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Transportation Research Challenges Based on the Analysis of EU Projects

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ABSTRACT

In recent years several projects have been realised in the field of transportation, but there is a lack of systematic analysis of research challenges connected to these projects. Thus, the main aim of this paper is to provide an overview of these challenges through EU funded projects in the field of smart, green and integrated transport. Based on EU strategic documents, reports and roadmaps, 10 topics are identified playing a crucial role in transportation-related research. A systematic analysis of the projects is realised, where the projects collected from an online database in the Horizon 2020 framework programme from 2015 to 2020 are categorised into these topics. The results show that travel behaviour, big data and open data, sustainable mobility planning and smart solutions are covered by several projects which reflect the main research trends. While active and shared modes, multimodal transportation, trip optimisation and Mobility as a Service are also popular topics. Based on the results, the most underrepresented research areas are artificial intelligence and social networks. The analysis of the connections between the research topics could enable the achievement of a long-term paradigm shift in urban mobility, which is beneficial for researchers, professionals and policy makers.

KEYWORDS

transport research; Horizon 2020; research topics; challenges.

1. INTRODUCTION

The fast development of intelligent transportation systems, the spread of multimodal travel planners, the novel methods of travel behaviour analysis and a better understanding of social interactions enable efficient interventions in planning transportation networks, urban planning and policymaking. Smart mobility solutions are featured in EU transport strategic documents, especially in the White Paper, where the use of intelligent solutions is promoted to increase the efficiency of transportation and infrastructure. Various EU funded projects, especially in the Horizon 2020 research framework program, cover the issues of sustainable solutions and support travel behaviour change through the development of concepts and the application of technologies. The Horizon 2020 programme ran between 2014 and 2020 with a total budget of 6339 million euro provided by the European Commission for transportation-related topics. Within this programme (H2020-EU.3.4.), "Smart, green and integrated transport is aimed at achieving a European transport system that is resilient, resource-efficient, climate- and environmentally-friendly, safe and seamless for the benefit of all citizens, the economy and society. Funding priorities will be geared towards the present and future needs of citizens, businesses and EU markets and strive to maximise value for the transport sector, the wider economy and ultimately, the people. These priorities are aimed at creating new opportunities for sustainable growth and employment." [1]. The Innovation and Networks Executive Agency (INEA) founded by the European Commission aims to manage and support the technical and financial implementation of several programmes including "Mobility for Growth" calls dealing with mode-specific transportation integration and cross-cutting challenges. Furthermore, the agency is responsible for the evaluation of the proposals and for the organisation of info days about the calls and funding opportunities. Moreover, INEA provides communication guidelines and supports the exploitation of the project results [2].

In recent years several projects have been realised in the field of transportation, but there is a lack of systematic analysis of research challenges connected to these projects. Previous works attempted to collect and analyse research projects in various domains. Collective intelligence and crowdsourcing platforms are analysed based on 10 projects realised in the Horizon 2020 framework with the aim of understanding recent initiatives. In a previous paper, the list of selected projects with short descriptions was provided, where the selection process was based on research keywords and a specific timeframe [3]. In another research, the topic of eco-innovation was in the focus, especially how it appears in the projects of the Horizon 2020 program. The projects were chosen based on keywords in related documents. During the analysis, new rising topics and ideas were identified, as well [4]. Moreover, researchers discovered the field of electro-fuel production of the projects funded in the Horizon 2020 program. The projects were selected based on specific features under the "Secure, Clean and Efficient Energy" challenge [5]. In another paper, research projects on smart distributed energy systems were collected in the energy sector based on predefined keywords [6]. It can be identified that previous works apply similar approaches when analysing projects, where specific keywords and topics are chosen and the project results are analysed based on specific aspects. However, it seems that such an analysis has not been realised in the transportation domain yet.

Currently, there is no systematic analysis realised in the field of transportation to identify the main research topics. Although there is project data available, this kind of research topic analysis was not investigated. Based on this, a general research question can be formulated: What are the main topical challenges appearing in the field of transportation and how are these topics handled by EU funded projects?

Therefore, the main aim of this paper is to provide an overview of these challenges through EU funded projects in the field of smart, green and integrated transport. This aim will be realised by collecting project-related information from an online database, where specific filters will be applied to reduce the number of projects and to enable focusing on the main topics of this research. This approach helps to highlight those topics that are frequently handled by researchers and also find those topics that need further elaboration. Having the specific topics, it is possible to categorise research results and identify those topics, where more research is needed in the future. Moreover, the connection between the topics could also reveal new insights for the research community. It will also help to define the research topics that should be assessed and where calls should be announced, to facilitate more research in the field. The results of the analysis could enable the achievement of a long-term paradigm shift in urban mobility, which is beneficial for researchers, professionals and policy makers.

The paper consists of the following sections. First, a research overview is presented, where topics are identified and research projects are classified into these topics. After a short analysis, future challenges of the identified topics are described mainly based on relevant research papers and other contributions. At the end, the trends are summarised as a conclusion.

2. RESEARCH REVIEW AND TOPIC DEFINITIONS

For the definition of the main topics, the White Paper of transportation titled "Roadmap to a Single European Transport Area" is used providing a general vision on transportation systems with goals and strategies. The document covers various transportation issues, such as rail services, airports, ports, road freight, multimodal transport, security, safety and service quality. Moreover, it deals with innovation policy, sustainable behaviour, integrated urban mobility and transportation infrastructure [7]. In this research, smart, green and integrated transport is considered.

To provide an overview of the research topics, the Transport Research and Innovation Monitoring and Information System (TRIMIS) database is used to identify relevant projects and research directions. The database includes numerous projects on national and international levels. The Transport Research & Innovation Status Assessment Report provides an overview of transportation-related research and innovation projects based on the TRIMIS database [8]. The aim of the report is to map and analyse research trends and innovation opportunities, which is an excellent starting point for this research. The report analyses several research programmes based on the type of funding, spatial distribution and transport mode, but more importantly, it formulates key research and innovation pathways. The report identifies connectivity and social media as two main areas that transform the traditional concepts of mobility. The transportation system benefits from the introduction of innovative mobility services and online platforms as well as from the provision of real-time analysis of traffic situations.

Based on an extensive analysis of the TRIMIS database, the establishment of the Strategic Transport Research and Innovation Agenda (STRIA), which is a tool of the European Commission for exploring technology trends and opportunities of research and innovation in the field of transportation, is possible [9]. The STRIA builds on seven thematic transportation research areas, from which smart mobility and services are chosen as the most relevant for this research. These priority areas focus on specific actions, which provide future opportunities for research and innovation. Based on the listed EU strategic documents, reports and roadmaps, it is possible to identify 10 topics, which play a crucial role in transportation-related research and enable the definition of research challenges.

Travel behaviour. The way people travel and choose locations, transport modes, routes and time defines travel behaviour, which can be monitored, analysed and modified by soft and hard measures. Travel behaviour mainly consists of routines that travellers prefer to repeat based on their satisfaction of activity patterns in the past. The White Paper mentions sustainable behaviour as a main pillar of the research, innovation and development strategy in Europe [7]. To provide more efficient use of the transportation infrastructure, the cooperation of public and private providers and services should be planned, developed and realised [10]. Furthermore, other platforms support a shift in travel behaviour toward sustainable transport modes, for example, with the implementation of sustainable mobility plans [11].

Sustainable mobility plan. On the highest level, the White Paper suggests that mobility planning should be actively encouraged [7]. The STRIA roadmap and sustainable city strategies feature mobility services, which are necessary to support efficiency, decarbonisation and future multimodal systems. Mobility planning deals with different transport modes in urban and regional contexts and it aims to promote sustainable transportation and enhance accessibility, especially in rural areas. A benefit of sustainable mobility planning is that it covers technical features, infrastructural development, strategy definition, performance improvement and cost-efficient planning [12].

Multimodal transportation. Multimodality is mentioned several times in the White Paper mostly in terms of intercity travel and freight transport [7]. Novel solutions facilitate the increased efficiency of transportation systems. Up-to-date and reliable information at the hands of public transport users can improve the traffic flow and enable the more efficient use of the available physical infrastructure. Thus, public transport usage and the link to other transport modes can be improved. Multimodal transportation is the combination of various transport modes, which leads to minimised travel time, reduced costs and increased comfort features [13].

Active and shared modes. Active modes are alternatives to car travel, and the promotion of sustainable solutions enables the reduction of emissions and the mitigation of traffic jams, as stated by the White Paper, as well [7]. The popularity of bike-sharing and car-sharing has been rising over the last years. The basic concept is that individuals participating in a specific programme are allowed to use bikes or vehicles from a fleet on an hourly basis. Usually, local governments or companies operate these solutions, whose impact depends mainly on the scale of the system [14].

Trip optimisation. Travel demand in cities can be dispersed by digital technologies. The optimisation of the capacity and the optimal use of the infrastructure are relevant goals listed in the White Paper [7]. Rural and urban areas benefit from such solutions, where traffic flows can be optimised and traffic management might be improved. Traffic management strategies can be designed to prioritise sustainable transport modes and multimodal transportation systems can enhance the efficiency of trips in cities. Furthermore, digitalisation increases the efficiency of transportation systems through path optimisation algorithms and commuter behaviour profiling [15].

Artificial intelligence. Intelligent solutions enable the reduction of congestion and other negative transportation-related effects, as described by the White Paper [7]. The digitalisation in mobility provides an increasing amount of aggregated data from several sources. These data have to be processed with methods of data mining, data fusion, data analytics and visualisation. Artificial intelligence includes approaches that support solving traditionally complex issues, provide optimised solutions and thus enable intelligent travel behaviour. Nowadays, the application of artificial intelligence in transportation systems is picking up speed especially with the development of communication networks. Research in the area continues to evolve in line with the growth of automated transportation technologies. The challenge lies in using its potential to enable more efficient decision-making resulting in more benefits to the users [16].

Big data and open data. Big data describes a new paradigm, where a high amount of data is stored and analysed. Open data is all the information created or collected mainly by governmental organisations. Although these elements are not directly included in the White Paper, the idea of opening transportation markets is present [7]. Freely available data, sharing agreements between mobility stakeholders and development in terms of processing, capacity and communication are a few of the factors which contribute to the spread of big data. Big data enables spatial analysis and the optimisation of transportation networks. There are various applications of these solutions, such as social network applications, social media usage analysis and intelligent transportation optimisation [17].

Mobility as a Service. Mobility as a Service (MaaS) provides a combination of various transport modes, where the service providers' offers are integrated into mobility packages. This is extended with value added services, such as multimodal journey planning, booking of on-demand services and ticketing, all together in one application. MaaS is a novel paradigm, but providing integrated and connected services is part of the goals presented in the White Paper [7]. The core characteristics of MaaS are the followings: optimised journey planning, tailor-made packages, bundling of services, combination of transport modes within trips and advanced ticket delivery options. In order to enable an efficient operation of MaaS services, sharing data among the main players in the transportation domain is needed, so that travellers can make informed decisions. Dynamic traffic data, real-time arrival times and booking options are required to set up new mobility operators, who can serve the users during their trips [18].

Smart solutions. Smart solutions are available because of newly appearing trends, such as the spread of smart phones, the usage of mobile applications, the popularity of social media and the increased options of shared mobility. Smart solutions (e.g. online reservation and ticketing) are mentioned in the White Paper, too [7]. Advanced systems collect travel-related information about the users' patterns, the congestion on the roads and possible alternatives, which provide benefits both for the users and for the transportation systems. Smart solutions are spreading quickly and they introduce novel ideas, which not only impact strategic planning, but provide advanced services for the users, as well [19].

Social networks. The analysis of social media data can give indications about travel choices, such as departure times, route and transport mode choices. In addition, it can influence other levels of choices, such as travel destinations and long-term activity patterns. This term is not present directly in the White Paper because the topic is relatively new, but it is worth including this topic in the analysis. Data analysis can give stakeholders and decision-makers some insights into the travellers' choices. Extracted information from social networks can help to visualise the perception and acceptance of new mobility services. Moreover, it can help in sizing up the user preferences and decision-making factors to improve the efficiency of transportation [20].

3. RESEARCH TOPIC ANALYSIS

The analysis of transportation-related EU funded projects from 2015 to 2020 focuses on the Horizon 2020 framework programme as it provides one of the main sources of transportation research. In the TRIMIS database, 8514 projects are listed covering a wide set of scientific disciplines [8]. When filtering the transportation challenge-related programme (H2020-EU.3.4.), 390 projects remain. From this list, all types of projects, namely Research and Innovation Action (RIA), Innovation Action (IA) and Coordinator and Support Action (CSA) under the programme "Mobility for Growth" are chosen resulting in 153 projects. Finally, 33 projects are listed that are connected to the "smart mobility and services" topic of the STRIA roadmap and deal with the "road" and "multimodal transport" sectors and logistics.

In *Table 1*, some basic information about the projects is presented including their acronyms, project titles, the starting date and the ending date of the projects, the amount of funding, the numbers of project partners, the countries of the lead partners and links to the project websites (if available). It can be seen that most projects started in 2015 and 2017 and ended in 2018 and 2020. In terms of funding, the average amount was 4.6 million euro while on average, 16 project partners were involved per project. When considering the countries of the lead partners, it becomes clear that the majority of the projects are led by Western European organisations primarily from Italy, the United Kingdom, Belgium and Germany, as presented in purple, while other countries such as the Netherlands, Greece, Spain, Portugal, Austria, Norway, Denmark have only a few leading roles, shown in blue in *Figure 1*.

Table 1 – Basic data of the selected EU funded projects

Acronym	Project title	Start date	End date	Funding (million euro)	Project partners	Lead partner's country	Project website
BONVOYAGE	Intermodal mobility solutions and interfaces for people and goods supported by innovative communication network	2015	2018	4	11	Italy	bonvoyage2020.eu
CIPTEC	Collective Innovation for Public Transport in European Cities	2015	2018	3.5	12	Greece	ciptec.eu
Cities-4-People	New approaches for community-driven sustainable mobility innovations at neighbourhood and urban district level	2017	2020	4	13	Denmark	cities4people.eu
CREATE	Congestion Reduction in Europe: Advancing Transport Efficiency	2015	2018	4	18	United Kingdom	create-mobility.eu
DESTI-NATIONS	CIVITAS DESTINATIONS	2016	2021	18	32	Portugal	civitas.eu/projects/destinations
EMPOWER	EMPOWERING a reduction in use of conventionally fuelled vehicles using Positive Policy Measures	2015	2018	4.9	12	United Kingdom	empowertoolkit.eu
EBSF_2	European Bus System of the Future 2	2015	2018	10	51	Belgium	uitp.org/projects/ebsf2
ETC	The European Travellers Club: Account-Based Travelling across the European Union	2015	2018	4.5	7	Nether-lands	european travellersclub.eu
EuTravel	Optimodal European Travel Ecosystem	2015	2017	3.9	18	United Kingdom	eutravelproject.eu
FLOW	Furthering Less congestion by creating Opportunities for more Walking and cycling	2015	2018	3.8	16	Germany	h2020-flow.eu
HiReach	High reach innovative mobility solutions to cope with transport poverty	2017	2020	2	9	Italy	-
IMOVE	Unlocking Large-Scale Access to Combined Mobility through a European MaaS Network	2017	2019	3.7	14	Italy	imove-project.eu
LeMO	Leveraging Big Data to Manage Transport Operations	2017	2020	1.5	5	Norway	lemo-h2020.eu
MaaS4EU	End-to-End Approach for Mobility-as-a-Service tools. business models enabling framework and evidence for European seamless mobility	2017	2020	3.7	17	Belgium	maas4eu.eu
MASAI	Mobility Based on Aggregation of Services and Applications Integration	2015	2018	3.3	5	Belgium	masai.solutions
Metamorphosis	Transformation of neighbourhoods in a child-friendly way to increase the quality of life for all citizens	2017	2020	3.4	12	Nether-lands	civitas.eu/projects/metamorphosis
MIND-SETS	Mobility Innovations for a New Dawn in Sustainable (European) Transport Systems	2014	2017	1.8	8	Italy	-
MOBILITY4EU	Action Plan for the future of Mobility in Europe	2016	2019	2.9	19	Germany	mobility4eu.eu
MUV	Mobility Urban Values	2017	2020	4	14	Italy	muv2020.eu
MyCorridor	Mobility as a Service in a multimodal European cross-border corridor	2017	2020	3.5	17	United Kingdom	mycorridor.eu
NOESIS	Novel Decision Support Tool for Evaluating Strategic Big Data Investments in Transport and Intelligent Mobility Services	2017	2019	1.2	8	United Kingdom	noesis-project.eu
NOVELOG	New cooperative business models and guidance for sustainable city logistics	2015	2018	4.4	28	Greece	civitas.eu/projects/novelog
OPTIMUM	Multi-source Big Data Fusion Driven Proactivity for Intelligent Mobility	2015	2018	6	19	Belgium	-
PORTIS	PORT-Cities: Integrating Sustainability	2016	2020	16	34	Belgium	civitas.eu/projects/portis
Prosperity	Prosperity through innovation and promotion of Sustainable Urban Mobility Plans	2016	2019	3.2	26	Austria	civitas.eu/projects/prosperity
SocialCar	Open social transport network for urban approach to carpooling	2015	2018	5.9	26	Italy	-
STARS	Shared mobility opporTunities And challenges foR European citieS	2017	2020	1.8	9	Italy	stars-h2020.eu
SUITS	Supporting Urban Integrated Transport Systems: Transferable tools for authorities	2016	2021	4.1	22	United Kingdom	suits-project.eu
SUMPs-Up	European Programme for Accelerating the Take up of Sustainable Urban Mobility Plans	2016	2020	4	15	Germany	sumps-up.eu
SUNRISE	Sustainable Urban Neighbourhoods - Research and Implementation Support in Europe	2017	2021	4	16	Germany	civitas-sunrise.eu
TIMON	Enhanced real time services for an optimised multimodal mobility relying on cooperative networks and open data	2015	2018	5.6	11	Spain	timon-project.eu
TRACE	Opening the cycling and walking tracking potential	2015	2018	2.9	12	Portugal	-
U-TURN	Rethinking Urban Transportation through advanced tools and supply chain collaboration	2015	2018	2.7	10	Spain	civitas.eu/projects/u-turn

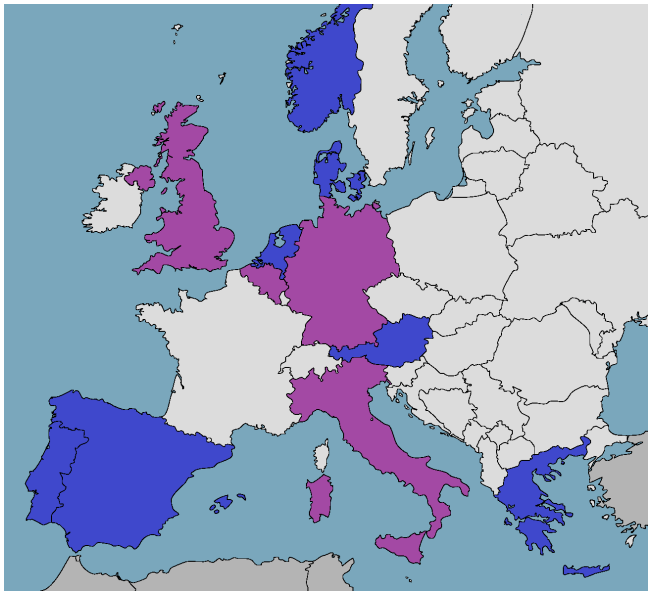

Figure 1 – The distribution of the countries of the lead partners

Table 2 presents the research topics based on the projects, where the projects are categorised into the following research topics: travel behaviour, sustainable mobility planning, multimodal transportation, active and shared modes, trip optimisation, artificial intelligence, big data and open data, Mobility as a Service, smart solutions and social networks. The basis of the categorisation is the project title, the project abstract and relevant deliverables of the project. When analysing the projects, three options are defined in *Table 2*. If a project is not connected to a category, it is not marked in the table. If a project deals with the topic to a limited extent, it is marked with "+", if it has a strong focus on a specific topic, it is marked with "++".

Focusing on the distribution of the research topics according to their starting years (*Figure 2*), it turns out that the topics of travel behaviour, big data and open data, active and shared modes and smart solutions appeared in 2015 and 2017, while multimodal transportation, trip optimisation and Mobility as a Service seem to be more evenly distributed among the years.

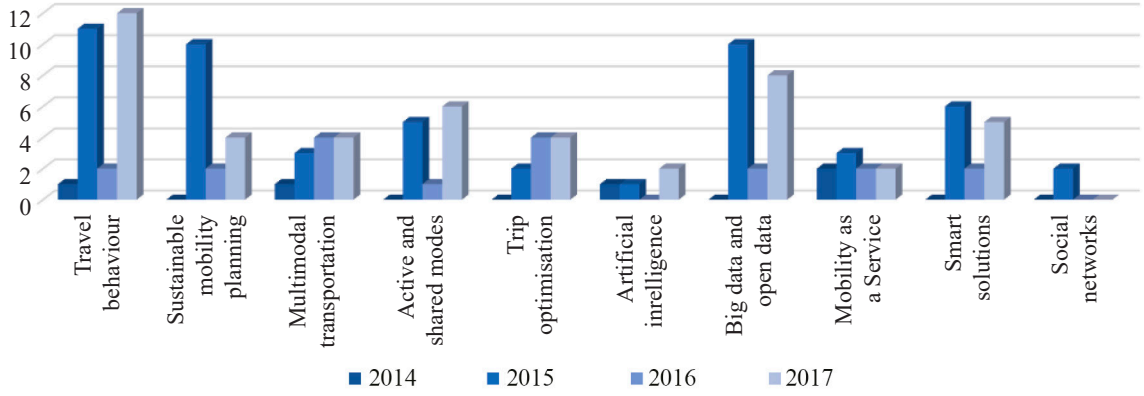

Figure 2 – The distribution of the research topics according to the starting year

In the next step, specific features of the projects are outlined, where the basis for grouping the projects is the identified categories connected to transportation-related topics.

Some projects (i.e. SUITS, SUMPs-Up, PROSPERITY, DESTINATIONS) aim to support high quality sustainable urban mobility plans, whose measures are implemented by local authorities. They also deal with changes in travel behaviour and data collection but only to a limited extent.

Other projects (i.e. EuTravel, BONVOYAGE, ETC, MASAI) aim to develop multimodal services using open data from different data sources to provide information to travellers. Usually, trip planning, ticketing and

Table 2 – The research topics of the examined EU funded projects

Acronym / research topic	Travel behaviour	Sust. mobility planning	Multimodal transportation	Active and shared modes	Trip optimisation	Artificial intelligence	Big data and open data	Mobility as a Service	Smart solutions	Social networks
BONVOYAGE			++		++		+	+		
CIPTEC	++		+						+	+
Cities-4-People	++			+						
CREATE	++	+		+						
DESTINATIONS	++	++								
EMPOWER	++			++						
EBSF_2					+		+		++	
ETC			+				++	+	++	
EuTravel			++		+		+	+		
FLOW	++	+		+	+					
HiReach				+	++				+	
IMOVE	+						+	++		
LeMO			+				++			
MaaS4EU	+		+			+		++		
MASAI					+		+		++	
Metamorphosis	++	+								
MIND-SETS	+		+						++	
MOBILITY4EU	+		++						+	
MUV	++	+					+			
MyCorridor	+		+				+	++		
NOESIS						+	++			
NOVELOG		++			+		+			
OPTIMUM	+				+		++		+	
PORTIS	++								+	
Prosperity		++		++						
SocialCar	+			++	+		+		+	+
STARS	+	+		++						
SUITS	+	++					+			
SUMPs-Up		++								
SUNRISE	+	++								
TIMON	+					+	++			
TRACE	+			++		+	+			
U-TURN		+							++	
SUM	30	18	12	14	10	4	21	9	16	2

personalised information are present. They offer smart solutions, but they do not include social networks as a possible data source.

The focus of several projects (i.e. FLOW, EMPOWER, CREATE) is on changing travel behaviour to encourage more sustainable transport mode choice. This is achieved by introducing evaluation and monitoring tools for measures and by promoting walking and cycling. These projects do not cover artificial intelligence or big data analysis to reach their aims.

A group of projects (i.e. TIMON, OPTIMUM, TRACE, NOESIS, LeMO) include big data analysis to a high extent, which is usually connected to artificial intelligence and travel behaviour, but these projects do not consider multimodality, shared modes or smart solutions.

Mobility as a Service is the main topic of some projects (i.e. MaaS4EU, MyCorridor, IMOVE), where travel behaviour change, multimodality and artificial intelligence are partially present. However, other relevant aspects are not combined.

In the case of other projects (i.e. MIND-SETS, MOBILITY4EU), the aim is to find future mobility solutions including long term travel behaviour change, the usage of sustainable transport modes and the utilisation of multimodal travel options.

A group of projects (i.e. MUV, Cities-4-People) aim to reach travel behaviour change through participatory approach, gamification (i.e. the usage of playing elements as a marketing technique to encourage use engagement) and co-creation, which is a very promising research direction. However, these projects do not utilise technical solutions to a great extent.

Only in a few projects (i.e. SocialCar, STARS, PORTIS) are shared modes in the focus of the research, where the combination of other modes providing smart solutions and changing travel behaviour are important, as well.

Additionally, U-TURN and PORTIS apply smart logistics-based solutions. Only SocialCar considers social networks as suitable data sources. CIPTEC uses crowd sourcing to receive information about travel behaviour, which can be interpreted as an innovative way of data collection. Furthermore, only HiReach deals with demand responsive transport and ride sharing as real options even though these fields have much higher optimisation potential.

Travel behaviour change is covered by most of the projects as it is an easily defined and general aim, which can be a long-term effect of several measures. Big data and open data are present in numerous projects, which reflects a popular research trend at this particular time. Furthermore, sustainable mobility planning is a very popular project aim, as such plans aim to shape the future of mobility. Active and shared modes appear in some projects, however not to a large extent. Mobility as a Service is the focus of some specific projects. Multimodal transportation, trip optimisation and smart solutions are found in less than half of the projects, which is quite surprising as they are expected to be more in focus. Based on the summary, the most underrepresented research areas are artificial intelligence and social networks.

Considering the connections among the topics, the following three connection types are defined: weak, moderate and strong connections. The basis of defining the connection types is the categorisation of projects in *Table 2*. Connections are pairwise defined. A weak connection means that some projects deal with both topics, but there is a limited overlap. A moderate connection means that several projects focus on both topics, but some projects consider only one topic. Strong connection describes such pairs where most projects include both topics.

The analysis of EU funded projects (*Figure 3*) identifies travel behaviour as the most popular topic, which has connections to many other topics. Trip optimisation, big data and open data, multimodal transport and smart solutions have several connections to other topics; thus, widely applicable research results can be expected. At the same time, artificial intelligence, social networks and sustainable mobility planning are not much connected, which means that these topics are very specific and do not have much interaction with other transportation-related areas. In most cases, the connections are weak or moderate, but four strong connections can be found, which can be highlighted as two research topic triangles. The first research topic triangle is between multimodal transport, Mobility as a Service and big data and open data, which means that these topics are strongly linked and their interrelationship may deliver more diverse research results. The second research topic triangle is between sustainable mobility planning, active and shared modes and travel behaviour. The combination of these three research topics could enable the achievement of a long-term paradigm shift in urban mobility.

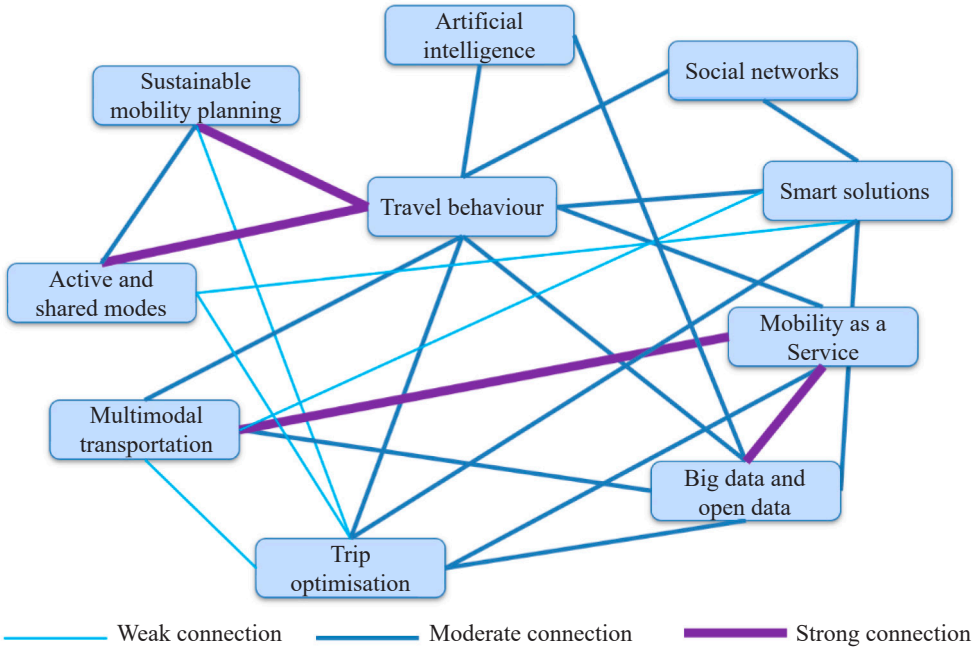

Figure 3 – The categorisation and connection of the research topics

4. DISCUSSION

Based on the analysis of the EU funded projects, the same categorisation is applied to define the main challenges in transportation research. In each category, some potential gaps are presented and research challenges are identified. The aim is not to provide a full and comprehensive list of the potential challenges, but to highlight some of the most interesting ones. Travel behaviour is not assessed separately as it is a wide research area and it is well connected to all other topics, multimodal transportation and trip optimisation are combined, while the other topics are discussed separately.

4.1 Sustainable mobility planning

Sustainable mobility plans are based on the following four main pillars: stable financial situation, proper policies for transportation-related issues, realised strategic investments in infrastructure, joint planning and development of the stakeholders. In general, policies have to be present, but the actions have to be flexible to reflect the main challenges and changes in the transportation system. This can be achieved only by discussions with the public about the planning processes [21].

Involving citizens in the decision-making process is an effective way to explore a broad stakeholder opinion. By using this approach, the local issues can be easily integrated and suitable solutions can be elaborated. By reaching consensus, collective decisions can be realised, which serves in general the needs of the citizens. Thus, decision support methods and multi-criteria analysis should be further developed; hence, public involvement and participation becomes a fundamental and efficient alternative [22].

To have a comprehensive plan, continuous collaboration with different stakeholder groups should be realised. Therefore, not only the number of involved stakeholders is relevant, but the feedback mechanisms and the iterative processes are needed before making the final decisions, too. Cities implementing these suggestions realise measures resulting in more sustainable solutions and potentially influencing mode choice in the long term [23].

4.2 Multimodal transportation and trip optimisation

Multimodal transportation is realised by multimodal journey planning applications. There is a huge number of multimodal information systems across Europe, mostly with an urban focus connected to the local public transport. However, cross-border information is hardly integrated due to organisational, administrative and interoperability issues. There is a definite need for cross-border information, which can be realised by a journey

planning system, which has a distributed database and practically connects several journey planners through their services across Europe [24].

The functionality and services provided by the journey planners supporting multimodal transportation should be explored and further developed. These online services should enable users to plan with all the potential transportation services at hand combining individual and public transport multimodal experience [25].

In a more connected transportation ecosystem, more complex services should be developed based on information provision and value-added services. These services need to be connected through standardised interfaces with data sharing opportunities. Traveller information services should offer more settings related to personal requirements, realise better optimised routing algorithms and present enhanced comfort information to the users [26].

4.3 Big data and open data

Big data is the result of technological innovation and the popularity of digital devices. Although vast resources are present, transforming data into valuable information requires advanced computational methods, which are suitable to find general trends and the patterns of rather large datasets. Open data supports and enhances the availability and potential of big data. Several local communities have created websites to distribute the collected data; however, the formats have not been standardised, the update frequency has not been regulated and privacy issues have not been clarified yet [27].

Although cloud computing for the analysis of big data has been broadly accepted, several issues have not been addressed yet. For example, service providers need to store the data, which have to be permanently and continuously available for the users. However, with the increasing number of users and data requests, very robust services with low latency are required. In addition, data quality is a potential issue because the information originates from different sources. This means different types and representation forms, which results in incompatible formats and inconsistency. Only after providing data reliability and data consistency can transportation developments efficiently supported with such datasets [28].

4.4 Artificial intelligence

In general, artificial intelligence can assist in overcoming the challenges of travel demand, emissions, safety and environmental issues. The main types of artificial intelligence methods are neural networks, genetic algorithms and fuzzy logic models. In order to apply these methods efficiently, the provided data and their characteristics have to be well understood. For example, optimisation issues can be solved with genetic algorithms, but to provide useful results, the parameter settings and the definition of the utility function are crucial. In the case of predictions, data preparation, feature extraction and model validation are the main elements, which are required to have meaningful results. With proper settings, artificial intelligence can provide advanced outputs, but it has some limitations in terms of finding the optimal solution, computation complexity and generalisation options [29].

An interesting issue is the responsibility of applying artificial intelligence in the decision-making process, which is called the "responsibility gap". In this case, the decisions are fully made by the machine, where advanced algorithms provide the results. While it has its advantages, it generates a set of problems about culpability, morals, accountability and active responsibility. Thus, it seems that liability and legislation are behind the technological development, which hinders the spread of the new paradigms [30].

4.5 Active and shared modes

The young generation experiences collaborative consumption, which is related to the decrease in owning vehicles. They are more interested in experiencing than in having, which leads to the spread of shared transportation options. These new mobility options require planning in advance and limit the freedom of usage, but with proper technical solutions and a critical mass of registered and active users, these issues are not visible for the average user [31].

Car-sharing and ridesharing represent new transportation services, which appear besides traditional services, but their impact on the market is not well analysed. Thus, understanding these impacts on travel demand, network performance and land use developments is a crucial issue. Modelling tools should include these transport modes to support the transportation planning processes and estimate the travel demand of specific trans-

port modes in the future. In order to do that, technical, social and environmental factors have to be addressed and the potential effects on car ownership and travel behaviour should be explored [32].

Another relevant new mobility type is bike-sharing, which has been spreading especially quickly during recent years. The electric version is expected to be much more of a success; thus, it plays an important role in changing travel behaviour and solving transportation-related issues. However, one has to determine how such services can be implemented and how they can be integrated with the existing traditional transport modes. The adoption rate of this new mobility service depends on the users, the service provider and the governmental bodies [33].

4.6 Mobility as a Service

Mobility as a Service aims to cover all kinds of transport modes and to integrate currently fragmented services, such as planning, booking, payment and ticketing. By providing integrated transportation solutions and a seamless mobility service, a decrease in the usage of private cars is foreseen [34]. Mobility as a Service is a novel mobility paradigm, but implementation issues have not been addressed yet. Some attributes, such as personalisation, customised services, several payment options, reliability and usage analysis, should be highlighted during the realisation. When applying MaaS in a realistic context, suitable business models, potential impacts on travel demand and operator benefits should be examined [18].

The changes in passenger mobility have an effect on the roles and responsibilities of governmental bodies as they regulate the service providers. Exploring the changing situation of public authorities and the operational models of transportation services might support the understanding of the usage patterns of these new transportation opportunities. Additionally, from the user side MaaS solutions mainly aim to influence the young generation, who generally more often use smartphones to receive travel-related information. However, the benefits of new mobility services for the older generation have not been extensively studied yet [35].

4.7 Smart solutions

As technology advances, it creates a new market for smart solutions, as local governments want to address transportation issues with smart solutions. However, it is often debated whether one unified index can really determine the usefulness of a specific smart solution. Thus, the strategic plans, the planning methods and the evaluation of the realised solutions should be executed in a more cohesive way including different visions, stakeholders and priorities [36].

Although Smart City-related solutions are widespread, there is still confusion about what really a smart solution is, which would provide a real added value to the users. Currently, smart solutions appear both on the strategic level in the visions and in the strategic documents of cities and on the practical level by realised solutions and measures. Both the strategies and the smart solutions should meet the user requirements and should be tailor-made considering the technical, social, legal and environmental context [37].

4.8 Social networks

The expansion of social networks produces a high amount of data reflecting various aspects. Social media can be considered as a new means of sensor, which is able to capture information in a very quick and exact way while considering the local context. There is a real potential for using data from social media to develop models, which could serve specific aims, such as travel demand estimation, service operation management and strategic planning. However, it has to be noted that this kind of data may include biases, especially because of the typical usage patterns of specific user groups, primarily the younger generation [38].

Data from social networks has a great potential to gather a deeper understanding of travel behaviour, especially because social media data combined with other sources can be used to extract travel attributes. Several techniques, such as data mining, machine learning, statistical models and classification methods, have already been applied to understand the travel patterns. However, the full potential of these data has not been realised yet [39].

Furthermore, to provide a practical implication of the list of challenges, *Table 3* shows examples where the challenges have been handled successfully. In the projects, usually, the elaborated innovative methods are tested in specific pilot locations. Thus, the examples are selected from the pilot cities of the realised projects. Sustainable mobility planning is covered by Malmö, where an innovative travel survey technique is tested with

a target-based microscopic model for traffic analysis. Multimodal planning with linking services is realised in Rome, where specific interfaces and intermodal mobility solutions are utilised. In Ljubljana, the focus is on traffic data providing highly accurate predictions on traffic congestion. A MaaS solution is developed in Budapest, where a so-called personal mobility assistant is realised with booking and ticketing functionalities together with a simple route planning solution. Related to smart solutions, a Park & Ride pilot is set up in Luxembourg to demonstrate the multi-functional possibilities of account-based ticketing, where the users could earn loyalty points when parking. In the case of the artificial intelligence and social networks, the pilots do not really include these topics, they only appear among the general objectives of the projects. This specifically highlights that there is still room for further improvements and future research projects to uptake the listed challenges. A potential reason for not having so many direct applications for these challenges is that the level of artificial intelligence was not as robust and mature in the analysed period to be reliably applied in real-world circumstances.

Table 3 – Examples of successful implementations regarding the challenges

Challenges	Project	City	Topic
Sustainable mobility planning	SUMPs-Up	Malmö (Sweden)	Innovative travel survey technique with a target-based microscopic model for traffic analysis
Multimodal and trip optimisation	BONVOYAGE	Rome (Italy)	Door-to-door multimodal planning with linking services
Big data and open data	TIMON	Ljubljana (Slovenia)	Enhanced real time traffic data providing highly accurate predictions on traffic congestion
Artificial intelligence	-	-	-
Active and shared modes	EMPOWER	Newcastle (United Kingdom)	Travel awareness campaign with a mobile app focusing on cycling
Mobility as a Service	MaaS4EU	Budapest (Hungary)	Personal mobility assistant with booking and ticketing functionalities
Smart solutions	ETC	Luxembourg (Luxembourg)	Park & Ride app to demonstrate the multi-functional possibilities of account-based ticketing
Social networks	-	-	-

For the main challenge a successfully developed solution is added in *Table 4*. It has to be mentioned that these are not the results of the listed projects in the Horizon 2020 framework program, but other specific results connected to the listed challenges. Here the aim was to reflect the nowadays available and existing applications in Europe.

As a result of a research project, the Meili app can collect travel related data from the users based on the movements of the smartphone and suggest the used transportation mode based on these data, which facilitates the mobility planning process. The BudapestGo applications used up-to-date information about the public transport vehicles combined with the location of the bike-sharing stations, where multimodal planning is realised. The navigation system of TomTom provides real time traffic data based on a huge number of observations and through advanced algorithms it can predict the status of traffic. The Naviki app provides very easy planning options for bikers with personal heatmaps and CO2 saving calculations. While the Moovit app offers a routing solution with the support of artificial intelligence, the usage of real time traffic information and service alerts on the chosen trip. The Whim application provides access to several transport modes through one single application, where besides routing, booking and ticketing is also available for public transport, shared bikes and taxis. Parkl helps to find available parking spaces on the street and in parking garages with automatic payment options, where electric charging options are also listed. When using the Waze application, the information about the traffic originates from other users, which is collected and used to indicate congestion, accidents, or other events.

Table 4 – Examples of existing applications regarding the challenges

Challenges	Application	Description	Weblink
Sustainable mobility planning	Meili	Innovative travel survey technique with semi-automatic transport mode detection	https://play.google.com/ store/apps/details?id= riwu. mobilitycollector
Multimodal and trip optimisation	BudapestGo	Door-to-door multimodal planning including different transport services	https://play.google. com/ store/search?q= budapestgo&c=apps
Big data and open data	TomTom	Enhanced real time traffic data providing highly accurate predictions on traffic congestion	https://play.google.com/ store/ apps/details?id= com.tomtom. gplay.navapp
Artificial intelligence	Moovit	Routing solution with artificial intelligence powered services	https://play.google.com/ store/apps/details?id= com. tranzmate
Active and shared modes	Naviki	Travel awareness with a mobile app focusing on cycling and CO2 emission	https://play.google.com/ store/ apps/details?id= org.naviki
Mobility as a Service	Whim	Personal mobility assistant with booking and ticketing functionalities	https://play.google.com/ store/ apps/details?id= global.maas. whim
Smart solutions	Parkl	Park & Ride app to demonstrate multi-functional possibilities with electric charging locations	https://play.google.com/ store/ apps/details?id= net.parkl. androidclient
Social networks	Waze	Community based navigation and traffic information	https://play.google.com/ store/ apps/details?id= com.waze

5. CONCLUSIONS

The main research challenges are identified in this research through the analysis of transport related research projects, where 10 research topics are defined and 33 EU funded projects are analysed. Based on the results, travel behaviour change is the most relevant topic that appears, while big data and open data, sustainable mobility planning and smart solutions are also present in many cases. The most underrepresented research areas are artificial intelligence and social networks. Considering the connections, trip optimisation, big data and open data, multimodal transport and smart solutions have several connections to other topics.

The main limitation of the research is that it uses a relatively simple methodological approach with the analysis of an online database about transport related projects. This could be enhanced by applying advanced machine learning solutions and text-based analysis tools to provide a deeper understanding of potential connections. However, it has to be noted that this research aimed to provide a general overview of the research challenges, while the deep analysis could be the topic of another paper.

In the future the systematic analysis could be extended with novel results of the Horizon Europe program, where new projects have been started. It would also be interesting to analyse the improvements in terms of the identified topics and see which topics are mostly popular. Moreover, other topics could also be analysed, not only strictly transportation. Also, a similar analysis could be realised for research papers.

The challenges and gaps in the identified research areas are various and illustrate the complexity of the rapid advances in technology and the changing trends in travel behaviour within urban environments. MaaS services might bring a shift in consumer demands and impact not only the public transport contracts, but possibly the accessibility and traffic flows in cities, while social interactions and trends in mobility behaviour have to be further explored.

Integrated approaches between sustainable mobility planning and management are necessary to manage the demand in a more adequate way. Public involvement and participation in determining the best mobility solutions for cities are crucial, while smart solution developments depend on the local context to a great extent. Analysing and verifying a high amount of data from various data sources of different quality requires skills and technological infrastructure. Furthermore, the amount of the generated data might become too complex to

manage, where advanced algorithms take over the processing and analysis of big data volumes. Future systems need to be designed to eliminate the uncertainties and ambiguities.

Disruptive transportation services, like car-sharing, are now widespread, but despite the positive aspects, their impact on the market remains poorly understood. Cities still need to determine how these systems can be implemented in a way that best suits the local characteristics. The sharing of information by online communities can offer a glimpse into the unpredictable nature of these disruptive services and should thus be considered as a potential source of information. Modelling such changes offers challenges not exclusively to mobility researchers, but to the countries aiming to be early adopters of such services, as well.

The technological innovations bringing challenges in mobility management should not be considered alone as the drivers of changes. The social interactions and trends in mobility behaviour have to be further explored, as well. Data from social media can give us insights into the public opinion about mobility services. Nonetheless, methods ascertaining the reliability of such data still need to be developed.

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Esztergár-Kiss Domokos

Közlekedési kutatási kihívások EU-s projektek elemzése alapján

Absztrakt

Az elmúlt években több projekt is megvalósult a közlekedés területén, de hiányzik a projektekhez kapcsolódó kutatási kihívások szisztematikus elemzése. Ezért ennek a cikknek az a fő célja, hogy áttekintést nyújtson ezekről a kihívásokról az EU által finanszírozott projekteken keresztül az intelligens, zöld és integrált közlekedés területén. Az EU stratégiai dokumentumai, jelentései és ütemtervei alapján 10 olyan téma kerül azonosításra, amelyek kulcsfontosságú szerepet játszanak a közlekedéssel kapcsolatos kutatásokban. A projektek szisztematikus elemzése valósul meg, ahol a Horizont 2020 keretprogramme online adatbázisból összegyűjtött 2015-től 2020-ig megvalósult projektek kerülnek kategorizálásra a témák alapján. Az eredmények azt mutatják, hogy az utazói szokások, a big data és a nyílt

adatok, a fenntartható mobilitás tervezés és az intelligens megoldások számos projektben szerepelnek, amelyek tükrözik a fő kutatási trendeket. Míg az aktív és megosztott módok, a multimodális közlekedés, az utazások optimalizálása és a mobilitás mint szolgáltatás szintén népszerű téma. Az eredmények alapján a leginkább alulreprezentált kutatási területek a mesterséges intelligencia és a közösségi hálózatok. A kutatási témák közötti összefüggések elemzése lehetővé teszi a városi mobilitás hosszú távú paradigmaváltásának megvalósítását, ami előnyös a kutatók, a szakemberek és a döntéshozók számára.

Kulcsszavak
közlekedési kutatás; Horizont 2020; kutatási témák; kihívások.