVR system:

- #1 – Accidents, congestions, and other incidents (actual traffic information, updated continuously)
- #2 – Major planned roadworks/closures for main roads, secondary roads (updated daily)
- #3 – Major planned roadworks/closures for motorways/expressways (updated daily)
- #4 – Information regarding road and weather conditions (updated several times a day)
- #5 – Dispatching services of other companies (phone numbers)
- #6 – Privacy Policy

- #7 – Talk to the operator

On a normal day, the number of incoming calls is between 150-200. 7th January in 2023 was a busy day for the information service. 15 cars crashed in 5 accidents along motorway M1, 15 km long queue has built up, at another crash site on motorway M5, and workers from Eastern Europe were heading back from the Christmas Holiday. **Figure 1.** shows the visible impact on the number of information requests via the call centre, and the number of visitors at the website.

2. Social media

Companies today use social media platforms as a new channel to reach their customers. Following profit oriented private companies, more and more public service providers appeared on these platforms, and started to make efforts to produce content for their followers. Hungarian Public Roads usually publishes posts on a daily basis, but sometimes only 1-2 posts are published per week. The company has currently 38,000 followers (the number of likes is 37,000). In 2021, a total of nearly 2.19 million people were reached thanks to the Facebook posts, which was 38% increase compared to 2020. During this period, the followers of the Facebook page increased by 4,541 people (17%). In 2021, the company put a lot of effort into launching the Instagram page. Thanks to the conscious and persistent strategy, the number of followers of the page increased by 13,841 people, which means a 60% grow in one year. The site's reach exceeded 1.1 million, which is a 35% increase. Through the YouTube channel, 2.32 million views were achieved in 2021 and the number of subscribers increased by 1.628, which means an increase of 90%.

TikTok was the company's most dynamically developing social media site, which attracted nearly 34,000 followers in 2021, so already that year it overtook the number of Facebook followers and is closely following the Instagram profile. The secret of success is continuous experimentation, publication of confrontational content, monitoring and application of trends, youthful communication that fits the needs of the target audience. Similar to Instagram and YouTube, the male-to-female ratio of followers here is 70-30. In 2021, a total of 45 posts were created, which generated 8.725 million views. By the end of 2022, the TikTok profile reached 58 thousand followers and collected 1.1 million likes.

Although Hungarian Public Roads is indeed one of the most active companies operating in the domestic transport sector, with typically 1-2 entries per day, the road management/motorway management companies of neighbouring countries are, in many cases, even more active. However, the volume of posts is not the best measure of the effectiveness of a social media platform. I examined the social media presence and the number of followers on Facebook of road operator companies of Visegrád group and neighbouring countries. It was obvious that besides an official website, every company is present on

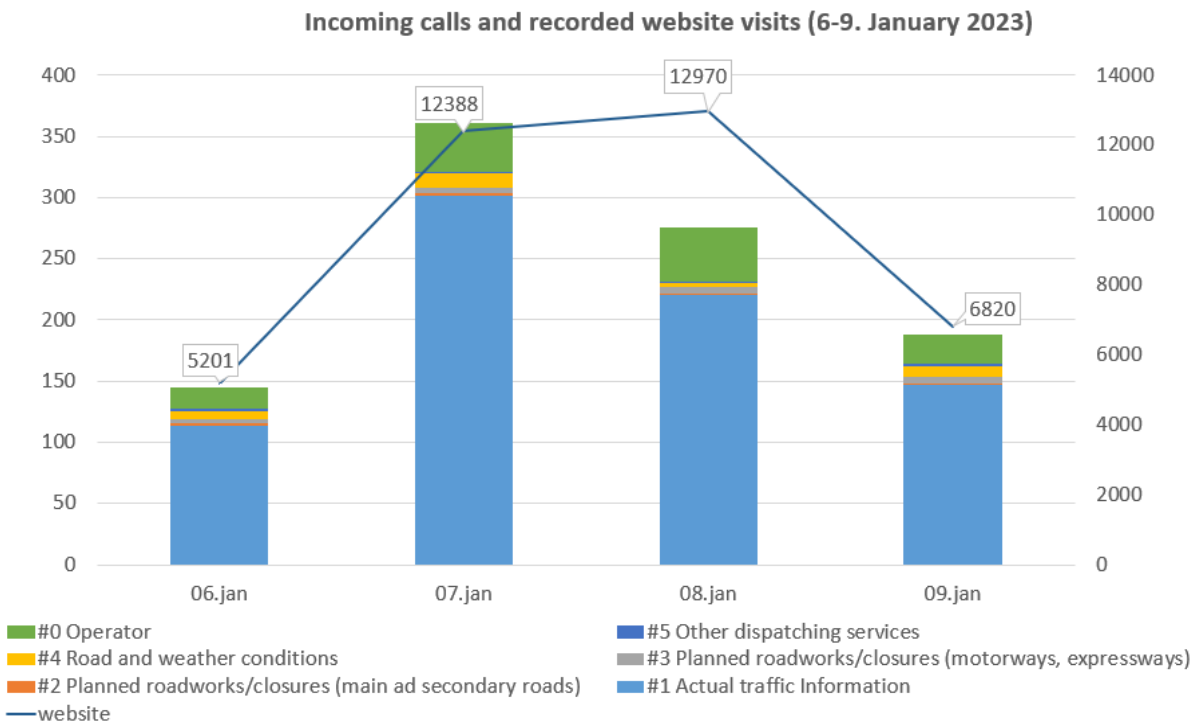

Figure 1. *Impact of serious incidents on information requests (website and call centre)*

Table 1. *Social media presence of road operator companies in the CSEE region*

Company	Country	facebook	Instagram	youtube	twitter	linkedin	Tiktok	Mobil App.	Followers on facebook [1000 follows]
DARS d.d.	SLO	+		+	+	+			57,4
ASFINAG	A	+	+	+	+	+		+	80,4
NDS AS	SK	+		+					25,9
Promet SI/DARS	SLO	+			+			+	9,1
Hungarian Public Roads (MK)	HU	+	+	+	+	+	+		38
CNAIR SA	RO	+		+					66
RSD CR	CZ	+	+	+	+				20,7
GDDKIA	PL	+	+	+	+	+			64
Putevi Srbije	SRB	+	+	+	+	+		+	10,3
MKIF	HU	+	+	+					0,8
HAC	HR		+	+				+	

social media. This is also the case with the new Hungarian motorway concession company (MKIF), which, in addition to the most popular Facebook, has an official Instagram and YouTube account, too. Only the Croatian motorway company does not have a Facebook page. However, the Slovenian DARS company has two registrations, as the Promet SI, the local information centre similar to Útinform, can also be found on Facebook with more than 9,000 followers (see **Table 1**).

Regarding the activity of the companies, again based on Facebook, the Serbian and Austrian companies are the most active with 3-4 posts per day, and the Czech, Romanian and Polish companies also share content on a daily basis. Several posts are also published daily at Promet SI, but it should be noted that this site specifically shares traffic information, and a large amount of traffic information is also included on the Czech RSD site. Of course, there is a significant difference in the content shared by the companies, as the activities of road managers differ from country to country, in many cases the road operator is carrying out investments, and in some cases the collection of tolls is one of its tasks (such as in Slovenia and Austria). In such cases, of course, the palette will be expanded with communicating the achievements of developments, as well as information related to toll collection. Despite the fact that it is the duty of each company to inform travellers, there are companies where traffic information is not in focus at all. This is the case with Hungarian Public Roads, or ASFINAG, too. These sites rather give an insight into the company's activities, employee stories, or share information related to customer services.

3. Variable Message Signs (VMS)

There is a great variety of VMSs using different technologies to indicate traffic signs. However, only a few versions of the two main types have spread widely in practice. Among electromechanical signs, only prism VMSs are still in use today. Among lighting technology signs, light emitting diode (LED) and fibre optic panels are the ones worth mentioning. On the Hungarian road network, most of the displays are the most modern light-emitting diode (LED) panels. There are also a number of fibre optic signs in which the light from the bulb inside the VMS is conducted at the appropriate points on the front side via fibre optic cables. These signs can only display the previously "wired" signs. There are also LED signs displaying only predefined signs, but most of the panels are full matrix signs, where the displayed images can be designed and modified free. Colour LED signs produce colours using the three basic colours (red, green, blue), which means that one pixel on the surface of the sign consists of three light emitting diodes, such as mobile phone displays, but the pixel distance is much higher, typically 20-25 mm. On text only displays, one pixel consists of only one single yellow LED but, any edited image can be displayed on them, too.

We can distinguish three main functions of VMSs:

- Traffic management: this function includes measures related to traffic diversions and restrictions, such as lane closures, diversions, overtaking bans for lorries, variable speed limits, sometimes different for each lane, and the display of the recommended speed
- Danger warning: warning road users of unexpected events (accidents, congestions, road works, any other potentially hazardous incidents) or adverse road and weather conditions (such as fog, slippery road surface, icing, etc.). For such purposes in most cases a specific VMS type is used called Dynamic Route Information Panel (DRIP).
- Useful information: this might be information about a specific section or the entire network (e.g. journey times between junctions, waiting times at border crossings, closing bridges in the capital, possibly displaying detours). Traffic safety content can also be displayed as part of a comprehensive traffic safety campaign.

The appearance of the gantry and the layout of the VMSs show significant differences depending on whether the display is for information only or is part of a traffic management system. For instance, the above mentioned Dynamic Route Information Panels are mainly used for the purposes of danger warning. Neither their layout nor the distance of the gantries allows them to be used for traffic management purposes. VMS gantries operating as part of a control system always have an overhead VMS per each lane, as speed limits placed above the traffic lanes always apply to the given traffic lane in a speed management scheme. For other types of dynamic management systems, additional traffic signs (e.g. danger warning signs) may be placed above the lane lines or on the two sides of the carriageway in order to provide more detailed information. According to the special function of the M0, and due to the number of alternative routes through the city, a special type of VMS gantries was applied along the Budapest Ring road, combining the capabilities of DRIP and the dynamic lane management types. The gantries have two levels, on the lower level, there are colour displays suitable for displaying traffic signs, while on the upper level there is a large, monochrome text display. At the lower level, the two signs positioned at the two sides of the carriageway are able to display restrictions or danger warning signs valid for the entire cross-section, while the others (signs above the lanes) can display a restriction apply only to the traffic lane below.

When we compare the use of C-ITS with the traditional VMSs (as they can take over their functionality in the long run) we can see significant differences, in implementation and operation costs. The implementation of a VMS is approx. 10 times higher, and the energy consumption is even higher. On the other hand, the information transmitted via the VMSs is quite limited, 2-3 pictograms and approx. 3×20 characters long text can be displayed on it. In comparison, the C-ITS system is capable of practically unlimited data transmission, and the communication is bidirectional, it can also receive information from the vehicle.

This does not mean that no more VMS gantries will be built from tomorrow on, in fact, roadside C-ITS transceivers will be installed on VMS gantries and will gradually replace LED displays over a long period of time. Until then, of course, the legal background needs to be improved to handle speed limits appearing in the form of bits and bytes instead of roadside traffic signs, visible to everyone. And this information will be interpreted by the infotainment systems of the car instead of the driver.

V. Automatic data provision/exchange

1. Traffic Message Chanel (TMC)

One of the first and still existing real-time travel information services was the so called Traffic Message Chanel (RDS-TMC). The RDS-TMC service was developed in the 1980s and it has widely spread across Europe, and some other parts of the world. With the help of RDS (Radio Data System) technology, the broadcaster can transmit traffic information using the radio signal that provides real-time information on the traffic situation / events. The message appears on the RDS display of the vehicle's FM radio in the user's language without interrupting audio broadcast services or on the display of a navigation device capable of receiving TMC, and the navigation device even incorporates the received information into the route planning and, if necessary, recalculates the route based on the information received. The bandwidth available for the service is very low, so the messages has a very limited content, the events and their position are all coded. It is therefore essential for the operation of the system to have the same code table on the receiving and sending side, otherwise the message cannot be interpreted. Event codes are fixed, but the road network is slowly but steadily changing, new sections and junctions are being built, so the location table needs to be updated from time to time and downloaded to the navigation device for the proper operation.

TrafficNav is a private limited company, registered in Hungary. Its main activity is to collect real-time traffic data, process and deliver it to end users. Such processed data forms the basis of the TMC service in Hungary that TrafficNav is providing. The service has been operating since the 1st of August 2008. TrafficNav started a TMC service in Slovenia in June 2009, and later the service was launched in the Irish Republic, Greece, Bulgaria and Turkey, too. [9]

2. National Access Point (NAP) [10]

"The accessibility of accurate and up-to-date static road data, dynamic road status data and traffic data are essential for the provision of real-time traffic information services across the Union. The relevant data is collected and stored by road authorities, road operators and real-time traffic information service providers. In order to facilitate the easy exchange and re-use of this data for the provision of such services, road authorities, road operators and real-time traffic information service providers should make the data, corresponding metadata and information on the quality of the data accessible to other road authorities, road operators, real-time traffic information service providers and digital map producers through a national or common access point. The access point can take the form of a repository, registry, web portal or similar depending on the type of data."

The first version of the data exchange platform in Hungary was launched years before the above quoted 2015/962 Commission Delegated Regulation, in the framework of the EasyWay project (data portal development). On the basis of this work, the data exchange platform was upgraded in 2015, in phase I of the CROCODILE project. The development of the data portal included the upgrade of the system to the latest version of the automated data exchange standard (DATEX v2.3), and also the implementation of the full code table that makes it possible to define all the information – contained in the standard – on the receiving side and at the same time the information optionally collected / available can be published (e.g. measured traffic data and weather data can be published). [11] The developed system relies primarily on the topology data of the National Road Data Bank (OKA), but it can handle several standard location identification systems, such as ALERT-C (ISO 14819-3:2004) and the WGS coordinate system, or DATEX HUB completed in the CROCODILE project was also expanded with the OpenLR standard during

Table 2. *Data categories available via NAP Hungary [12]*

Data category, description	Type of the data	Localization of data	Format
Static road network data Current, up-to-date, comprehensive map database of the national road network, regularly updated with OKA content. A current, up-to-date, complete map database of Budapest's road network, regularly updated by Budapest Közút.	National road network data (express road, main- and secondary road, cycle path network)	nationwide	shape-zip; gml2; gml3; json; kml; gpkg
	Annual cross-sectional traffic data	nationwide	
	Road segmentation	nationwide	
	Speed limits	nationwide	
	Total number of vehicle lanes	nationwide	
	Static data for rest and P+R parking	local/ nationwide	shape-zip; gml2; gml3; json; kml; gpkg; DATEX
	Bridge usage conditions (e.g., restrictions)	nationwide	shape-zip; gml2; gml3; json; kml; gpkg
	Road name and category	nationwide	
	Road identification points	nationwide	
	Type and width of enclosure	nationwide	
	Bus stops	nationwide	
	Refuelling station and e-station data	local	shape-zip; gml2; gml3; json; kml; gpkg; DATEX
	Budapest roads data (geometry, road junctions, road classification, freight zones, destination restrictions)	local	shape-zip; gml2; gml3; json; kml; gpkg
Dynamic parking information	Truck dynamic parking data	nationwide	DATEX
	Dynamic data of P+R parking	local	
Information on traffic signs (e.g. bridge conditions, permanent traffic restrictions: height restrictions, weight and speed restrictions).	TN-ITS data	local/ nationwide	via TN-ITS link
	Location and availability of transport areas	local	shape-zip; gml2; gml3; json; kml; gpkg
XML link to MK ÚTINFORM news, fresh, complete, regularly updated news file.	Roadworks	nationwide	DATEX
	Dynamic data of road status	nationwide	
	Traffic management measures	nationwide	
	Temporary traffic management measures	nationwide	
	Real-time traffic data	nationwide	
	Traffic safety information	nationwide	
	Unforeseen events and circumstances	nationwide	
Multimodal information	Timetables and information on multi-modal transport		In preparation

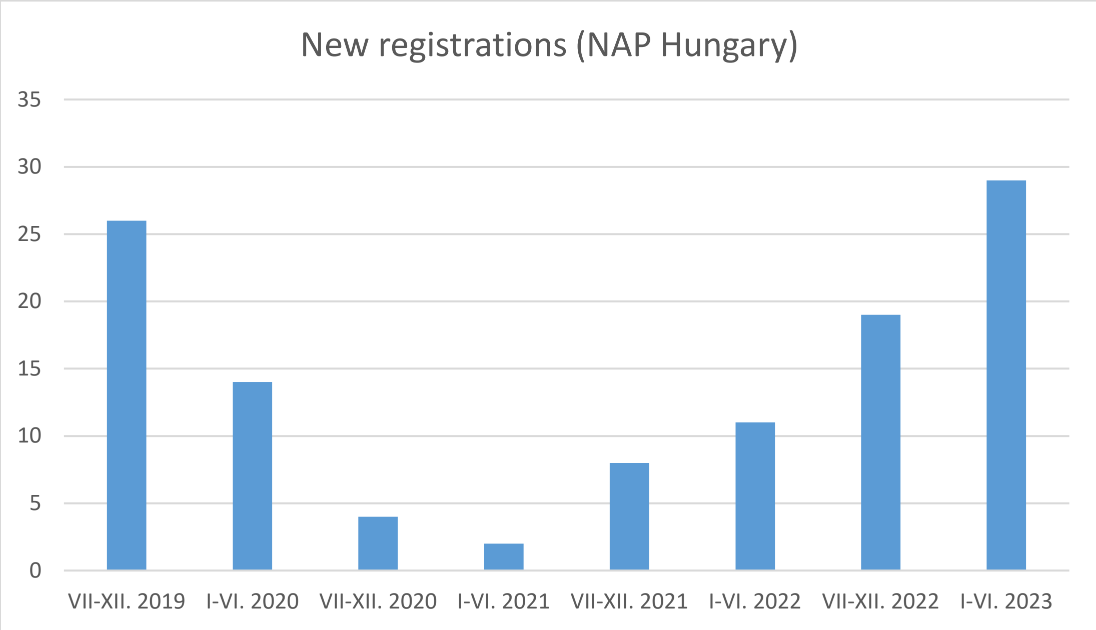

Figure 2. *New registrations (NAP Hungary) until 2022*

development. The currently available data categories are the following:

The monitoring, and evaluation of the system is continuous, and there is also useful feedback from the registered users. In 2021, a complete revision of the portal and the admin functions was carried out, paying particular attention to implement user-friendly features and menu structure. As a result of the assessment process, several minor modifications, corrections and a number of change requests and further development needs were identified. The first upgrade of the system was published in February 2022 containing most of the minor improvements. As some of the tasks require major changes in the code, a second phase development package was set up for the complex developments. Within the framework of the CROCODILE 3 Hungary CEF (Connecting Europe Facility) funded project, besides DATEX II. version 2.3., we have introduced the latest v3.3 version and the D2Light standard, too. By introducing these new standards, we expect to reach more clients both on the data provider's and user's side.

Currently there are two active data providers publishing datasets via the NAP portal: Hungarian Public Roads (local) and Budapest Public Roads (nationwide), however through the Útinform service of Hungarian Public Roads and the National Road Data Bank (OKA), also operated by Magyar Közút, data recorded on the sections of the concession motorway companies (MKIF, AKA, M6 Duna, M6 Tolna, M6 Mecsek) are also available. On the data user side, a number of private individuals, and several Hungarian and multinational tech companies and digital map service providers have registered to the portal. In the first 3 years of operation, after the initial boom, there was a decline in the number of new registrations, but a second run up can be observed (**Figure 2.**) starting from the second half of the year 2021.

3. Cooperative ITS (C-ITS)

Cooperative ITS (C-ITS) is a set of technologies and applications that allows effective and direct data exchange through wireless communication channels between components and actors of the transportation system, most commonly between vehicles (vehicle-to-vehicle or V2V) or between vehicles and infrastructure (vehicle-to-infrastructure or V2I). C-ITS deployment in Hungary has started back in 2015. One of the main drivers to foster C-ITS deployment in Hungary was the involvement in the above-mentioned European CROCODILE project [4][13]. The project objectives were to improve the quality and availability of traffic data, to secure exchange of this data with neighbouring countries in DATEX II format, to improve road safety, i.e. in work zones, and to provide quality traffic information services to drivers. In line with the above-mentioned objectives, Hungarian Public Roads company has selected part of its network for C-ITS services deployment, a 136 km-long stretch of motorway M1 between Austria and Budapest. The system is in operation from December 2015. The pilot system itself has covered the following 'Day-1 services': Traffic jam ahead warning, Hazardous location notification, road works warning, Weather conditions, In-vehicle signage, In-vehicle speed limits. The communication between RSUs and OBUs was thus far based on ITS G5. ("ITS-G5 technology supports vehicle-to-vehicle, vehicle-to-everything short range, ad hoc communication. The defined access layer of the communication stack is collectively called ITS-G5”). [14]

Meanwhile, several research and pilot implementations were carried out Europe-wide, like the European ITS Corridor [15]. The need for a harmonised approach was identified on the basis of the insights gained in all previous initiatives and, at the same time, commitment and readiness for deployment was also visible. However, at the technical level, the projects and corridor initiatives did not take the final step to a coordinated pan-European approach, which was however necessary to ensure that all national efforts grew together in a harmonised way. To ensure this cross-border harmonisation of C-ITS, the C-Roads Platform was realised in 2016 [16]. Hungary has joined the platform as an observer right from the start, and became a core member in 2017.

Recent deployments in the framework of C-Roads Hungary concentrated on the upgrade and extension of the 2015 pilot in terms of coverage and functionality, and implementing the ability of a hybrid (G5, and cellular) communication (deployment sites: **Figure 3**). Additional so called Day-1 use cases were introduced with the capability of hybrid communication along motorway M1 (towards Austria), and motorway M7 (towards Croatia and Slovenia). Besides core network corridors, special attention was also paid to urban applications. Traffic light controllers were improved in the town of Győr in order to provide Time-to-Green (TTG)/ Green Light Optimum Speed Advisory (GLOSA) information at 10 neighbouring junctions along the main traffic route, where intersection safety services are also available. The pilot sites have been operational since February 2021.

Hungary has also signed the grant agreement for C-Roads 2 Hungary, as a continuation of the C-ITS deployment. The planned Hungarian work programme devotes particular attention to the creation of an urban test environment for connected and automated vehicles in the town of Zalaegerszeg, linked to the Automotive Proving Ground Zala (APZ), building on the experiences of the pilot project in Győr. The deployment will focus on Day-1 and Day-1.5 C-ITS services with the option of scaling up to Day-2 C-ITS services. The “ZalaZone” is the greater area that includes the town and the test track that will be ready for autonomous vehicle testing, but there are even more ambitious plans. As part of trilateral multi-level cooperation, Austria, Slovenia and Hungary plan to implement cross-border test routes [13]. C-Roads 2 Hungary will enhance this effort by implementing C-ITS services in the greater city area of Zalaegerszeg, and TEN-T corridors (with domestic and cross-border sections).

VI. MULTIMODAL TRAVEL INFORMATION

Multimodal journey planners will raise the efficiency of the transport system, as they ensure

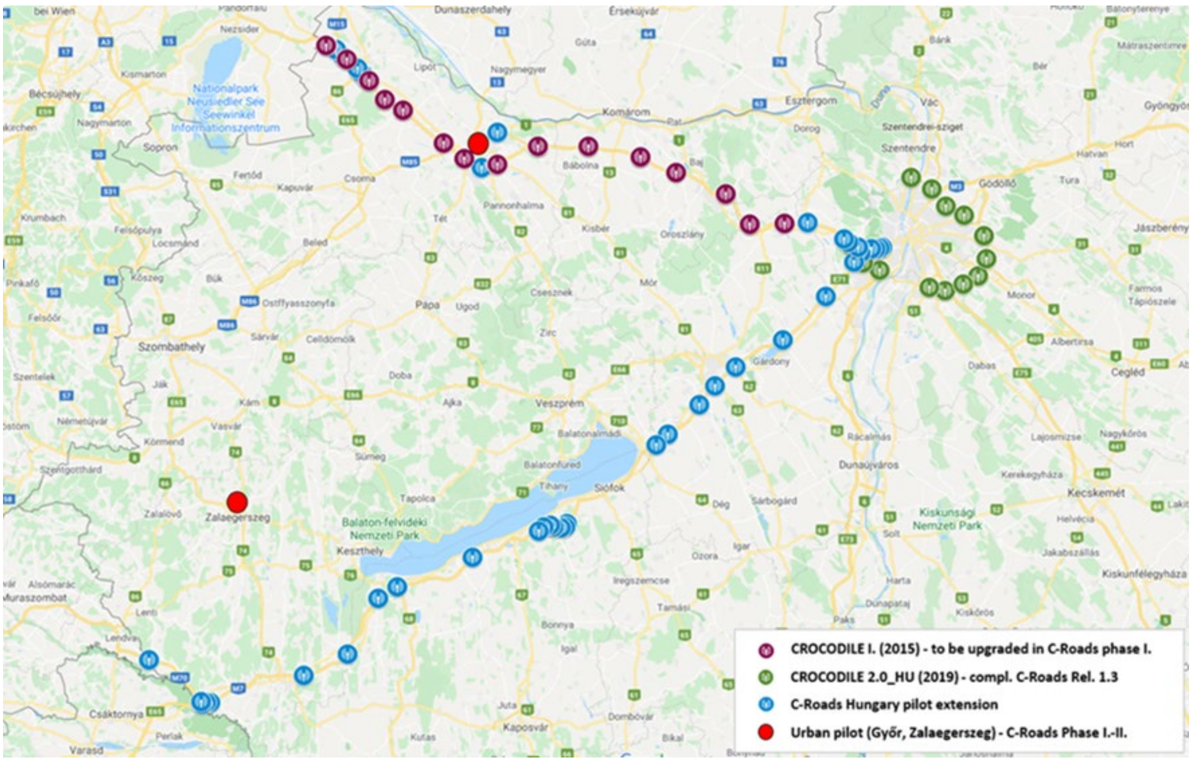

Figure 3. *C-ITS deployments (until 2022)*

seamless door-to-door travel information integrating different transport modes, and service providers. In line with Directive 2010/40/EU, EU specifications have been adopted in order to ensure compatibility, interoperability and continuity for the deployment and operational use of Intelligent Transport Systems. In order to further support the harmonised implementation of the provision of EU-wide multi-modal travel information services, EC has adopted Commission Delegated Regulation (EU) 2017/1926 with regard to the provision of EU-wide multimodal travel information services [17]. According to the delegated regulation National Access Points should collect travel and traffic data (static data, timetables, etc.) from all modes of transport from public and private service providers. Travel information service providers shall share routing results that help linking the travel information services for other service providers. The main goal is to provide useful tools/applications for travellers, supporting their responsible mode choices, and their mode shifts to sustainable means of transport. [18]

It is obvious that there are huge differences in the preferences of drivers, and passengers of public transport. Drivers prefer navigation-based information, with voice directions, and/or directions on an interactive digital map, displaying the hazards, speed limits, alternative routes, etc. When using public transport, it is easier to use e.g. social media for this purpose, but the leading sources are the multimodal travel planner applications like Google Maps. The apps of Hungarian Public Transport companies have remarkable penetration, too, both MÁV (national railways), and BudapestGO (Centre for Budapest Transport) apps have more than 1 million downloads, but they are not real multimodal apps. BudapestGO has reached the highest grade in this regard, with integrating suburban transport routes operated by the national railways (MÁV), and the bus company (Volánbusz), and integrating some basic information of micro mobility (BUBI bike share docking stations, and the number of available bikes). Both MÁV and BudapestGO provides on-line purchase of the tickets, but only for travel services within their own responsibilities. The first Mobility-as-a-Service (MaaS) trial was implemented in the framework of MaaS4EU (End-to-End Approach for Mobility-as-a-Service tools, business models, enabling framework and evidence for European seamless mobility) project [19]. The main objective of the project was to remove barriers, and establish the frameworks and tools of a co-operative, interlinked and unified solution in line with the MaaS concept. The project has proven, that it is possible to integrate different service providers like public transport operators, shared mobility service providers, cab companies in one single mobility platform, where one only need to register once to use and pay for all available services offered via the MaaS operator, using a single mobile app.

VII. European dimension

As stated in the chapters before, Hungary has implemented its NAP system according to the directive 2010/40/EU, just as the other European countries also did in the late 2010's. The most important perquisites were fulfilled, with launching those sites, providing datasets described in the directive, but there were no obligations regarding visual appearance, content requirements or accessibility needs. As a result, the 27 EU Member states and other countries have established for each country an individual portal. Each site fulfils the needs of the directive, but those differ in many ways from the NAPs of neighbouring countries, causing a fragmentation on a European level. On a microscopic view the directive has reached its purpose, but on the macroscopic approach it has caused a new problem what had to be solved to ensure interoperability.

"As it has become apparent, the existing NAPs are quite different in their setup and data access interfaces. Also, the data formats and standards used differ throughout Europe. To work on a better alignment the National Access Point Coordination Organisation for Europe (NAPCORE) project was started.

NAPCORE is co-financed by a Programme Support Action under the European Commission's Connecting Europe Facility. NAPCORE has been launched as coordination mechanism to improve interoperability of the National Access Points as backbone of European mobility data exchange. NAPCORE improves the interoperability of mobility data in Europe with mobility data standard harmonisation and alignment. Also, NAPCORE increases access and expands availability to mobility related data by coordinated data access and better harmonisation of the European NAPs. Furthermore, NAPCORE empowers National Access Points and National Bodies by defining and implementing common procedures and strategy, strengthening the position and the role of NAPs, supporting steps towards the creation of European-wide solutions to better facilitate the use of EU-wide data." [20]

The harmonisation process is not only on structural, visualisation and content level of each NAP, but very much on a technical as well. Many standardised, yet different data formats are used currently EU-wide, like DATEX, TN-ITS, Multimodal and Metadata, to exchange different types of data. The overall aim is to ease and to atomise the data exchange processes and deliver the data in a machine-readable format, independently of the sender/receivers whereabout and data format, if it is within the accepted datasets. To create and enhance automatising, so called API (Application Programming Interface) is necessary. These APIs are a set of definitions and protocols which enables the building and integrating application software on the data. A separate workgroup within the project is busy with developing an API prototype which will be released probably early 2024.

Among previously mentioned others, the projects goals are to:

- facilitate EU wide coordination of NAPs and the supervisor National Bodies (NB) for the harmonization of the implementation of the European specifications on the ITS Directive
- increase interoperability by (further) establishing standards and recommendations for data exchange formats, content, access, and data availability in the mobility domain in Europe [21]
- empower the NAPs as the backbone for ITS digital infrastructure and mobility data exchange in Europe
- address existing and upcoming developments and challenges with a joint European strategy, vision, and voice.

The project is working closely with DG-Move and the NAPCORE Advisory Board (which consists of experts from several organisations among others e.g. CEDR, C2C, EAFO, TISA and many more) to continuously guide the project according to legislations and market needs. The project has furthermore delegated ambassadors within the project to drive the important topics. Currently parking, cycling, MaaS and alternative fuels have an own ambassador group to represent and drive these continuously evolving topics.

The EC, on the other hand envisions not to stop at an individual yet harmonised approach. In their opinion there is a need for a European Access Point (EAP). This EAP would receive all the datasets defined in the delegated regulation and would work as a data hub above the member states' individual NAPs to enhance the interoperability of data on an EU level. This would not only be a link repository, but would be a fully automatized data site, harvesting the data from the individual NAPs. The establishment of this ambitious approach is not in the scope of the NAPCORE project itself, but during the project a commonly agreed interface to facilitate this data exchange will be reached. This sets the importance of the harmonisation and technical coordination work done by the project even higher.

VIII. THE IMPORTANCE OF ALTERNATIVE FUELS (AF) AND DIGITALISATION

"Mobility plays a key role in the EU economy. However, the EU transport sector still relies heavily on fossil fuels and is responsible for one quarter of Europe's greenhouse gas (GHG) emissions — a share that keeps growing. In addition, the sector is a significant source of air pollution despite significant progress achieved since 1990, especially of particulate matter (PM) and nitrogen dioxide (NO2), as well as the main source of environmental noise in Europe. Current efforts to limit the sector's environmental and climate impacts in Europe are not sufficient to meet the EU's long-term climate and environmental policy objectives." [22] These long term ambitious goals are set in The European Green Deal, and the goal of being the first climate-neutral continent by 2050 requires ambitious changes in transport, too. The Council adopted this year on 29th March, the regulation setting stricter CO2 emission performance standards for new cars and vans. The new rules aim to reduce emissions from road transport that has the highest share of emissions from transport - and provide the right push for the automotive industry to shift towards zero-emission mobility while ensuring continued innovation in the industry. The new rules set the following targets:

- 55% CO2 emission reductions for new cars and 50% for new vans from 2030 to 2034 compared to 2021 levels,
- 100% CO2 emission reductions for both new cars and vans from 2035.

A regulatory incentive mechanism for zero- and low-emission vehicles (ZLEV) will be in place from 2025 until the end of 2029. As part of this mechanism, if a manufacturer meets certain benchmarks for the sales of zero- and low-emission vehicles it can be rewarded with less strict CO2 targets. The benchmark is set at 25% for cars and 17% for vans.

The regulation contains a reference to e-fuels, whereby following a consultation with stakeholders, the Commission will make a proposal for registering vehicles running exclusively on CO2-neutral fuels, after 2035, in conformity with EU law, outside the scope of the fleet standards, and in conformity with the EU's climate neutrality objective.

The regulation includes a review clause that foresees that in 2026, the Commission will thoroughly assess the progress made towards achieving the 2035 100% emission reduction targets and the possible need to review them. The review will take into account technological developments, including with regard to plug-in hybrid technologies and the importance of a viable and socially equitable transition towards zero emissions. [23]

The ambitious goals set, need harder commitment from the countries as well and new datasets need to be collected and processed. The current version of the delegated regulation, which is still is in force has been extremely outdated in only a few years, before all the member states could even implement it. The revision of the delegated regulation 2014/94 is currently being finalized and will be published in the upcoming months. This version will contain very strict requirements regarding the development of alternative fuel infrastructure and the sharing of the data related to alternative fuels.

A PSA called IDACS (ID & Data Collection for Sustainable Fuels in Europe) was started in 2019 to build up a unified database and coordinated data transfer on alternative fuel filling points, in line with the EC's expectations and to implement a unique identification method for electromobility actors. [24] Yet only a bit more than half of the EU Member states participated in this project and implemented the local IDRO (ID Registration Office) which collects the data and forwards these to the national NAPs, so there are still a considerable number of NAPs – which comply with all the delegated regulations – yet they do not have any data related to alternative fuels.

The number of EVs and hydrogen powered vehicles are progressively growing, and the technical advancement of these vehicles and the battery/charging technology enables a larger range (distance travelled / recharging). Not long ago, approx. 10-15 years, the maximal range of these vehicles was 100-150 km, which made them good option for domestic travels. Nowadays ranges can exceed 500-600 or even 800 km with one charging, which makes trans-European travels viable. With this transition the CPOs (Charging Point Operators) had to adapt and open their services to new foreign users, but still having their own registration, charging and payment methods used. As this segment is profit driven and lot of different standards were used, furthermore some of the data collected is sensible, and not all the data providers are willing to share for e.g. the availability of their charging points or the price of ad hoc charging costs caused severe gaps in the data sharing services. Furthermore, this also caused a cumbersome preparation necessary before and during every international travel with an EV as every CPO had its own database, available only after pre-registration. Usually, one country is covered with more than one, up to 3-5 bigger CPOs and many smaller ones. As this gap in the market appeared, many third-party suppliers have built a service from this, by acquiring this data and showing it on a digital, opensource map and providing the data to their subscribers. Yet these secondary databases were still not complete, did not contain all the charging point data or were not up to date, causing even more confusion to the users.

The EC has a clear view, how to change this chaotic situation. As mentioned earlier, the revision of the delegated regulation 2014/94 will contain standardised data formats and data fields, what every Member state must make publicly available, for free of charge. The CPOs will be forced to do so and will be held responsible for the quality of their data. The previously mentioned, locally operated, yet harmonised on an EU level NAPs will fill the mediator role and collect all the national data from the CPOs and publish them on a local level and with the support of the APIs it will be also possible to automatically harvest this data to the envisioned EAP at a later stage.

IX. Conclusions

Enabling the interoperable exchange of travel and traffic data in accordance with the requirements outlined in ITS Directive and its Delegated Regulations improves traffic information and traffic management services. These services contribute directly to improvements in efficiency and sustainability, by stimulating and enabling traffic information service providers develop new services and tools.

Útinform, as the main traffic information hub in Hungary collects and distributes traffic related data, and information for the national road network. Through the Útinform website, the call centre, media relations, and live broadcasts or via the automatic data exchange channels the Road Information service tries to ensure that the essential information reaches the end users. With the help of the automatic data feed, traffic information can also be accessed via several online navigation devices, by browsing websites of road operators abroad, and popular mobile applications (e.g. waze). C-ITS is a relatively new branch of intelligent transport services, and it takes time to raise the penetration rate without EU legislation, however the service is ready to use, and there are a lot of services available even in Hungary. There is a huge potential in this new service, that can save a number of lives on roads. The above-mentioned automatic channels gained huge relevance in delivering traffic related information to the end users recently, and their importance will keep on raising in the coming years. Despite these new channels, and the popular mobile applications, there is still a huge amount of costumers, who still prefer to visit a conventional website or talk to a dispatcher, and that must be taken into account during a transition period towards higher level of automation.

As our vehicles and the infrastructure collects and generates more and more data, and this data is crucial to analyse due to traffic safety and environmental protection, harmonisation, regulation sharing of Mobility data on an EU level was never so important. There are several measures which the member states will have to take in the upcoming years, yet this is the way, the green path towards a sustainable Europe.

AUTHOR CONTRIBUTIONS

T. A. Tomaschek: Conceptualization, Data collection, Writing, Review and editing.

A. M. Selmeczy: Writing, Supervision, Review and editing.

Disclosure statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ORCID

If the authors have ORCID identification, it must be given in this section.

Tamás Attila Tomaschek https://orcid.org/0000-0002-9201-3559

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