www.piarc.org
2023R49EN

NEW MOBILITY AND ROAD INFRASTRUCTURE

FINAL REPORT

TASK FORCE 2.1 - *NEW MOBILITY AND ITS IMPACT ON ROAD INFRASTRUCTURE AND TRANSPORT*

PIARC

STATEMENTS

The World Road Association (PIARC) is a nonprofit organisation established in 1909 to improve international co-operation and to foster progress in the field of roads and road transport.

The study that is the subject of this report was defined in the PIARC Strategic Plan 2020– 2023 and approved by the Council of the World Road Association, whose members are representatives of the member national governments. The members of the Technical Committee responsible for this report were appointed by the member national governments for their special competences.

Any opinions, findings, conclusions and recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of their parent organisations or agencies.

This report is available from the internet site of the World Road Association (PIARC): http://www.piarc.org

World Road Association (PIARC)
Arche Sud 5° niveau
92055 La Défense cedex, France

International Standard Book Number: 978-2-84060-753-3

Front cover © Shutterstock

NEW MOBILITY AND ROAD INFRASTRUCTURE

FINAL REPORT

TASK FORCE 2.1 - ***NEW MOBILITY AND ITS IMPACT ON ROAD INFRASTRUCTURE AND TRANSPORT***

AUTHORS/ ACKNOWLEDGEMENTS

This Report has been prepared by PIARC's Task Force 2.1 New Mobility and Its Impact on Road Infrastructure and Transport. The aim of the Task Force is to investigate what impact new forms of connected, autonomous, shared, electric mobility are expected to have on the design, operation, and maintenance of physical and digital road infrastructure over the next 30 years from a Road Network Operations (RNO) perspective.

The Task Force was established in July 2022 and has undertaken an external questionnaire survey, literature review, published an Interim Report as well as presenting and holding discussions at the 2023 PIARC World Road Congress. All work is based on six focus areas: Automated and Connected Mobility, C-ITS, Digital Highways and Next Generation ITS, Mobility As A Service (MaaS), Vehicle Platooning and Electric Mobility. This Report sets out evidence and findings around these areas as well as cross-cutting horizontal issues. These are relevant to Road Network Operators and PIARC Members generally, including the new Technical Committee 2.5 (Road Infrastructure for Connected and Autonomous Mobility) which has been established for the new 2024 – 2027 Strategic Planning Cycle.

The Task Force members and contributors to the preparation of this Report are presented below in alphabetical order:

- Andreas Nordost (Sweden)
- Annette SMITH (UK)
- Antonio GRANADO (Spain) (Spanish Secretary)
- Abdelmename HEDHLI (France) (French Secretary)
- Ana Luz JIMENEZ (Spain) (Chair)
- Carmen POSTIGO ARCE (Spain)
- Dezao HOU (China)
- Hamid ZARGHAMPOUR (Sweden)
- Ian PATEY (UK) (English Secretary)
- Ignacio GONZALEZ RODRIGUEZ (Spain)
- Jean-François RIOUX (Canada-Québec)
- Jonathan SPEAR (UK)
- Martin BÖHM (Austria)
- Steve PENMAN (New Zealand)
- Shoichi SUZUKI (Japan)
- Tamas TOMASCHEK (Hungary)

The following individuals also contributed to material presented in this Report:

- Maria Eugenia MARTINEZ (Spain) (TC 1.1)

Finally, Task Force 2.1 would like to thank colleagues from Technical Committee 1.1 (Performance of Transport Administrations) which provided evidence and advice on key aspects on the impacts of new mobility on road and transport infrastructure which is also reflected in this Report.

EXECUTIVE SUMMARY

2023R49EN

NEW MOBILITY AND ROAD INFRASTRUCTURE

PIARC has been concerned, for some time, about the challenges and opportunities presented by Connected and Autonomous Vehicles for Road Network Operators. These were explored by two Task Forces (B.1 and B.2) between 2018 and 2020, and the rapid and disruptive arrival of a wider range of mobility technologies, digital and service concepts required a review and update.

The new forms of mobility refer both to the new vehicle types and technologies that are beginning to circulate on streets and highways, as well the new ways in which citizens are using those vehicles, including customer proposition, asset ownership, demand management and shared services. A broader review of new mobility concepts and their impacts on road and transport infrastructure is therefore required, leading to the creation of a new Task Force 2.1 (New Mobility and Its Impacts on Road Infrastructure and Transport) in July 2022.

The Task Force is focused on six technical areas: Automated and Connected Mobility, Cooperative Intelligent Transport Systems (C-ITS), Digital Highways and Next Generation ITS, Mobility as a Service (MaaS), Platooning and Electric Mobility, as well as considering cross-cutting Horizontal (Financial, Social and LMICs) Issues. Key references are set out in Annex A.

The Task Force published its Interim Report in July 2023, setting out some findings and conclusions based on a literature review and questionnaire survey. This Final Report, dated March 2024, updates this analysis with discussions during the Task Force's Technical Session at the World Road Congress in Prague in October 2023.

The order of reporting is:

- ✓ The first activity, **an external questionnaire survey** was completed between October 2022 and January 2023 by PIARC members and relevant mobility actors. The questionnaire sought views on the importance and impacts of defined mobility concepts. The survey is summarised in **Chapter 3** with further details in Annex B.
- ✓ The second activity was focused on a literature review arising from **an internal literature survey by Task Force members**. This collected bibliographical references, case studies and use cases related to new mobility concepts, classified under the six technical areas and the horizontal issues. The results of this activity are reported in **Chapters 4 and 5** of this Report. The use cases, and case studies come from the European Union, Spain, United States, Hungary, France, United Kingdom, Sweden, South Africa, Canada, Japan, China, Austria, and Australia. The focus on LMICs considers a number of other countries at different stages of development.
- ✓ **Chapter 6** of this Report sets out the **conclusions** obtained from the two activities as updated with the Technical Session at the World Road Congress (reported in Annex C). A wide range of emerging conclusions and recommendations are presented. In the long-term, new mobility initiatives will have a significant impact on the planning, design, construction, and operation of road infrastructure. By considering these implications and adapting to the changing transportation landscape, Road Network Operators can make more limited changes to support early deployment and contribute to the development of more efficient, sustainable, and resilient transportation systems.

Finally, it is clear from the various reports that innovative mobility solutions will have a number of implications for the future design and operation of the physical road infrastructure, although at present there is a great deal of uncertainty about the changes that may be required to infrastructure assets, especially in the longer-term.

New mobility will also have a range of wider financial, commercial, business model, social and development impacts which must be considered so that innovation can be encouraged whilst promoting public value, inclusivity and sustainable outcomes. These impacts will also depend on the income level of developing countries.

This Final Report concludes the work of Task Force 2.1. Consideration of key issues are now being taken forward between 2024 and 2027 by a new Technical Committee 2.5 – Road infrastructure for Connected and Automated Mobility – with a number of further reports to be published by PIARC in due course.

CONTENTS

1. INTRODUCTION

The World Road Association, PIARC, aims to foster and facilitate global discussion and knowledge sharing of road and transport policies and practices. Within this remit, the objective of Task Force 2.1 is to investigate what impact new forms of connected, autonomous, shared, electric mobility are expected to have on the design, operation, and maintenance of physical and digital road infrastructure over the next 30 years from a Road Network Operators (RNO) perspective.

The combination of new technologies and service models is dramatically altering the landscape of how people view mobility, how they travel, and their attitudes, behaviour and expectations with regards to travel. The convergence of new technologies with the shared economy to connect people, places and things, driven mainly by the private sector, and to create ecosystems of increasing complexity, responsiveness and personalisation, is resulting in transport agencies and enterprises re-evaluating their policy and regulatory frameworks, business-models, infrastructure plans and operational approaches, as well as their future organisational structures, skills and capacities.

This is an area which is moving rapidly in terms of technological and service-concept development, testing and adoption, with significant and complex implications for road infrastructure planning, design, management and operations. It is important that such dynamic changes are properly anticipated, understood, managed and implemented in a structured manner to provide certainty and confidence, of process and outcome, within government, the private sector, customers and society more widely. This needs to focus on the emergence of a new mobility ecosystem around a number of major trends, including connectivity, cooperative systems, autonomous driving, shared use models, micromobility, and zero or low emission vehicles. These concepts will need new use cases, deployment approaches and operating models from road authorities and agencies.

PIARC has been interested in studying the impact of these new technologies on roads for some time. Work started in 2018 through Task Force B.1 on Connected Vehicles, followed in 2020 by Task Force B.2 related to Autonomous Vehicles. PIARC also supported a Special Project in 2021 that considered Smart Road Classification, whilst Technical Committee 1.1 (Performance of Transport Administrations) focused between 2020 and 2023 on The Role of Transport Agencies in Shaping Disruptive Technologies and Service Models. Task Force 2.1 (New Mobility and Its Impact on Road Infrastructure and Transport) was convened in 2022 to consider the key issues further, broadening the range of technologies under examination and with a specific focus on future infrastructure planning and design and implications for road network operators.

These Task Forces and Technical Committees have overlapped over three PIARC Strategic Planning cycles. A new Technical Committee (T.C. 2.5 – Cooperative, Connected and Autonomous Mobility) has been launched in the new PIARC Strategic Planning Cycle 2024 – 2027 to continue the work in this area. The creation of this Committee is the result of the need to consider how these new technologies may have an impact on road network operations, specifically equipment, digital maps, architecture, and connectivity.

The activation of the new Technical Committee 2.5 has impacted the remit and work programme for TF 2.1 and led to a need to produce this Final Report to conclude its activities since July 2022.

These activities are as follows:

- **Review of the Final Reports of Task Forces B.1 and TF B.2** related to Connected and Automated Vehicles and their impact on Road Network Operations;
- An **external survey of PIARC members and sector stakeholders** regarding the likely impacts and responses to new mobility technologies in different regions, and expectations for the future;
- **Case studies, use cases and bibliographical reviews** provided by membersof the Task Force, including experiences from the European Union, Spain, United States, Hungary, France, United Kingdom, Sweden, South Africa, Canada, Japan, China, Austria, and Australia;
- Support from a **literature review and additional sources** provided by TC 1.1 (Performance of Transport Administrations);
- A dedicated Technical Session undertaken by TF 2.1 at the **World Road Congress (WRC)** in Prague in October 2023, with presentation of key conclusions and discussion around concrete recommendations; and
- Consolidation of the above activities to draw final conclusions and recommendations, encapsulated within this Report, which can be considered by TC 2.5 and other stakeholders within PIARC.

All these inputs have been synthesised in this Report, structured in six main chapters, starting with this **Chapter 1 Introduction** to provide the context for the work being documented. The remaining components of the Report are as follows:

- **Chapter 2** explains the methodology used by the Task Force for extracting the information of interest from the various inputs, aligning with the Task Force Terms of Reference;
- **Chapter 3** highlights the main outcomes from the external questionnaire survey undertaken in late 2022, covering the main concerns and opportunities associated with new mobility;
- **Chapter 4** focuses on mobility innovations impacting Road Network Operators, focused on six main topics: Autonomous and Connected Vehicles, Cooperative ITS, Digital Highways, Platooning, MaaS (Mobility as a Service) and Electric Vehicles;
- **Chapter 5** covers Horizontal Issues related to mobility technologies overall, including financial issues, social impacts and implications for Low- and Middle-Income Countries (LMICs). This Chapter also draws on evidence from a literature review previously prepared by TC 1.1; and
- **Chapter 6** sets out our key conclusions, including those of specific relevance and interest to the incoming TC 2.5, as well as final recommendations developed following the discussions at the Prague WRC.

Task Force 2.1 is grateful to the efforts of its members, contributions from other Task Forces and Technical Committees, as well as colleagues across PIARC for the evidence and analysis presented and commends its work for future use in the 2024 – 2027 Strategic Planning Cycle.

2. METHODOLOGY

2.1. INTRODUCTION

An extensive literature search was undertaken to understand the impact that new vehicle capabilities and new forms of mobility are likely to have on roads and transport. A particular focus was placed on the planning, design, operation and management of infrastructure. This search was structured through an internal survey whereby a range of documents were collected by TF 2.1 members relating to projects, research, trials, and policy development. The references to the key documents collected are set out in Annex A.

A wide range of topics were examined and categorised under six themes:

- Connected and Automated Mobility (CAM);
- Cooperative ITS (C-ITS);
- Digital Highways and Next Generation ITS;
- Mobility as a Service (MaaS);
- Platooning; and
- Electric Mobility.

In addition, several documents collected during the work conducted by PIARC TC 1.1 (Performance of Transport Administrations) for its report on The Role of Transport Agencies in Shaping Disruptive Technologies and Service Models were incorporated into this literature review as a complement to the Task Force 2.1 internal survey.

In order to achieve a well-informed and useful outcome, TF 2.1 also conducted an external survey to gather knowledge from various countries and regions worldwide. The survey was designed to be completed by individuals within road and transport organisations possessing the greatest knowledge regarding the subject matter. The survey consisted of four sections: Organizational Information, Impact of New Mobility Technologies and Services, Social Implications, and Request for Further Information. The content and results of this survey are presented in Chapter 3 and Annex B of this Report.

Finally, following publication of an Interim Report in July 2023, setting out emerging findings from the literature review and survey, the Task Force presented its work at a Technical Session at the World Road Congress in Prague in October 2023. This allowed the further discussion of key issues and formulation of specific recommendations, including the for the incoming Technical Committee 2.5 (Road Infrastructure for Connected and Automated Mobility) in the new 2024 – 2027 Cycle.

2.2. OVERALL METHODOLOGY

The literature review was carried out using the overall approach shown in Figure 2.1 below, divided into several phases, each of which is briefly described.

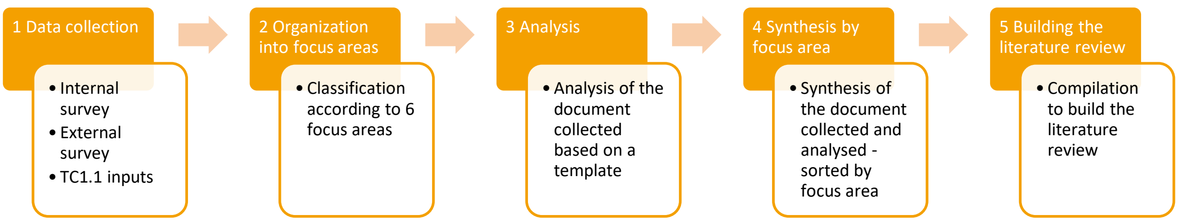

Figure 2.1: Methodology for Literature Review

Phase 1 – Data Collection

Data was collected from the internal survey, an external questionnaire survey and evidence provided by TC 1.1. The documents during this stage of work are described in the next two paragraphs.

Phase 2 – Organization into Focus Areas

The evidence was sorted and classified into the six mobility themes listed above, as well as considering horizontal (cross-cutting) areas.

Phase 3 – Analysis of Sources

The TF 2.1 member who proposed a case study/document within the literature analysed that source using a consistent template structured for completion under the following focus areas:

1. New mobility technology or theme;
2. Demand management;
3. Challenges and opportunities for road operators;
4. Implications of the mobility concept for the future planning, design, construction and operation of road and right of way infrastructure;
5. Digital needs of Road Network Operators;
6. Financial Issues and Business Models;
7. Social Impacts; and
8. LMICs.

Phase 4 – Synthesis by Focus Area

Several TF 2.1 members worked together to synthesise the individual document review templates and produce high level summaries of key findings under each focus area.

Phase 5 – Building the Literature Review

This Phase combined the synthesised evidence from the source documents into a single working text suitable for preparation of this Report.

2.3. BUILDING THE LITERATURE REVIEW INTO THIS REPORT

2.3.1. Overview

A structure of the Literature Review as a stand-alone document was developed and agreed by the Task Force. The analysis of the documents collected during the various surveys (internal and external), as well as the evidence provided by TC1.1, were directed to Chapters 3 to 5, with other sections covering Introduction (Chapter 1), Methodology (Chapter 2) and Conclusions (Chapter 6).

2.3.2. Link between Document Analysis and Reporting

Each of the six technical focus areas plus the three Horizontal Issues are synthesized in Chapters 4 and 5 respectively, based on an analysis of documents collected during the internal survey and those supplied by TC1.1 , as shown in Figures 2.2 and 2.3.

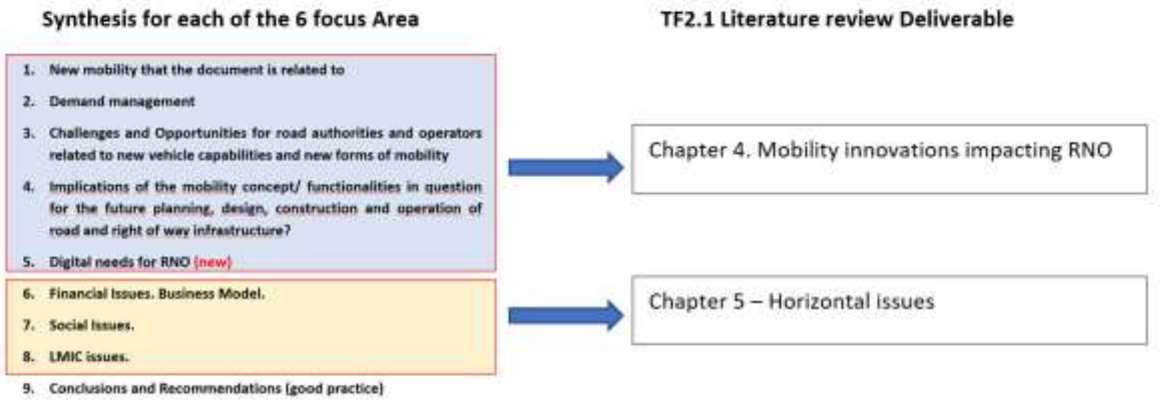

Figure 2.2: Linkages between Document Analysis and this Report

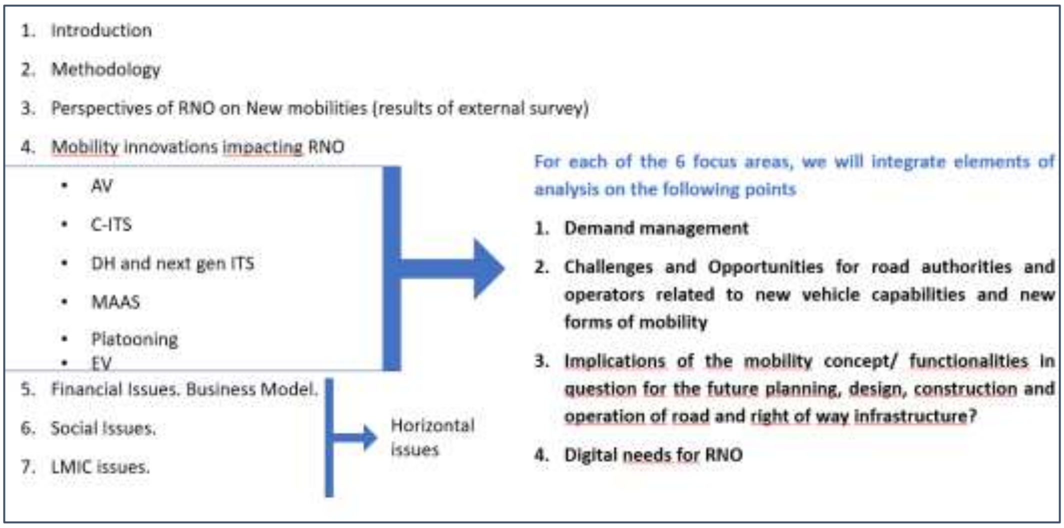

Figure 2.3: Focus Areas Reviewed for New Mobility Concepts

2.4. Interim and Final Reporting

Compiling the Interim Report in July 2023 was done as an initial draft, followed by a review by key individuals of the Task Force for technical quality, editorial presentation and readability. All Task Force members were given the opportunity to comment on the emerging findings and the process of finalising the Report also allowed additional concepts and evident conclusions to be included.

The Task Force subsequently presented some key concepts and findings from the Interim Report at the World Road Congress in Prague in October 2023. This allowed additional ideas and thinking to be added, which informed the production of this Final Technical Report, including specific recommendations.

The Task Force recommends that the findings of this Final Technical Report be taken forward by Technical Committee 2.5 (Road Infrastructure for Connected and Autonomous Mobility) as a key component of its evidence base for 2024 – 2027.

3. EXTERNAL QUESTIONNAIRE SURVEY

3.1. APPROACH

With the main objective of assessing some key aspects related to new mobility concepts under the remit of TF 2.1, an online questionnaire survey was designed and published to evaluate different aspects considered to be of great interest. Responses were received from a significant number of countries, representing different income levels and regions. Responses were collected during the second half of 2022 and analysed in February 2023.

The focus of this survey was on identifying challenges and opportunities, social implications, and good practices transport organisations can adopt in responding to new mobility concepts in respect of planning, design, investment, management, regulation, operation, and maintenance.

In addition, a short glossary of new mobility technologies and services covered by the survey, together with some use case examples, was included for additional help and information.

Category	*Definition and Examples*	*Use Case Examples*
Automated/ Autonomous Vehicles	Automated vehicles are equipped with driving automation systems that perform part or all of the dynamic driving task (DDT) on a sustained basis. Six levels of automation are defined by SAE: Level 0: No Driving Automation Level 1: Driver Assistance Level 2: Partial Driving Automation Level 3: Conditional Driving Automation Level 4: High Driving Automation Level 5: Full Driving Automation Autonomous vehicle are Road vehicles able to sense their environment, control motion and trajectory without the need for intervention of a human driver. Otherwise known as self-driving transport or driverless vehicles.	Automated/autonomous micro-transit for short-distance trips and first-last mile connections Smart delivery vehicles for neighbourhood food and groceries
Connected Vehicles	Road vehicles equipped with advanced communication technologies that allow the exchange of data and information between various elements of the transport system.	Connected vehicles for vehicle to pedestrian safety detection and warning Connected trucks for platooning on strategic roads (note, this example also includes driving automation systems)
Digital Highways & Next Generation ITS	A collective term for technologies and data, otherwise known as smart or digital highways, which allow dynamic monitoring, management and control of road and other transport networks, including sharing and coordination of information between network users and managers.	Roadwork warning systems with associated variable message signs and/or increasingly digital communication technology solutions
E-Deliveries	The concept, sometimes called smart logistics, includes automation of freight transport, online ordering of goods and services for delivery.	Automated last mile neighborhood delivery vehicles
Electric and Alternative Fuel Vehicles	Road vehicles powered by electric motors, electric batteries or alternative fuels such as compressed natural gas or hydrogen, rather than a petrol or diesel internal combustion engine.	Electric vehicle charging infrastructure for cars and light vehicles making long trips on strategic roads Battery electric or fuel-cell electric commercial vehicles (trucks and coaches) and associated infrastructure for long-distance and heavy-duty trips
Shared Mobility	A service model which allows users to request, book and pay for personal travel (or delivery of goods) by car, taxi, public transport and other modes on a personal and on-demand basis. It is often branded as Mobility as a Service, and also extends to travel options such as car sharing, bike sharing and ride hailing.	Multi-modal mobility as a service platform and associated business models Shared micromobility (e-scooters and e-bikes) for public hire

Figure 3.1: Focus on Chapter 4 – Mobility Innovations Impacting Road Network Organisations

The design of the survey was a coordinated work within the Task Force and was agreed upon by all members. In order to disseminate the survey more widely, it was developed in three languages (English, French and Spanish) and was programmed for dissemination via two different areas:

- By TF 2.1 members within their main institutional and corporate areas; and
- Through the PIARC General Secretariat, by means of the usual dissemination mechanisms involving First Delegates, country representatives and members of other Technical Committees and Task Forces.

The survey developed consisted of 11 questions divided into 4 sections:

- Section 1 – Organisational Information;
- Section 2 – Impact of New Mobility Technologies and Services;
- Section 3 – Social Implications; and
- Section 4 – Request for Case Studies and Further Information.

Section 1 – Organisational Information

This section consisted of 6 questions focusing on:

- The type of organization participating, employees and geographic coverage;
- Gross National Income (GNI); and
- The kilometers of road that the organization operates or for which it is responsible.

Section 2 – Impact of New Mobility Technologies and Services

This section consisted of several questions focused on:

- Predominant impact of new technologies on roads over the next 30 years;
- Predominant impact of new and emerging Automated/Autonomous, Connected, Electric and Shared technologies (ACES) and services on key outcomes over the next 30 years;
- Analysis of the expected impact of Automated/Autonomous vehicles, Connected Vehicles & Services, Electric Vehicles, Shared Vehicles & Services on the road transportation system, evaluating key aspects such as network design, physical and digital infrastructure, road operations, maintenance, investment, revenue and regulation; and
- The contribution to the change in the transportation system of Automated/Autonomous Vehicles, Connected Vehicles & Services, Electric Vehicles, Shared Vehicles & Services.

Section 3 – Social Implications

This section focused on the social impact of new mobility technologies and services based on key aspects such as social equity, gender equity, environmental sustainability, public health, user experience, quality of life and economic competitiveness. :

Section 4 – Request for Case Studies and Further Information

This section sought agreement or proposals to provide further information or suggest specific case studies at the organisational level.

Some 33 responses were received. The survey has made it possible to access a wide range of expertise and knowledge from across different countries and regions of the world to ensure TF 2.1's work is well informed, up to date, and useful to the widest possible audience.

The remainder of this chapter summarizes the results obtained from the survey with the 11 questions split into four sections as follows:

- Organisational Information;
- Impact of New Mobility Technologies and Services;
- Social Implications;
- Request for Case Studies and Further Information.

The full graphical and tabular results of the survey are shown in Annex B. The most relevant aspects of each section are discussed below.

3.2. ORGANISATIONAL INFORMATION

Of the responding organisations, 67% were public sector, made up of Government Ministries (37%) and Public Sector Agencies (30%). Private sector and academia also responded.

In terms of type of organization: 64% had national coverage, 15% international, 12% local or city coverage and 9% regional. 37% of respondents indicated that their organization operates or is responsible for more than 15,000 km of road length, followed by 24% of respondents whose organizations have responsibility for between 1,000 and 5,000 km. 37% have between 500 and 3000 employees.

Regarding the Gross National Income (GNI) of each country, 49% of the answers came from High income countries.

In summary, a large proportion of responses came from public sector organizations in high-income countries, with national coverage, with responsibility for more than 15,000 km of roads and with a staff between 500 and 3,000 employees.

3.3. IMPACTS OF NEW MOBILITY TECHNOLOGIES AND SERVICES

The predominant impact for most new mobility technologies was seen as positive. In the case of Digital Highways and Next Generation ITS, 33% of the answers considered a Very Positive predominant impact. However, for micromobility, the predominant impact will be neutral (36%). For Platooning an overall negative impact is expected (27%).

Regarding the third question, about the predominant impact these new and emerging technologies and services are expected to have on the following road transport outcomes over the next 30 years, the majority of responses indicated that positive impacts are expected in terms of efficiency and congestion (58%), accessibility, climate change, resilience, safety, economic development and energy efficiency. It is worth noting that a very positive impact is expected on road safety, according to 48% of respondents.

All respondents answered that no predominant very negative impact is expected for any of the cases.

Regarding the scale of the expected impact on road management activity in the next 30 years, most responses indicated a medium impact for platooning (27%), micromobility (27%) and MaaS (27%). Whilst a high impact is expected for AVs (36%), E-deliveries (42%), Connected vehicles (30%), EVs (33%), alternative fuel vehicles (21%) and digital highways (33%).

The expected impacts of Autonomous Vehicles are opportunities for road design and construction, for digital infrastructure, for the communications network and traffic operations as well as for transportation investment.

Aspects such as cybersecurity and regulation, are considered more of a challenge, particularly for existing road infrastructure and for data exchange. On the other hand, the impact is considered neutral for aspects such as road maintenance and transport revenue.

No serious challenges are expected for Connected Vehicles. Similarly with AV, it is considered that moderate challenges may exist for road design, data management and cybersecurity. For aspects such as existing infrastructure, road maintenance and transport revenue the impact is considered neutral.

Regarding Electric Vehicles, the majority of responses consider that their impact will be neutral, except for new infrastructure and transport revenue, where for both cases, the impact was classified in 30% of the responses as an opportunity.

Shared Vehicles & Services are expected to have a neutral impact on most aspects, while data management and sharing is considered as a challenge in 36% of the answers collected.

The scale of system change in relation to AV is expected to be major in all aspects considered in the survey, except for current infrastructure, traffic operations, maintenance and transport revenue for which a scale of significant is considered.

In the case of Connected Vehicles the scale of system change is mixed, being considered in most cases as significant and in some aspects (traffic operations, transport investment and regulation) as moderate.

For Electric Vehicles, a significant scale of impact is considered in the aspects of network design, new roads, digital infrastructure and transport investment. However, a minor scale of change is expected for existing road infrastructure. The other aspects are considered by most of the respondents to be on a moderate scale.

On the last question related to the scale of system change for Shared Vehicles & Services, the responses are more dispersed, between negligible and significant scale of change. For example, for the case of change in existing road infrastructure and data management the number of responses between those who consider a minor scale and a significant scale are equal (27%). Something similar occurs with traffic operations, for which significant and negligible are also equal (24% for both).

In conclusion the following findings emerged:

- **Automated Vehicles:** An opportunity for road design and construction, for digital infrastructure, for the communications network and traffic operations as well as for transportation investments. Aspects of cybersecurity and regulation are considered a serious challenge.

  The scale of system change is expected to be major in all aspects considered in the survey, except for current infrastructure, traffic operations, maintenance and transport revenue for which a scale of significant is considered.

- **Connected Vehicles:** A challenge for road design, data management and cybersecurity. For aspects such as existing infrastructure, road maintenance and transport revenue the impact is considered neutral.

  The scale of system change is considered in most cases as significant and in some aspects (traffic operations, transport investment and regulation) as moderate.

- **Electric Vehicles:** Impacts will be neutral, except for new infrastructure and transport revenue, for both cases, the impact was classified in 30% of the responses as an opportunity.

  A significant scale of impact is considered in the aspects of network design, new roads, digital infrastructure and transport investment. However, a minor scale of change is expected in existing road infrastructure.

- **Shared Vehicles and Services:** A neutral impact on most aspects analysed, while the data management and sharing is considered as a challenge in a 36% of the answers.

  The answers related to the scale of system change are more dispersed, between negligible and significant scale of change.

3.4. Social Implications

A positive impact is expected for social equity, accessibility, public health, citizen acceptance and experience, wellbeing and quality of life and economic competitiveness and prosperity. For climate change 39% of respondents mark very positive and positive impact. For gender equality, most respondents (52%) mark a neutral impact.

3.5. Request for Case Studies and Further Information

Some 52% of the respondents are willing to provide a case study on the topic and provide more details about contact persons.

As noted, the full graphical and tabular survey analysis and data is set out in Annex B.

4. NEW MOBILITY AND ROAD NETWORK OPERATIONS

4.1. INTRODUCTION

As noted in Chapter 2, the documents collated during the internal survey have been reviewed to understand their relevance to Road Network Operators (RNO) within each of the six focus areas:

- Connected and Automated/Autonomous Mobility (CAM);
- Cooperative Intelligent Transport Systems (C-ITS);
- Digital Highways and Next Generation ITS;
- Mobility as a Service (MaaS);
- Platooning; and
- Electric Vehicles.

For each of the focus areas, the documents have been analysed to understand their potential impact in four areas of interest to RNOs:

1. Demand Management;
2. Challenges and Opportunities for RNO;
3. Implications for the Planning, Design, Construction and Operation of Road Infrastructure; and
4. Digital Needs for Road Network Operators.

The cross-cutting (horizontal) issues of Financial and business models, social impacts and Low- and Middle-Income Countries are presented in Chapter 5.

4.2. CONNECTED AND AUTOMATED MOBILITY (CAM)

4.2.1. Introduction

Connected and Automated Mobility is often referred to as CAM; with the vehicles involved referred to as CAV. In practice a connected vehicle may not have any significant degree of automation, although both connectivity and automation are often considered together. The compilation of documents from the internal survey provides a comprehensive overview of the development and implementation of connected and automated mobility systems, with a particular focus on 5G technology and automated driving.

The 5G-MOBIX project serves as a platform for showcasing the advantages of 5G technology in connected and automated mobility applications across different countries and settings. Use cases in highways, public roads, and urban environments demonstrate the potential of these technologies.

The report on connected and automated vehicles evaluates the technological capabilities of manufacturers in achieving higher levels of autonomy, considering factors like cybersecurity, connectivity, and road conditions. Examples from China highlight the successful deployment of various mobility technologies such as automated taxis, 5G-assisted driving, and truck platooning. Japan's reports cover legal amendments and findings from field tests conducted in rural areas, while Spain emphasizes the progressive development of regulatory frameworks and the facilitation of automated driving tests.

European projects address the requirements for network operators and the infrastructure support necessary for automated vehicles. The Rhode Island pilot study in the USA presents a case study of an automated shuttle service, showcasing real-world application and operational cooperation. The strategies and regulations outlined in the reports provided from France prioritize safety, modernization, and stakeholder coordination in the deployment of automated and connected road mobility.

The documents collected and reviewed in the internal survey underscore the significance of collaboration, technology development, and robust regulatory frameworks in realizing the full potential of connected and automated mobility systems.

4.2.2. Demand Management

The documents from the internal survey offer valuable insights into travel demand management from a RNO perspective concerning automated and connected vehicles.

Some participants in the 5G Mobix project in Spain responded positively to connected and automated vehicle services, finding them useful, reliable, and trustworthy, especially due to the added value provided by 5G-enabled features. A report from a national vehicle manufacturer in Spain focused on the progress and implementation of automated and connected vehicles - although it didn't specifically mention travel demand, it expressed expectations of advancements in these technologies. The case study from the People's Republic of China discussed a new mobility concept centered around demand management, highlighting the importance of optimizing transportation resources and reducing congestion. It emphasized the need to manage demand for transportation services and to design infrastructure accordingly. Various automated driving solutions were examined from a travel demand perspective. Examples such as some Robotaxis, some Buses, and experience from various private companies were discussed in terms of their potential to reduce private car ownership, increase ridership, optimize freight transportation, ensure service continuity during extreme weather, and optimize delivery operations.

Smart mobility decisions were highlighted across these automated driving solutions, encompassing route optimization, passenger matching, real-time traffic information sharing, synchronized movement of multiple trucks, and efficient management of delivery demand. The reasons for mobility included: commuting, freight transportation, resilience during extreme weather events, and delivery services. Triggers of mobility included factors such as work or school commutes, transportation of goods, adverse weather conditions, and the demand for delivery services.

While one of the Robotaxi specifically promoted carpooling by matching passengers with similar routes, other solutions such as some Buses companies and other private companies' solutions contributed to a more efficient and sustainable transportation system by optimizing vehicle usage and reducing the need for private car ownership. The Japanese report on automated driving in regional communities highlighted the adoption of shuttles to ensure mobility opportunities for the elderly and in rural areas, catering to small demands and aiming to improve business continuity. The French national strategy and regulation emphasized supporting the deployment of automated and connected road mobility, promoting safety, prioritizing and coordinating connectivity systems, financing investment projects, and supporting local authorities and operators in service deployment. These actions aimed to increase the demand for automated road mobility services. The final report from PIARC TF B2 discussed the impacts of automation on road network operations and traffic capacity. It mentioned potential changes in road usage and increased road capacity due to smaller gaps between connected and automated vehicles. The impact on road capacity, however, depends on the level of penetration of automated vehicles in the fleet.

In conclusion, travel demand management plays a crucial role in the development and implementation of automated driving technologies. Considering travel demand implications, making smart mobility decisions, and promoting carpooling and equivalent high-occupancy strategies are essential strategies for road operators to efficiently meet the transportation needs of passengers and businesses.

4.2.3. Challenges and Opportunities for Road Network Operators

The key challenges and opportunities identified across various inputs are:

4.2.3.1. Challenges

Technical Challenges:

- Physical implementation issues, coverage optimization, and configuration challenges are significant technical hurdles that road operators need to address.
- Cross-network interconnectivity issues and seamless roaming activities pose challenges in ensuring a smooth transition between different networks.
- Device and infrastructure availability are crucial considerations for road operators to ensure the successful deployment of automated vehicles.

Legal and Regulatory Challenges:

- Temporal permission for experimental networks and availability of spectrum licenses are legal challenges faced by road operators.
- Tight regulations and complicated procedures with public institutions require detailed prototype equipment and adherence to specific bands.
- EU regulatory landscape for automated vehicles highlights the need for standardization and policy improvements to enable better cooperation across 5G for connected and automated mobility (CAM) value chain.

Environmental Challenges:

- The need to address environmental concerns, such as reducing carbon emissions and eliminating diesel emissions from conventional buses.
- Challenges related to the impossibility of acting in environmentally protected areas, restricting the installation of additional infrastructure.

Social Challenges:

- Building user confidence in new technologies is a social challenge that road operators must tackle.
- Ensuring the adaptation of vehicles to universal accessibility criteria is essential for accommodating diverse user needs.

Safety and Security Challenges:

- Ensuring road safety and compatibility of automated vehicles with existing traffic rules and infrastructure.
- Addressing cybersecurity concerns and protecting the significant volume of data collected by connected and automated vehicles from cyber-attacks.

4.2.3.2. Opportunities

Improved Road Safety and Efficiency:

- Automated vehicles and 5G mobility offer the opportunity to enhance road safety, traffic management efficiency, and driving comfort.
- Compliance with speed limits, headways between vehicles, and relatively quick reaction times of automated vehicles can contribute to improved traffic safety.

Traffic Management and Infrastructure:

- Road operators can capitalize on the introduction of new vehicle capabilities and mobility concepts to improve traffic flow and design infrastructure that supports new forms of mobility.
- Enhancing transportation efficiency, reducing congestion, and optimizing road capacity are potential benefits of automated vehicles.

Environmental and Sustainability Benefits:

- Automation and 5G mobility can help reduce carbon emissions and create more sustainable transportation systems.
- Promoting shared mobility options and optimizing vehicle routes can contribute to reducing traffic congestion and emissions.

Technological Advancements:

- Development in cloud computing, the Internet of Things (IoT), and artificial intelligence (AI) are important for supporting the advancement of connected and automated vehicles.
- Technological innovations can lead to the improvement of transportation services, reliability, and advanced infrastructure development.

4.2.3.3. Additional Considerations from TC1.1 Review

The following additional considerations emerged from literature reviewed by TC 1.1:

Physical Infrastructure:

- *Traffic signs and road markings:* Uniformity and visibility improvements are needed to accommodate CAVs, with lane and other surface markings being a particular priority.
- *Incident and roadworks communications:* CAV-readable emergency signs and real-time roadside communications are required.
- *Pavement structure and surface:* Considerations for higher stiffness materials, increased maintenance, and relaxation of coefficient of friction requirements.
- *Parking:* Redesigning parking lots with digital infrastructure, Bluetooth, and near-field communications to support automated parking, as well as a longer-term reduction in size and capacity requirements.
- *Service stations:* Future service stations may require more chargers to accommodate CAVs if these are also electric.
- *Safe harbor areas:* Design and frequency considerations for safe places for CAVs to stop or restart in emergencies.
- *Bridges:* Updating design standards to cater to the needs of platooning heavy trucks.

- *Geotechnical aspects:* Narrower lanes, extra lanes, reduced road gradients, embankments, and tunnels to support platooning.
- *Drainage:* Improving drainage infrastructure to avoid severe surface water accumulation that can affect CAV systems (for example by obscuring lane markings or creating reflected headlight glare).
- *Digital:* Providing physical locations and designs (e.g. voids and ducts) for the installation of digital equipment, power and communications by or under the road.

Digital Infrastructure:

- *Digital communications:* Roadside digital infrastructure with sensors and internet connectivity to meet CAV connectivity requirements.
- *Smart signage:* Implementation of smart signage with digital *information for CAVs to improve navigation and understanding of road conditions.*
- *Road mapping:* Accurate road mapping required for safe CAV operation.
- *Traffic management:* Improved traffic incident information sharing and additional safety measures for changing road layouts.

Design Standards and Policies:

- *Geometric design:* Potential reduction in required lane widths, additional lanes, and considerations for rutting and road surface degradation.
- *Bridge design:* Reassessment and updates to accommodate changing loading patterns and increased loads from automated freight vehicles.
- *Cyclists and pedestrians:* Potential new installation widening of cycle paths and footpaths, installation of physical barriers on high-speed roads, or digital equipment for V2C or V2P communications.

Parking and Service Stations:

- Redesign of parking facilities for increased efficiency, closer parking, and inclusion of charging and maintenance stations for electric vehicles.
- Integration of parking locations with commercial practices and utilization for shared automated vehicles operated on a fleet basis.

Operation and Maintenance:

- *Intersections:* Consideration of exclusive lanes for CAVs to ensure safety and efficiency and as a means of accelerating deployment and shorterning the transition.
- *City maintenance:* Standards for road markings, pavement, and bridges to detect and address deterioration and ensure clear signage.
- *Curbside space:* Redesign for pickup, drop-off, transit stops, and regulation during different hours of the day, including dynamic, real-time curb management systems and procedures.
- *Public transport integration:* Accessibility of trains, stations, bus stops, and mobility transfer hubs for automated vehicle commuters.
- *Intersection control:* Research on design and control of CAV-oriented intersections, including short-term interaction between CAVs and vehicles driven by humans.

In conclusion, RNO face significant challenges from the introduction of automated vehicles and connected mobility, including technical, legal, environmental, and social aspects. They also have opportunities to improve road safety, traffic management, sustainability, and technological advancements by addressing these challenges and leveraging the benefits of automation and connectivity.

4.2.4. Implications for the Planning, Design, Construction and Operation of Road Infrastructure

The introduction of connected and automated mobility into a road network creates a range of implications for RNOs, for the planning, design, construction and operation (including maintenance) of the road infrastructure. The key findings from the documents reviewed are summarised under the headings of:

- Adoption of new mobility concepts;
- Connectivity and C-ITS centres;
- Road network quality;
- Adaptation to automated vehicles;
- Resilience to extreme weather;
- Cooperation and integration; and
- Traffic management and safety.

Adoption of new mobility concepts: The adoption of automated driving modes and vehicle-infrastructure connectivity necessitates the planning, design, construction, and operation of road infrastructure that can support these new forms of transportation. This may include the incorporation of dedicated lanes, sensors, and communication devices to accommodate automated vehicles and ensuring compatibility with their requirements.

Connectivity and ITS centers: The successful adoption of connected and automated vehicles requires a reliable 5G network and full coverage in specific areas. The establishment of Intelligent Transportation Systems (ITS) Centers staffed with dedicated personnel is essential for effective communication with, and coordination of, vehicles.

Road network quality: A higher-quality road network plays a vital role in facilitating the safe and efficient operation of automated driving modes and vehicle-infrastructure connectivity. Upgrading the infrastructure, such as road geometry, signage, and traffic management systems, can enhance compatibility and support the seamless integration of new mobility technologies.

Adaptation to automated vehicle technologies: Road infrastructure and layouts may require some adaptation to accommodate automated vehicles, such as wider roads to accommodate platooning or the addition of dedicated lanes, sensors, and communication devices. Planning for parking facilities, pick-up/drop-off zones, and rest areas also needs to consider the growing demand for automated vehicles.

Resilience to extreme weather: Road infrastructure should be designed and maintained to withstand extreme weather conditions. This includes incorporating advanced materials, construction techniques, and weather-sensing technologies into the infrastructure to provide real-time weather information and ensure the safety and efficiency of automated vehicles.

Cooperation and integration: Collaboration between network operators, vehicle manufacturers, and other stakeholders is crucial for achieving consistency within and between networks. This collaboration helps to address local or national requirements, ensure the quality of road infrastructure, and establish optimal strategies for the deployment of automated driving systems.

Traffic management and safety: Traffic management systems must be updated to accommodate the increased use of connected and automated vehicles. This may involve changes to traffic signals, signage, and real-time data sharing capabilities. Road safety remains a priority, necessitating the integration of real-time connectivity between traffic management systems and vehicles.

In conclusion, the implications of mobility concepts and functionalities, driven by the rapid development of connected and automated vehicles, will have a significant impact on the future planning, design, construction, and operation of road and right-of-way infrastructure. By considering these implications and adapting to the changing transportation landscape, road authorities and operators can contribute to the development of more efficient, sustainable, and resilient transportation systems. The successful integration of new mobility technologies requires collaboration, connectivity, and a comprehensive approach to infrastructure planning and design, ensuring compatibility, safety, and progressivity in the deployment of connected and automated vehicles.

4.2.5. Digital Needs for Road Network Operators

The deployment of CAV requires a robust digital infrastructure to support their safe and efficient operation. RNOs have a crucial role to play in meeting the digital needs necessary for the integration of CAVs.

The literature review identified the following digital needs:

- **HD Maps:** RNOs need high-definition maps that provide detailed and accurate information about the road network to support automation at various levels. These maps enable some CAVs to navigate effectively and safely;
- Vehicle-to-Infrastructure Connectivity: CAVs require communication systems that enable seamless data exchange between vehicles and infrastructure. Vehicle-to-infrastructure connectivity allows for real-time sharing of traffic conditions, road hazards, and updates, enhancing the capabilities of CAVs;
- **Real-Time Data Provision:** CAVs need a digital infrastructure capable of providing real-time data on lane markings, landmarks, and other dynamic road conditions. Real-time data enables CAVs to adapt to changing road conditions and make informed decisions;
- Development and maintenance of back-office infrastructure for information sharing and updates;
- Collaboration and agreements with digital infrastructure stakeholders;
- Ensuring the reliability and availability of power supplies to support digital and communication infrastructures; and
- Installation of fixed monitoring stations for data collection and forecasting.
- Coordination and prioritization of connectivity systems and data exchange infrastructure.

The specific use cases related to automated driving industry applications within the Peoples Republic of China, 2022 highlighted additional needs for communication systems. For some Robotaxi, real-time data sharing and communication systems optimize routes and integrate AI-driven algorithms. Some bus companies utilise 5G infrastructure for real-time data sharing and route optimization. Private companies may focus on real-time data sharing between truck platoons and traffic management centres, enabling route optimization and traffic flow management. Solutions for automated trucks in extreme weather involve integrating advanced weather-sensing technologies for real-time weather information sharing and data sharing between automated trucks, traffic management centres, and meteorological agencies. Other companies emphasize real-time data sharing and coordination between automated delivery vehicles and traffic management centres.

In conclusion, to support the integration of connected and automated vehicles, RNOs must address their digital needs, including HD maps, vehicle-to-infrastructure connectivity, real-time data provision, and collaboration with stakeholders. Investing in digital infrastructure and adopting advanced technologies will enable RNOs to create efficient, safe, and resilient transportation systems for the future.

4.3. Cooperative Intelligent Transport Systems (C-ITS)

4.3.1. Introduction

All papers reviewed from the internal survey considered existing as well as potential future use-cases for Cooperative Intelligent Transport Systems (C-ITS). C-ITS encompasses a group of technologies and applications that allow the effective exchange of data through wireless communication technologies between components and actors in the transport system. C-ITS includes communications both between vehicles (V2V) and between vehicles and infrastructure (V2I). The exchange of data is bi-directional and enables RNOs to receive data directly from the vehicles, acting as floating sensors (probe vehicle data).

The ability to alert drivers to incidents such as road closures and congestion is a core operational tool for RNO. The full benefits from C-ITS cannot be realized just from communications between vehicles themselves and between infrastructure and vehicles, there is a need for complementary traffic management and control systems (operated by the RNO).

C-ITS services rely on the presence of supporting communications infrastructure - to enable connectivity with C-ITS ready vehicles and deliver relevant, consistent and reliable information to road users. As vehicle technologies continue to move towards higher levels of automation, and as the demand for vehicle use continues and increases, it is very likely that the need for monitoring and control of the network will continue and increase.

C-ITS is seen as having great potential in the areas of automated driving, traffic management and urban public transport management.

4.3.2. Demand Management

C-ITS services have the potential to manage travel demand by providing information about road network congestion – enabling travellers to make informed choices. The adoption or implementation of C-ITS does not, in itself, change the number of vehicles on the roads.

The full potential of C-ITS relies upon all actors being willing to share data.

4.3.3. Challenges and Opportunities for Road Network Operations

The key challenges and opportunities identified across various inputs are:

4.3.3.1. Challenges for RNOs

The challenges are in the deployment of Road Side Units (RSUs), user acceptance, the regulatory frame uncertainty, privacy and cybersecurity. A technological challenge comes when the volume of connected vehicles is relatively low – providing low volumes of data and with relatively few vehicles to receive the information. The greatest challenges as well as opportunities for RNOs lie in the receiving of data directly from the vehicles (V2I) and in parallel informing the vehicle on safety critical issues (I2V).

4.3.3.2. Opportunities

C-ITS has the potential to increase traffic efficiency, comfort, information, and road safety. As the number of connected vehicles equipped with C-ITS on-board equipment increases, the potential to acquire various types of road environment information also increases. This data (known as probe vehicle data (PVD)) transmitted to Traffic Management Centres (TMCs) will enable RNOs to improve their oversight of the network and respond faster to road events such as accidents, wrong-way-drivers, and queues, as well as unsatisfactory asset conditions (e.g. potholes or road surface friction/skid resistance). RNOs will have the ability to use C-ITS data to optimise the capacity of the network and provide more efficient and proactive road management. PVD will reduce the cost of traffic data collection and infrastructure, eventually removing the need for infrastructure altogether.

Ideally vehicles would exchange the following data with the RNO:

- Location, velocity, acceleration/deceleration of the vehicle to improve the traffic conditions;
- Identified hazardous locations (e. g. triggered by heavy deceleration, weather sensors, ESP, airbags);
- Deviations from expected infrastructure features (corrections of digital maps) – future potential; and
- Aims and intentions of the vehicles (tactical and strategic) - future potential.
- The following RNO data could be sent to the vehicle:
- Hazardous Location Notification (HLN) - Warning of e.g. accident zones, traffic congestion ahead, critical weather conditions, slippery roads, obstacles on the road, emergency vehicles, public transport vehicles or wrong way driving;
- Road Works Warning (RWW) - Information on e.g. lane closures, road closures; warning of mobile road works, winter maintenance or road operator vehicles;
- In-vehicle Signage (IVS) - e.g. dynamic speed limit information, lane management, shock wave damping;
- Signalised Intersection (SI) - e.g. signal phase information or prioritisation of special vehicles (partly also V2I);
- Reliable (and potentially legally binding) information for automated vehicles - future potential;
- Extended sensor information of the vehicle (transmission of a dynamic digital map) - future potential;

- Tactical and strategic recommendations or commands to individual vehicles. - future potential; and
- Commercial services, e.g. advertisements - future potential.

4.3.3.3. Potential Impact on Users

The potential impact on users was considered in European studies. The studies found that users react to C-ITS messages by changing their driving behavior. The main driver for C-ITS is to improve road safety. In-Vehicle Signage provides motorists with earlier and higher quality information, by providing continuous signage information directly in the vehicle. The impact on traffic efficiency through the change in driving behavior is seen as relevant. Simulation studies, which consider high penetration rates of C-ITS services by 2030 estimate savings of up to 3% of total time spent on roads for passenger cars and buses in urban areas. A positive environmental impact was recorded for use cases linked to intersections. C-ITS services are well accepted by users, but with limited willingness to pay for the services. Travel time savings, reduced congestion, and improved traffic flow and therefore smoother driving results in significant benefits in fuel consumption and associated CO_2-emissions. User convenience is improved when the information is provided in the user's native language.

4.3.4. Implications for Planning, Design, Construction and Operation of Road Infrastructure

Implementing a C-ITS service needs to be considered alongside other potential tools and mechanisms that can contribute to, or support the achievement of, transport policy objectives. Communications services are required for the implementation of C-ITS services. C-ITS is only one tool to support travellers, it needs to be embedded into the whole service chain and not seen as standalone solution.

The starting point when considering C-ITS is the consideration of a combination of direct short-range communication and long range communication based on cellular networks. This combination of both technologies is called a hybrid communication mix. Specific road-side-units (RSUs) connected to the traffic and road operators' data communications network need to be installed for short-range communications.

Data will be exchanged when connecting different actors; this data needs to be combined with data from roadside sensors to enable an improved level of traffic management.

When a high penetration rate of connected vehicles is reached, a more significant potential impact on the road design can be seen. Variable message signs or speed limit information along the roadside may become redundant and signal control could be optimised based on the "conversations" between vehicles.

4.3.5. Digital Needs for Road Network Operators

C-ITS places various demands on digital infrastructure and communication technologies provided, operated and maintained by RNOs.

Synergies with other projects and existing digital infrastructure can be identified and exploited when considering the deployment of C-ITS. C-ITS should not be designed or provided as stand-alone infrastructure. The proposed Use Cases may have an impact on the digital infrastructure required. C-ITS needs to be considered alongside security, and cyber security. The automation of processes and services within the Traffic Control Center should be considered, to enable efficiency within service provision.

Gaining an understanding of the current legal framework is required before designing any interactions between the various stakeholders and systems. The boundary conditions are set through the security framework, compliance assessment framework, spectrum allocation, governance framework, standards and privacy framework. Since many actors contribute to a C-ITS service, it should be defined clearly who will contribute to which part of the service chain. For a smooth information flow, interfaces to other C-ITS actors should be identified. Interfaces are technical and organisational, including agreements, duties, expectations (including Service Level Agreements) as well as specifications.

Road side units are required when short-range communications are employed to deliver the C-ITS services. The best locations for fixed or mobile roadside units should be evaluated to consider signal quality, reliability and the number of units required. Roadside units require an internet connection. Further considerations include the use of edge computing (with associated servers) and the use of a C-ITS hub on the MEC server to contain the necessary intelligence to detect abnormal situations occurring along the road stretch and then inform the vehicles travelling through it, thus providing safer cooperative driving.

At traffic signals, specific technical specifications for Signal Phase and Time and Map Data (SPaT/MAP) must be taken into consideration when developing future traffic controller designs. SPaT/MAP offers a potential channel for detailed information exchange between traffic systems and road users. Based on SPaT data the vehicles (or drivers) can be informed about the current status of the road network and changes of traffic signal aspects ahead as well as about the next signal stage change. It also provides information about approaching traffic to optimize the signal system. MAP data describes the physical geometry of one or more intersections.

4.4. Digital Highways and Next Generation ITS

4.4.1. Introduction

The documents reviewed from the internal survey highlighted a range of topics relevant to digital highways and next generation ITS:

- Digital tools to design, construct, maintain and operate digital roads;
- Connected vehicles, digital highways and next generation ITS;
- ETC2.0 probe data collected by C-ITS;
- The Internet of Things (IoT), the establishment of digital twins, augmented and virtual reality and Artificial Intelligence (AI) to build climate resilience into infrastructure systems;
- Resilience analytics. A data-driven process that leverages resilience based on descriptive, predictive, and prescriptive modelling. They provide the means to visualise the performance of critical infrastructure, determine the impact of interdependencies to mitigate uncertainty, and ultimately facilitate prioritisation in decision-making. Analytics, strengthened by emerging digital technologies and data, incentivise climate resilience and sustainability more efficiently than traditional approaches by leveraging Big Data, and aggregating it more quickly;

Unmanned aerial vehicles (UAVs), commonly known as drones, are likely to have a role in road safety, traffic and highway infrastructure management. Particularly, the collection of traffic and driving behaviour data and network information via cameras for use in signal optimisation, network management, traffic congestion responses and compliance activities;

- Deep learning technologies for vehicle detection, average speed determination, lane level traffic parameters such as headway, lane-specific speed, individual vehicle speed and trajectory;
- Traffic laws for machines in the future. How can we ensure that trustworthy data on traffic regulations is exchanged in order to promote technological innovation such as improved driver aid and automated driving technologies?

4.4.2. Demand Management

Demand management featured only within three of the documents reviewed. From the UK, National Highways' strategy for digital roads includes a workstream "Digital for customers" which is designed to manage demand using data and traffic information. It envisages a situation where real-time information is accessible to all customers to plan and manage their journeys – with the aim that journeys are planned to avoid times when the network is most congested. Similarly, papers from Japan describe the potential of using Look-ahead Information (LAI) to select routes that avoid congested sections.

4.4.3. Challenges and Opportunities for Road Network Operators

The key challenges and opportunities identified across various inputs are:

4.4.3.1. Challenges

The main challenges for RNOs are associated with the changes to transport layouts, physical design and land use that CAVs may require for their adoption.

- Immediate term issues are the consideration of road markings, traffic signs and signals and the ability of CAV to read and interpret them.
- In the medium term (2025 to 2035), ensuring the availability of suitable safe stopping zones on motorways may be required.
- In the longer-term (2035 and beyond), supporting remote parking facilities and mobility hubs may assist to support further adoption of self-driving vehicles.

A risk inherent in the greater use of emerging digital technologies is an increase in vulnerability to cyber-attacks that in some cases may escalate to cyberwarfare, leading to security and citizens' privacy risks and misinformation. These technologies also remain heavily reliant on power supplies and the interdependencies between their operators.

An acknowledged challenge of digital twins is the lack of full-scale benchmarks for the built environment.

4.4.3.2. Opportunities

The increase in the number of connected vehicles equipped with C-ITS on-board equipment will create opportunities for RNO to reduce investment in roadside sensors and equipment:

- CAVs can acquire various types of road environment information, including LAI, independent of roadside sensors, which may improve road safety and comfort for users; and
- The generation of LAI enables the identification of traffic conditions by lane, enabling more efficient road operations and traffic management.

Digital technologies are not naturally carbon neutral. Using digital twins to predict traffic patterns and re-route automated vehicles to avoid traffic jams can save energy use; data centers can become carbon–neutral by using renewable energy.

4.4.3.3. Opportunities and Challenges Associated with Urban Air Mobility

To realize the full benefits of UAVs, RNOs need to navigate barriers to wide scale deployment including airspace use regulations and public acceptance, which vary by jurisdiction. Authorities need to develop regulations that address safety, privacy, and noise concerns and at the same time increase the efficiency of the services provided by UAV technology. More capable drones weigh more and pose greater risk in the event of failure.

Working digitally in conjunction with traffic control has an inherent value for decision-making authorities, and the data generated may subsequently be utilised for a variety of purposes inside the municipality/authority.

4.4.4. Implications for Planning, Design, Construction and Operation of Road Infrastructure

Data and digital tools enable the whole lifecycle of a road network (from design to operation) to be conceived and managed more safely and efficiently than ever before.

Combining probe data from C-ITS services with data from roadside sensors will enable information to be generated and shared far more quickly.

Road authorities must embrace system complexity to minimize cascading failures resulting from unexpected disruptions, by decoupling unnecessary dependencies across infrastructure and making necessary connections controllable, visible and resilient. It is essential to design communication between interconnected parts of the infrastructure and add resources and redundancies in system-crucial components to safeguard functionality. Standards, design codes and guidelines are vital in this regard. These could include resilience analytics, informed by infrastructure monitoring, management, deployment of digital data, related cloud architecture, as well as regulating digital technologies, particularly in relation to cybersecurity.

Vehicles may be used more effectively, and more energy-efficient transportation options can be developed, by introducing dynamic performance-based restrictions with geofencing that are managed by digital systems and utilizing shared data. According to field studies, it can result in fuel savings of 10–25% and a 10–25% increase in energy efficiency, as well as a 30–40% reduction in the number of vehicles. A shift to performance-based restrictions suggests there is potential to lessen the negative effects of heavy trucks on noise, traffic, and accidents.

Cooperative perception requires new approaches in planning roadside sensor infrastructure, and communication channels. A new concept in traffic management is needed.

The importance of a digital representation of the road network is growing. Digital and machine-readable traffic regulations are one component of this. Data on traffic regulations is an essential component in a digital environment. Data on traffic rules opens up whole new possibilities, such as more dynamic traffic laws, which can contribute further to beneficial impacts for the transportation system and society. It is also required for the introduction of self-driving vehicles on public highways, as automated vehicles would require a dependable digital infrastructure.

4.4.5. Digital Needs for Road Network Operators

The main digital needs identified for RNOs are:

- Digital twins. Digital infrastructure to facilitate V2I and V2X communications;.
- Probe data from C-ITS services;
- National and European data-sharing networks;
- Tackling legal issues about IT, data interchange and the principle of openness;
- Highly accurate (HD) digital maps, new sensor technologies are necessary. Building up digital twins via sensor data fusion, and implementing cloud control requires special skills, and exceptional computing capacities;
- More accurate and comprehensive knowledge over the whole road network is required; and
- Digital traffic regulation solutions must be adopted by more decision-making bodies, and the procedures for creating traffic laws must also be standardized.

4.5. Mobility as a Service

4.5.1. Introduction

The convergence of various projects in the field of new mobility highlights several key themes that align with the principles of Mobility as a Service (MaaS):

- **Sustainable and environmentally-friendly solutions:** These projects prioritize sustainability by integrating eco-friendly options and digital infrastructure. The focus is on developing greener transportation systems that reduce environmental impact at an affordable cost to users.
- **Integration of multiple transportation modes:** Emphasizing the essence of MaaS, the projects aim to seamlessly integrate various modes of transportation. This includes combining automated vehicles, electric vehicles, buses, subways, carpooling services, and taxis to provide a comprehensive, affordable and interconnected MaaS experience.
- **Real-time information and data-sharing:** Recognizing the importance of real-time data, the projects emphasize sharing user-generated information, providing up-to-date traffic updates, and utilizing vehicle and infrastructure data. This enables efficient decision-making and enhances the overall reliability of MaaS solutions.
- **Collaboration and interoperability:** Collaboration among stakeholders is essential in MaaS initiatives. The projects focus on fostering partnerships between public and private entities to create a unified roadmap and establish common access points. This enables seamless ticketing, data sharing, and interoperability among different mobility services.
- **User-centric experience:** User satisfaction is at the forefront of MaaS projects. Personalized journey planning, convenient access to transportation options, and information on sustainable choices are key factors in enhancing the overall user experience within the MaaS ecosystem.

These common points highlight the shared objective of creating sustainable, integrated, and user-centric mobility systems in line with the principles of MaaS. By leveraging digital technologies, real-time data, collaboration, and a focus on sustainability, these projects aim to transform transportation into an efficient, interconnected, and user-friendly MaaS ecosystem.

4.5.2. Demand Management

Demand management plays a vital role in optimizing MaaS systems. It involves aligning the supply and demand of vehicles within the transportation network. By efficiently managing demand, MaaS aims to address fluctuations in transportation needs and ensure the availability of vehicles when they are most required.

One approach to demand management is enabling vehicle owners to share their vehicles during peak demand periods. This allows for better utilization of resources and reduces the underutilization of privately owned vehicles. By encouraging vehicle sharing, MaaS can potentially minimize the need for additional investments in fleet size by transportation service providers.

Implementing effective demand management strategies, such as advanced scheduling and dynamic pricing, contributes to the overall efficiency and cost-effectiveness of MaaS. These strategies help match transportation supply with customer demand, ensuring optimal utilization of available vehicles and reducing inefficiencies. Integrating shared digital keys or access systems may also facilitate seamless access to various modes within MaaS. This integration enhances the convenience and accessibility of transportation services while meeting the diverse needs of customers.

In summary, demand management is a fundamental aspect of MaaS that focuses on optimizing the supply and demand of vehicles. By implementing strategies such as vehicle sharing, advanced scheduling, and dynamic pricing, MaaS aims to improve resource allocation, reduce underutilization, and enhance the efficiency and cost-effectiveness of transportation services.

4.5.3. Challenges and Opportunities for Road Network Operators

The key challenges and opportunities identified across various inputs are:

4.5.3.1. Challenges

- *Planning and integration:* Implementing new vehicle capabilities and integrating emerging mobility services into existing transportation systems requires careful planning, coordination, and seamless integration with multiple stakeholders.
- *Regulatory frameworks:* The evolving nature of new mobility models, such as sharing economy services, often leads to uncertainties in regulations and legal frameworks, making it challenging for road authorities and operators to adapt and ensure compliance.
- *Stakeholder collaboration:* Successfully implementing MaaS requires effective collaboration and cooperation among road authorities, transport operators, service providers, and other relevant stakeholders, which can be complex to achieve.

4.5.3.2. Opportunities

- *Integrated and seamless mobility:* MaaS offers the opportunity to provide users with seamless and interconnected transportation options, integrating various modes of transport into a unified platform for a smoother and more convenient travel experience.
- *Enhanced data and insights:* New vehicle capabilities and MaaS generate vast amounts of data, which, when collected and analyzed, can provide valuable insights for optimizing transport systems, improving resource allocation, and enhancing infrastructure planning.
- *Customer-centric solutions:* By embracing new vehicle capabilities and MaaS, RNOs can focus on delivering customer-centric solutions, providing users with a wide range of transportation options, personalized services, and real-time information.

To leverage these opportunities, road authorities and operators need to address the challenges related to planning, regulatory frameworks, and stakeholder collaboration. By embracing innovation, fostering partnerships, and utilizing data-driven approaches, RNOs can drive the development of integrated and sustainable mobility systems that enhance user experiences and address the evolving needs of modern transportation.

4.5.4. Implications for Planning, Design, Construction and Operation of Road Infrastructure

The MaaS concepts and functionalities that have implications for the planning, design, construction, and operation of road and right-of-way infrastructure can be summarized as follows:

- *Data-driven decision-making:* The utilization of data plays a crucial role in informing road planning and meeting the diverse needs of road users. By leveraging the data collected through MaaS apps, planners can make informed decisions to optimize road infrastructure and ensure it aligns with the demands of users.
- *Integration of mobility services*: The integration of various mobility services into combined solutions is essential. MaaS acts as a catalyst for this integration, allowing for seamless experiences by combining different transport modes. Incorporating MaaS into infrastructure planning & design enables efficient and accessible transportation systems.
- *Collaboration across sectors:* Successful implementation of MaaS requires collaboration between the public and private sectors. MaaS platforms facilitate partnerships between transport authorities, service providers, and infrastructure managers, fostering a collaborative ecosystem to plan and deliver integrated mobility solutions.
- *Regulatory considerations:* Existing regulations may pose challenges to the implementation of MaaS. It is necessary to establish regulatory frameworks that support and incentivize the adoption of MaaS, enabling its seamless integration into road infrastructure. This may involve revisiting and adapting current laws to accommodate new modes of transportation and service providers.
- *User-centric approach:* A user-centric focus is paramount in shaping future road infrastructure. MaaS emphasizes personalized experiences, tailoring transportation options based on individual preferences and needs. By considering user needs during the planning and design stages, road infrastructure can be optimized to deliver efficient and convenient mobility solutions.

In conclusion, the implications of MaaS for RNOs include data-driven decision-making, integration of mobility services, collaboration across sectors, regulatory frameworks, and a user-centric approach. These factors collectively contribute to creating a more efficient, accessible, and user-friendly transportation system.

4.5.5. Digital Needs for Road Network Operators

The operation of MaaS requires a digital platform tailored to needs of the RNO. This platform encompasses system architecture, communication, storage, and integration, enabling efficient management and enhancement of operations within the MaaS framework. To fully utilize the digital platform in the context of MaaS, RNOs must meet specific requirements such as IP whitelisting and obtaining digital certificates for secure communication within the platform.

Recognizing the transformative impact of digitalization on mobility, RNOs should understand its potential in improving transportation services and creating enhanced mobility experiences for users within the MaaS paradigm.

In summary, from a MaaS perspective, a tailored digital platform benefits RNOs by addressing their unique requirements and enabling secure and efficient operations within the MaaS ecosystem. By embracing digitalization, RNOs can enhance services and contribute to an improved mobility experience for users in the context of MaaS.

4.6. Platooning

4.6.1. Introduction

Truck platooning is the linking of two or more trucks to form a convoy, using connectivity technology and automated driving support system. Platooning has the ability to lower the environmental impact of road transport by saving fuel, and (to a lesser extent) enhancing traffic flow and safety, as well as decreasing driver hours in the long term. To enable these benefits, it must be demonstrated that there are viable business justifications for all relevant actors.

4.6.2. Demand Management

Platooning has the potential to reduce the total cost of logistics for the supply chain, and increase road capacity. This is, however, unlikely to reduce the demand for road-based travel demand.

Sharing fuel savings is essential for platooning to succeed. There are different sharing models to employ and ways to calculate the gasoline savings:

- Scoring system to balance fuel savings among platooning members. For each mile the followers travel, they pay the leader 2/N points. The vehicle with the lowest score takes the lead when assembling a new platoon.
- If a points system is deemed to be insufficient or unfair, other options can be considered:
    - Cash transactions rather than just points - the Split-to-Leader (SNL) model.
    - A more detailed model for calculating and allocating savings.

4.6.3. Challenges and Opportunities for Road Network Operators

The key challenges and opportunities identified are:

4.6.3.1. Challenges

The most significant challenge is the standardization of the solution, including relating to design and operation of the physical and digital infrastructure.

4.6.3.2. Opportunities

- Increased safety of heavy-duty vehicles in mixed traffic;
- Increased competitiveness of OEMs and suppliers in the automotive industry;
- Increased economic activity and prosperity;
- Improved traffic management due to more efficient utilization of road capacity;
- Cost reduction in logistics and supply chain; and
- Increased road and heavy-duty vehicles safety towards a fail-safe objective.

As an indirect benefit, the digitalization enabled by platooning allows RNOs to monitor and regulate freight transport, provided that truck operators are willing or allowed to share precise data about their journey.

4.6.4. Implications for Planning, Design, Construction and Operation of Road Infrastructure

In order for truck platooning to be practical and beneficial a system that can alert vehicles to platooning opportunities is required. Platoons can be established either dynamically on the road or at hubs. Trucks must be informed of potential platooning possibilities in both situations. The location of hubs and facilitation of the formation of platoons may require changes or additions to road infrastructure.

4.6.4.1. Platoon Operation

The operation of platoons depends on various factors, such as whether they are the responsibility of the RNO or the truck/logistics companies is an issue that needs to be considered and agreed upon before platooning can be considered as a viable solution.

Waiting for a platoon to form incurs expense for the haulage operator. The decrease in fuel use varies based on location in the platoon. For haulage operators to be willing to participate in platooning, expenses and benefits must be shared. It is therefore critical to have intermediary services that can give information and broker platooning opportunities. The requirement for a platoon to comprise vehicles from various operators/manufacturers emphasizes the necessity for mediation services.

Matchmaking is one such mediation service that assists vehicles equipped for platooning in finding others to join (particularly critical for multi-brand platooning). If such a service is not offered, creating platoons will be challenging, especially in cases when there are few platooning equipped vehicles in the same location, as would be the case during early adoption.

Another mediating service is needed for dispersing platooning revenues, which are unevenly allocated among the players. Although the platoon commander benefits from reduced fuel use, the benefits for the followers are greater. During the formation of a platoon, some vehicles must wait for others, causing them to arrive at their destination later and with lower utilization, which increases costs. Overall societal costs and benefits (e.g., decrease of CO_2 emissions) should be considered in some circumstances, which is helped by having a mediating service.

4.6.5. Digital needs for Road Network Operators

The digital needs for RNOs depends upon how the platoon is operated – where matchmaking and associated services are the responsibility of the truck/logistics companies then there may be no digital needs for the RNO (unless a safe operating environment relies upon RNOs understanding the presence and behaviour of platoons). The trucks themselves will require V2V communications to form, maintain and disperse a platoon; V2I communications enables RNOs to benefit from information about the location and movement of a platoon.

4.7. Electric Vehicles

4.7.1. Introduction

Electric vehicles (EV) featured in only one of the case studies in the literature review. A separate PIARC Task Force is considering the impact of Electric Road Systems, although the focus of that Task Force is on the in-road charging infrastructure itself. It is noted that vehicle electrification is considered by many to be a prerequisite and requirement for eventual automation. More focus on

Electric Vehicles is planned as part of the next PIARC Strategic Planning Cycle 2024 – 2027 given the investment now going into the development of public charging infrastructure across many road networks across Europe, North America, Australia and other regions across the World.

Innovations in mobility such as e-scooters and e-bikes have already had an impact on mobility in many countries. Their introduction into a town or city represents a significant change in active travel, modal share and the use of road and curb space, as well as potentially infrastructure for pedestrians and cyclists. Their impacts on RNO warrant a separate study or project and they have not been considered in any detail by Task Force 2.1.

4.7.2. Demand Management

Electric Vehicles are gradually replacing vehicles powered by internal combustion engines (ICE), a change driven by environmental issues and the globally accepted need to decarbonise road transport. Generally, an EV is seen as an alternative to an ICE powered vehicle with a like-for-like replacement taking place when leasing or purchasing a new vehicle. The market for used EVs, including the repurposing of batteries, is relatively immature.

Within this context, the potential for EV to change travel demand is considered minimal – the opportunity is when EV is considered within a shared-use context. That change is not something that is driven by the electric powertrain itself, but by cultural and societal changes.

4.7.3. Challenges and Opportunities for Road Network Operations

Challenges for RNOs as a result of EV come from the need to install electric charge points – at street level, in car parks and elsewhere. This can be done directly or through making land or concessions available to third-party charging infrastructure providers. It is important to consider the space, layout and operation of the vehicle parking space associated with the charging point and the traffic access and regulation issues associated with this.

Providing sufficient electricity supply and distribution capacity for these charge points is also a wider challenge and RNOs may need to engage with their counterparts in the energy sector to arrive at integrated solutions.

4.7.4. Implications for the Future of Toad Infrastructure

As noted, the principal infrastructure impact of EVs is the need to provide networks of EV charging points on public road networks, although there are niche alternative approaches such as swappable batteries and inductive roads. The design and operation of service stations will likely need to evolve in the future.

EV tend to be heavier than their ICE powered equivalents, due to the weight of the battery. This weight will have implications for RNO with regards to loading and maintenance of road surfacing.

4.7.5. Digital Needs for Road Network Operations

EV themselves have no specific digital needs, however by providing up to date traffic information and information regarding the location and availability of charging points, RNO can enable EV drivers to plan their journeys with confidence resulting in reduced levels of “range anxiety.”

4.8. Conclusions from Literature on New Mobility Initiatives

The literature from the internal survey, and further supplemented by the work done by TC1.1, demonstrate a greater level of maturity within connected and automated mobility (commonly referred to as CAM), C-ITS and MaaS. Platooning is not considered in many of the studies collected and may only be viable over large rural regions where haulage distances and associated driver requirements are considerable. Whilst both digital highways and Next Generation ITS and EV do feature, their potential impacts on RNOs are less mature in the studies reviewed. The whole field of road transport electrification requires a comprehensive effort by PIARC through an appropriate mechanism (e.g. Technical Committee, Task Force, Special Project).

The literature summarised in this Chapter shows that:

- New mobility initiatives will have a significant impact on the planning, design, construction, and operation of road infrastructure. By considering these implications and adapting to the changing transportation landscape, RNOs can contribute to the development of more efficient, sustainable, and resilient transportation systems.
- The precise form and timescale of adaptation of physical road infrastructure to connected and automated mobility is subject to considerable uncertainty, technical and professional debate and with a need for the development and validation of workable design and operational concepts. In the near-term, it appears that roads will look and operate much like today, but the deployment and scaling up of full Automated, Connected, Electric and Shared (ACES) Mobility concepts offers the long-term potential for a fundamentally re-imagining and re-engineering of how roads are built, managed and maintained.
- RNOs face significant challenges in implementing new mobility initiatives, including technical, legal/regulatory, environmental, and social aspects. However, they also have opportunities to improve road safety, traffic management, sustainability, and make technological and economic competitiveness advances by addressing these challenges and leveraging the benefits of automation and connectivity.
- RNOs face some considerable challenges in taking new mobility innovations forward, including HD maps, vehicle-to-infrastructure connectivity, real-time data provision, and collaboration with stakeholders. Investing in digital infrastructure and adopting advanced technologies will enable RNOs to create efficient, safe, and resilient transportation systems for the future.
- The adoption or implementation of new mobility initiatives does not necessarily change the number of vehicles on the roads, although some demand management strategies may be enabled (and indeed required) by technology deployment. Paradoxically, the adoption of CAVs at scale may require comprehensive and effective demand management measures if a smaller number of vehicles is not to result in the same or increased volume of traffic on the network with resulting congestion and other undesirable externalities.
- Whilst some services such as C-ITS have a favorable degree of user acceptance, there is currently limited willingness to pay for the services. Travel time savings, reduced congestion, and improved traffic flow and therefore smoother driving results in significant benefits in fuel consumption, associated CO_2 emissions and potential increases in productivity.

- The importance of a digital representation of the road network is growing. Digital and machine-readable tools for the implementation and enforcement of traffic regulations are one component of this. Data on traffic regulations is an essential component in a digital environment. Data on traffic rules opens up whole new possibilities, such as more dynamic traffic laws, which can further contribute to good impacts for the transportation system and society. It is also required for the introduction of self-driving vehicles on public highways, as some automated vehicles would require a dependable digital infrastructure.
- Data and digital tools enable the whole lifecycle of a road network (from design to operation) to be conceived and managed more safely and efficiently than ever before.
- Demand management is a fundamental aspect of MaaS that focuses on optimising the supply and demand of vehicles. By implementing strategies such as vehicle sharing, advanced scheduling, and dynamic pricing, MaaS aims to improve resource allocation, reduce underutilization, and enhance the efficiency and cost-effectiveness of transportation services.
- The implications of MaaS for road infrastructure encompass data-driven decision-making, integration of mobility services, collaboration across sectors, regulatory frameworks, and a user-centric approach. These factors collectively contribute to creating a more efficient, accessible, and user-friendly transportation system.
- By embracing digitalization, RNOs can enhance services and contribute to an improved mobility experience for users in the context of MaaS.
- Platooning has the ability to lower the environmental impact of road transport by saving fuel, and (to a lesser extent) enhancing traffic flow and safety, as well as decreasing driver hours in the long term. To enable these benefits, it must be demonstrated that there are viable business justifications for all relevant actors, as well as an understanding of how to manage impacts and risks on other road users.
- The operation of platoons depends on various factors. Whether these are the responsibility of the RNO or the logistics sector is an issue that needs to be agreed upon before platooning can be considered as a viable solution.

Aside from the technical issues set out above, it is important to consider wider questions of policy, financial and business models, social impacts (with a view to inclusivity and distribution of benefits) and also the challenges faced specifically by Low and Middle-Income Countries (LMICs). These are set out in the next Chapter, combining the internal survey of Task Force 2.1 with evidence previously collected by TC 1.1 (Performance of Transport Administrations).

5. HORIZONTAL ISSUES

5.1. Introduction

5.1.1. Overview

As well as the deep dive into the various technical aspects of specific new mobility technologies, infrastructure and services – for example, AVs, C-ITS and MaaS – which have been outlined in Chapter 4, TF 2.1 has been focused on reviewing so-called "horizontal" (or "cross-cutting") issues which are of wider interest and relevance across the full spectrum of future innovations in the transport and mobility sector.

The methodology for the literature review, previously described in Chapter 2, has sought to identify evidence and insights in the following three key areas:

- Financial issues and business models;
- Social impacts; and
- Implications of new mobility technologies for Low and Middle-Income Countries (LMICs).

These areas of focus encompass topics such as cost-benefit analysis, investment challenges, revenue generation models, the role of technology in optimising investments, social acceptance and differences in technology adaptation across different groups. By understanding these insights, stakeholders can gain valuable insights into the financial considerations, potential social impacts, and implications of advanced mobility solutions for LMICs.

5.1.2. Technical Committee 1.1 (Performance of Transport Administrations)

TF 2.1 has also benefited from the work of Technical Committee 1.1 (Performance of Transport Administrations) in researching *The Role of Transport Agencies in Shaping Disruptive Technologies and Service Models* over the 2020 – 2023 Strategic Planning Cycle. This research was published by PIARC in March 2023 and is partially based on an earlier Literature Review which included coverage of future social and economic impacts of new mobility technologies, considered LMICs and also the role of the private sector, under appropriate conditions of regulation, in creating new business models to drive innovation and the creation of new mobility products and services.

This Chapter therefore reports on the evidence collected by TF 2.1 during its internal survey and review of key literature, as well as referencing relevant findings from TC 1.1, before offering some overall conclusions in this area.

5.2. Financial Issues and Business Models

5.2.1. Costs and Benefits

The implementation of innovative mobility solutions, such as automated vehicles, shared mobility services and digital highways and connected systems, brings financial challenges and the opportunity and need for sustainable business models. Many mobility innovations are led by the private sector, and when technologies are at a developmental or prototype stage they are produced to bespoke standards in small quantities, before unit costs fall from technological maturity, emergence of clear industry standards and mass production of new products and services. Over time, the commercial viability and economics of new mobility concepts will improve, encouraging the development of sustainable technology ecosystems, but there are significant financial and business model challenges to overcome during the transition.

For example, the break-even cost-benefit analysis in the 5G MOBIX Project explored whether the potential benefits of cross-border 5G for Connected and Automated Mobility solutions outweigh the costs. The analysis considered factors like accidents, journey time delays, and carbon emissions, as well as estimating the required reduction in externalities to offset the investment needed. In the case of the 5G-MOBIX Project, the investment costs were shown to be offset by the benefits in a number of European corridors, such as Spain-Portugal, Germany-Netherlands and Spain-France, but not others such as Finland-Norway and Greece-Turkey, although additional trade and logistics benefits might be expected in the case cross-border use cases.

Similarly, AV applications in various Chinese cities include high upfront investment costs, ongoing maintenance and software update costs, and (uncertain) costs associated with upgrading and maintaining road infrastructure. These costs need to be offset against potential benefits, including those which can be directly monetised, as well as wider economic, social and environmental impacts.

5.2.2. Business Models and the Role of the Private Sector

Within the literature, the business models of different companies and projects are described, including different private companies. These models include revenue generation, and therefore cost recovery, through fees or subscription-based services, potential partnerships with public transportation agencies or operators, and external funding or sponsorship from various sources. The business models also highlight the importance of data exchange and collaboration with traffic management centres (and their managing agencies) and other stakeholders to facilitate route and traffic flow optimisation. Efficient investment planning is emphasised, whilst technology can also help optimise investments by providing real-time data on transport demand and operations which assists network management.

In Japan, the amended provisions of the Road Act define facilities and supporting infrastructure for automated driving and allow for various business models beyond road agencies, including enabling and facilitating investment in technology development, testing, demonstration and eventual mainstream deployment by the private sector. This is consistent with some key conclusions from TC 1.1 that effective partnerships between the public, academic and private sectors are essential to identify, progress, appropriately regulate and realise the benefits from new transport technologies and service models. These partnerships must acknowledge and balance the legitimate pursuit of private profit and return on investment (by private companies) with the identification and achievement of public policy goals and wider concepts of public value. Specifically:

- **Private sector companies** on the cutting edge of technology should realise the risks involved in their businesses and the need for proper regulation within a holistic framework for governance. They must work with regulators to understand the intricacies and practicalities of new technologies, how the associated products and services can be utilised, determine if any prior regulations are relevant and then to assess whether or not new licences, new permits or new regulations could be helpful in solving transitional issues. The private sector should lead solutions to problems that the public sector is trying to solve through being open to new business models through a free market solution.
- **Transport agencies**, including RNOs, should regulate to address risks of market failures, in which free markets do not result in an efficient allocation of resources leading to a loss of economic and social welfare. It is incumbent upon these agencies to keep themselves abreast of the latest changes in the industry, hire those with robust technology skills and

understanding of those working in the private sector. Agencies also should be wary of an excessive focus on short-term results at the expense of long-term agendas in such areas as climate change. There is urgency on some pressing matters of public value and interest and therefore no room for complacency.

In 20 years' time, the mobility ecosystem is seen as being demand-responsive, integrated and multi-modal, which can respond to the changing needs of communities by using public and shared transportation methods which are affordable, efficient, tech-enabled, inclusive and environmentally respectful. Transport agencies must prepare for the future proactively and make sure they have the governance processes, structures, skills and competencies to lead the way, whilst managing the transition.

Returning to the TF 2.1 literature, the French National Automated Vehicle Strategy aims to provide financial support, promote data exchange, and identify viable business models for automated and connected public transport services in the short, medium and long-term. The legal liability and associated insurance aspects of automated driving are a particular area of difficulty and focus of policy development since they raise questions about the changing rights and obligations of vehicle drivers, passengers, owners, manufacturers and operators under various scenarios of AV deployment and scaling up. In addition, the costs, benefits, revenue streams and resulting funding and financing needs in the context of automation, electrification, and digitization are also highly uncertain. Investments in V2X and other Connected Vehicle, C-ITS and digital systems are estimated to be significant, but it is less clear whether these should (and can) be met by public agencies as part of their existing network operations duties or at least partially shared with the private sector, especially where vehicle and technology suppliers will benefit directly from the service models and user propositions which are enabled.

5.2.3. Financial Challenges

The implementation of new mobility concepts like automated vehicles therefore poses substantial financial challenges, and stakeholders in both the public and private sectors need to carefully consider investment costs in infrastructure upgrades, operation and maintenance. This is especially where the successful deployment of CAVs may be predicated on the provision of certain digital infrastructure, or a higher standard (and consistency) of asset condition than is currently the case, or indeed affordable, through public budgets. The latter may also be put under further pressure where existing resources for road management come directly or indirectly from taxation based on fossil fuels which may decline in the event of substantial take-up of Electric Vehicles. Collaboration, data exchange, efficient and resilient investment strategies and adjustment of financing arrangements are therefore crucial for developing sustainable business models and achieving positive transport and mobility outcomes.

When discussing business models for road network operations, a range of literature sources monetise social benefits and compare these with deployment costs of new technology. Non-recurring costs reflect the investment required to enable C-ITS and other systems, segmented into planning, design, installation and commissioning. Recurring costs consist primarily of operational and maintenance considerations. Various studies have been undertaken to assess the cost-benefit analysis of such investment and appear to present highly promising results, with benefit-to-cost ratios varying between 1.5 and 7.4. Road and traffic operators can also generate indirect revenues by linking C-ITS and other deployments to tolling and other road pricing strategies, with users contributing to the costs of the improvements made in return for the added utility they receive. Vehicle manufacturers may also realise direct revenue from road users in the form of subscription fees from in-vehicle services, and vehicle data collection can inform road agencies and drivers about asset faults and maintenance needs, translating into adjusted maintenance intelligence, revenue and asset replacement sales.

The evidence is not always so positive and may vary by use case, geography and application. Research from Australia shows that investing in digital infrastructure that supports and enables CAV technology exhibits a negative benefit/cost ratio in many aspects, especially in lower density suburban or rural areas. The economic feasibility of such investments may improve over time with lower costs as the technology matures, scales up or is more targeted to deployment in higher-traffic areas such as city centres. In Japan, various measures by road authorities and operators based on ETC 2.0 data indicate that C-ITS will strongly benefit both road operators and road users in dense urban and inter-urban corridors. Hungary has considered societal costs and benefits to justify the deployment of CAVs, whilst Sweden suggests that state assistance and financial support may be used to expedite digitalisation of highway assets by public entities on a voluntary basis around local circumstances and benefits realisation.

5.2.4. The Case for Investment

Funding is clearly crucial for the development of MaaS platforms, often relying on support from public administrations, at least in its early stages, as well as a positive enabling policy and regulatory framework. Successful MaaS business models prioritise consumer confidence, trust, significant user value and modal shift to shared transit modes. However, financial issues arise when translating these advantages into agreed budgets for investment, particularly due to complex business models and uncertainty surrounding collaboration, including between public and private players and across multiple commercial actors. Technology plays a vital role in enabling more efficient investments for road authorities and operators in the domain, but does require adequate funding, viable business models, addressing financial and commercial challenges, and leveraging data to drive more efficient investments. The future of MaaS may lie less in development of new technology platforms and more in progress on viable business models and commercial arrangements which balance risk and reward.

Economic analysis has shown that fleet owners have a direct business case for investing in autonomy, connected vehicles and operating models such as platooning – seeking benefits from increased driver efficiency, reduced labour costs and manpower management. However, realising such benefits requires the technology to be certified, scaled up, approved for deployment by regulators and translated into standard operating procedures. The investment costs, as well as the practical and regulatory challenges involved in this are considerable, emphasizing the need for a close, effective, fair and equitable partnership and collaborative arrangements between the public and private sectors. The case for automated technology may also be influenced by the structure of labour markets, prevailing levels of unemployment and the cost of labour, as well as broader human capacity and skill considerations, in any given location.

5.3. Social Impacts

As connected and automated vehicles, digital highways and associated mobility services, continue to evolve, understanding their social impacts becomes essential.

5.3.1. Reducing Externalities

Current transport systems, focused on automobility, suffer from a range of negative impacts and challenges, for example congestion, inefficiency, accidents, environmental pollution carbon footprint, community severance and high prices. Extensive literature exists in this area, as well as concepts and proposals to mitigate problems and provide more efficient, sustainable and equitable transport infrastructure and services. Frameworks such as Avoid-Shift-Improve are useful in this regard and promise convenient, safe, and economic mobility, with less impact to health and the natural and built environment.

5.3.2. Social Inclusion

CAVs and shared mobility services have the potential to enhance inclusion and mobility for individuals with disabilities, young people and the elderly by improving accessibility and offering convenient transportation options. Features like accessible vehicle designs, wheelchair ramps, priority seating, and user-friendly interfaces play a role in this, as well as providing vehicle access and use for those without a driving license. Considering the needs, preferences, and safety concerns of both genders is also crucial for creating inclusive transportation systems. There is increasing evidence that men and women have different attitudes and may behave differently in respect of different levels and use cases for automation. Designing vehicles and services that cater to a diverse range of users fosters inclusivity.

Social acceptability is a significant driver of the take-up of automated driving technologies, with significant potential to constrain or accelerate the transition, alongside technological maturity, policy support and regulatory approval. Efforts should be made to align AV development and deployment with, social acceptance, addressing concerns regarding safety, data privacy, control relinquishment, data usage, personal security and public well-being. Achieving actual and perceived safety in automated and connected road mobility is essential, as is controlling the environmental impact of the supply chain to promote social well-being and sustainability. This is already being seen, for example, in increasing scrutiny over the environmental, labour and social impacts of mineral extraction for batteries and other electronic components to power Electric Vehicles. Accreditation and labelling of a sustainable, inclusive and ethical supply chains is likely to become an increasing industry requirement, extending from electric to other mobility technologies in due course.

5.3.3. Policies, Regulations and Ethics

Developing appropriate policies and regulations is crucial for addressing social challenges associated with automated vehicles. Considerations include type approval regulation, adaptation of traffic rules, changes to driver licensing, liability frameworks, and managing the transition period when both conventional and automated vehicles coexist, either in separate rights of way or in mixed traffic conditions. Automated mobility services can bridge transportation gaps, enhance transportation equity, and improve access, particularly for lower-income communities with limited private vehicle ownership, but only if they are appropriate regulated, operated and priced.

Public expectations for automated vehicles revolve around improved safety, security, time, and cost savings, as well as increased productivity for those previously focused on manual driving tasks. Concerns include relinquishing control, data usage, and overall safety and security. Addressing these concerns, as well as addressing various ethical concerns, is vital for gaining public trust and acceptance. Considering social aspects such as inclusion, gender perspective, safety, acceptability, and equitable access contributes to the development of equitable, sustainable, and resilient transportation systems.

C-ITS services, and associated concepts around digital highways, also have the potential to increase connectivity, efficiency of traffic flow, environmental conditions, user comfort, information, and road safety. They may also support climate resilience and future-proofing. For example, the literature includes examples of users showing a positive response to road works warnings, traffic jam alerts and weather warnings, with drivers changing their driving behaviour based on the information provided. However, the current evidence suggests only a minority of users are willing to pay for these services, despite finding them useful, and the question needs to be asked whether some applications will only find a place in premium-priced vehicles purchased by those on high-incomes and net worth, at least until the cost of the technology falls significantly.

5.3.4. Gaining Trust and Social Acceptance

Digital technologies can also enhance the climate resilience of critical infrastructure, but there is tension in relying on them due to public distrust and challenges in explaining and translating digital data into actionable and human terms. The recent abandonment of any new Smart Motorways in the UK, following a number of high-profile accidents reported and amplified within in the media, is a salutary lesson of the political consequences when public trust in the technology is lost. Ensuring equitable principles and leaving no one behind are crucial considerations in increasing infrastructure digitalisation, including protecting vulnerable road users, such as pedestrians and cyclists, from motorised vehicles whether automated or not.

In the context of MaaS, social considerations play a significant role. Inclusive mobility that caters to the diverse needs of individuals, including those with disabilities or limited mobility, is essential. Those on low incomes must also be assisted with appropriately-priced MaaS products. Some have also argued that current shared mobility concepts encourage a continuation of so-called "hypermobility" based on motorised transport modes (where services can be more directly monetised) and the model needs to adapt to provide information and utility for users to walk or cycle, with benefits for public health, environmental sustainability and quality public realm.

As with CAV and C-ITS technology, integrating a gender perspective into mobility planning and design within the MaaS context is essential for developing equitable and user-centric mobility options. By prioritising inclusivity and addressing social aspects in MaaS initiatives, a more equitable and accessible transportation system can be created that enhances the quality of life for individuals with diverse needs and promotes gender equality.

Finally, the literature suggests that vehicle platooning is expected to bring societal benefits such as more efficient use of road capacity, increased traffic safety, driver comfort, and energy savings. These are important, but the impacts of "road trains" on other users must also be factored in, such as allowing other vehicles to join and exit roads safely. Platooning combined with autonomy may also address shortages within the labour market and free up personnel to support more productive functions within freight supply chains.

5.3.5. Timing of Impacts

In terms of when these social impacts will occur, the UK Government Office for Science (2019) lists a set of technologies which will prove significant in the long-run. Table 5.1 sets out the key technologies against their reported inception dates, range from developing and niche (under development and first applications) to emerging (early market) and widespread (mainstream market). These current indications show how government decisions and social values could markedly slow down or speed up the adoption of these technologies.

5.3.6. Focus on Connected and Autonomous Vehicles

The remainder of this section further focuses particularly on Connected and Automated Vehicles (CAVs) in order to outline the possible future social and economic impacts, based on earlier literature review by TC 1.1, with the caveat that these impacts remain very uncertain, contested and yet to be supported by direct empirical evidence. More critical analysis around the leadership role of the private sector within technology development and deployment, compared to wider public interests, is also presented.

Table 5.1 – Technology Inception Dates. Source: (UK Government Office for Science, 2019)

Technology	2025	2030	2040	Notes and references
Electric cars	Emerging	Widespread	Widespread	Element Energy (2013)
Level 4 passenger vehicle automation	Niche	Emerging	Widespread	(Underwood, 2014); (Automotive Council UK and Advanced Propulsion Centre, 2017)
Level 5 passenger vehicle automation	Developing	Niche	Widespread	(Automotive Council UK and Advanced Propulsion Centre, 2017; London Assembly, 2018) Contrarily some claim L5 is unachievable (Wolmar, 2018)
Electric LGVs/vans	Emerging	Widespread	Widespread	Element Energy (2013)
Electric HGVs	Niche	Emerging	Emerging	<15 tonnes (Heid et al., 2017)
Level 4 truck automation	Developing	Niche	Widespread	(International Transport Forum, 2017a)
Level 5 truck automation	Developing	Developing/ Niche	Emerging	2042 self-driving trucks common (Transport Topics, 2017); 2035 (Frisoni et al., 2016)
Truck platoons	Niche	Emerging	Widespread	Truck Platoons 2021-2030 (Frost and Sullivan, 2016); 2022 (European Automobile Manufacturers Association, 2017); truck platooning on highways 2025-2030 (Frost and Sullivan, 2015; Underwood, 2014)
Flying cars	Developing	Niche	Emerging	2035, wider commercial applications (Frost and Sullivan, 2017a)
Delivery drones	Niche	Emerging	Widespread	(Walker, 2017)
Droids (ground-based drones)	Niche	Emerging	Widespread	(Yole Développement, 2016)
Hyperloop	Developing	Niche	Niche	2030 first scheduled to complete in Saudi Arabia (Virgin, 2018); Dubai 2022 (Reuters, 2017)
Autonomous underground trains	Niche	Niche	Emerging	London 2030 (Beard, 2014); although technically possible since 1967 Victoria line (Preston, 2017)
Autonomous overground trains	Niche	Niche	Emerging	1980s, DLR/Vancouver sky train for metros; 2022-2024 in France (Atelier BNP Paribas, 2017); currently semi-autonomous on Victoria, Central, Northern and Jubilee lines (Verdict, 2017); 2023 in France (Tarantola, 2017)
Autonomous freight trains	Niche	Niche	Emerging	Already used in Australia (Thompson, 2017; Railway Gazette, 2017; BBC, 2018a)

According to many sources, if properly regulated and priced, fully automated vehicle systems have the potential to significantly reduce traffic jams, pollution and consumption through optimized real-time route planning, shared-use, and space-efficient driving. As noted, they will also provide individual mobility to people without driving licenses, and significantly increase both travel comfort and efficiency.

However, CAVs in some cases also threaten the income and jobs of drivers, put in doubt the resilience and sustainability of some existing modes of transport, and raise several challenges in data protection and privacy. Benefits in terms of road safety may be countered by new threats of cybersecurity. Other impacts include the reproduction of car dependency exacerbating urban sprawl, shifting government investments away from mass transit, affecting city planning and considerably changing the laws of real-estate markets.

Many of the benefits claimed for the new technologies in safety and more efficient use of contested urban space are expected to be realised only when the transition to full autonomy is reached, and when these vehicles operate in a fleet capacity as “robotaxis” rather than in exclusive private ownership. This relates back to the point made above, that the business model and mode of deployment, as well as the actual technology itself, will be vital for determining overall impacts.

In terms of costs, self-driving vehicles may decrease mobility costs and increase the productivity of infrastructure and services by removing driver-associated expenses. Production and maintenance costs are also expected to be much lower than for traditional motorised transportation solutions.

Forecasts of the development, early adoption and mainstream use of CAVs vary sharply. In certain scenarios, it is expected that over 30% of total traffic volume will be carried out by self-driving cars, which would result in a decrease in public transit of 20% (Arthur D Little, 2018). While this decrease is expected to be offset by the overall increase in mobility demand, this would still limit the growth potential and financial sustainability of public transport. However, an increase in transit coverage through automated buses and pods could improve accessibility and well-being (e.g. for people that are not able to drive a vehicle themselves), as well as reduce dependencies on private car ownership. Different dynamics can be expected to be experienced in different countries and cities around the World.

5.3.7. Impacts on Road Infrastructure and Industrial Supply Chains

With regards to road infrastructure, studies report that the capacity of road infrastructure could be increased through digitalisation and self-driving cars by 80–270% (Arthur D Little, 2018). Similarly, several simulations have predicted that the introduction of self-driving cars will require between 30%-80% less parking, as cars will be better utilized, and less time will be spent searching for parking spaces. This will provide positive opportunities for urban planning and design with a recycling of space currently devoted to parking to green space, community facilities or commercial real estate. However, the battle for curb-space access among the different services and vehicles is likely to increase and strong management and regulation will be required.

KPMG (2019) sets out examples of how CAVs may affect specific industries as follows:

- **Policing:** Fewer resources may be needed on roads with CAVs programmed to obey traffic laws.
- **Healthcare:** Fewer traffic accidents may mean less demand for emergency surgery and fewer organ donors. CAVs may make it easier for older and infirm people to travel to appointments, allowing greater centralization of services.
- **Air and rail:** There may be fewer passengers on some routes if CAVs allow users to relax or sleep their way to long-distance destinations by road.
- **Media and advertising:** CAV users freed from driving could turn their attention from audio to video, written word, and social media; advertising could be targeted by location, potentially subsidizing the cost of travel.
- **Power grids:** Home EV charging will require strengthened local grids, but smart control of when to charge as well as use of plugged-in vehicles as batteries could smooth demand.

The Oxford Institute for Energy Studies (2018) points out that it is likely that AV technologies will need to be developed on a city-by-city basis and even on a road-by-road basis. For example, an AV developed to operate within a major western city cannot be transferred directly to a city in a developing country in Asia. It may not be possible to deploy the same CAV in situations where not just urban planning, but also traffic patterns, rule compliance, and driver behaviour are fundamentally different. In general terms, cities where roads form a grid pattern are likely to be easier to adapt to AV technologies than those with a more irregular layout, as are cities with fewer pedestrians and cyclists, and cities with more compliant driver behaviours.

Finally, it is important to note that the net impact of disruptive change in CAVs, for example, will come from the combination of automation, electrification, and shared mobility (ride-hailing, ride sharing, and car-sharing). Interactions between automation, electrification, and shared mobility are not yet clearly understood. Therefore, any projection of the impacts contain an important component of uncertainty.

Overall, CAVs, like all new forms of mobility, have the potential to radically transform transportation. At full maturity, CAVs are anticipated to provide significant safety and mobility improvements that could benefit nearly every aspect and user of the transportation system. However, due to the emerging nature of these technologies, it is difficult to predict with precision what the impacts will be and when they will reach a critical mass in providing widespread benefits. This reality creates both an opportunity and a challenge for transport agencies to properly plan for such a promising and uncertain future.

5.3.8. Micromobility

Similar discussions over a wide range of positive and negative impacts of new mobility solutions are seen in the recent debate over micromobility in many cities across the World. Since they emerged in Southern California in 2017, e-scooters have been presented by their supporters as offering convenient, efficient, affordable and sustainable mobility in local neighbourhoods, whilst their detractors have focused on safety concerns, disruption to pavements and pedestrians, the potential for undermining of public transport and the pursuit of private profit at the expense of public interests (Spear, 2020). Detailed investigation, further empirical evidence and debate is needed to arrive at an informed and balanced viewpoint and again, the precise outcomes in any given city may be highly context specific, as might be the policy and regulatory responses. Policy can also change over time in response to public debate, media coverage and political dynamics, seen for example in the different stages of shared e-scooter regulation in locations like Paris or Singapore in recent years.

As the array of actors, technologies, business models and operational rules evolves, so in turn do the relationships between user, provider, and government. Looking to the future and given the scale of changes in the transport sector, it is clear that government intervention could play a significant part in routes to adoption, to mitigate market failures, maximise equitable benefits to cities, and society as a whole, and also drive industrial, competitiveness, employment and city branding goals.

5.4. Social Critiques of New Mobility Initiatives

5.4.1. Technological Optimism

Much of the literature on new mobility technologies is positive about the future opportunities and possibilities to solve problems caused or exacerbated by automobility, such as air pollution, deaths through road accidents and physical inactivity and carbon emissions leading to unsustainable climate change. It also sees innovation in the transport sector as matching wider technological progress across society as a whole, in such areas as online shopping, cashless payments and increasingly sophisticated mobile apps, which will impact why we travel and how we access goods and services. This presents a paradigm of “technological optimism” where anything is possible, summed up by the phrase “We’ve seen the future and it works.” (Docherty, 2018).

5.4.2. Critical Approaches

Some commentators, however, are more sceptical in their perspectives (e.g. Marsden & Rearden, 2018). Whilst the potential benefits of future mobility technologies are not disputed, for example for road safety and on-street emissions, these are not guaranteed, and robust governance is needed to ensure positive outcomes are achieved for society as a whole whilst managing the equally possible downsides.

In particular, the observation is made that new mobility concepts are bringing a new set of predominantly private-sector actors to the transport arena. These include global technology giants such as Google and Apple, service aggregators such as Uber and Grab and a wide range of suppliers specialising in AI, robotics, batteries and other system components, as well as strategy houses, planning and design consultancies. These actors challenge the traditional role of Government as transport planner, regulator or provider and increasingly generate and support user demands and determine how transport infrastructure and services are used. Moreover, they often do not fit with, or may even actively challenge, existing policy and regulatory frameworks, with examples such as Uber in the ride-hailing market, Bird or Lime in micromobility and Waymo or Cruise in Automated Vehicles. This raises questions over the role of the State in such circumstances, as well as whether and how Government should intervene to direct or limit the behaviour of private sector companies, balancing their commercial interests with wider public value and interests of society as a whole.

For some of these commentators, there is an increasing shift from public-sector approaches to transport planning and delivery to market-driven approaches. The past few years have seen the emergence of a “hands-off” mindset amongst policy makers where the capacity for strategic thinking, planning and strong regulation has weakened due to an uncritical, even naïve, faith in technology and the organisations driving innovation, even in the face of deliberate “creative destruction” of regulatory frameworks and the rules by which mobility players operate.

This is dangerous, it is argued, since private sector mobility providers are motivated by maximising consumption of their product (mobility assets and services) and the revenue and investment returns which follow from this, whilst externalising costs onto others as much as possible. This ought not to be a surprise since “this is how market capitalism works.” (Docherty, 2018).

5.4.3. The Role of Government

The role of the State, in such circumstances, is to provide a regulatory counterweight to market forces, ensuring that public value is secured and that society as a whole benefits from the mobility transition. This includes identifying the risks, negative externalities, potential market failures and equity issues which may arise and mitigating and managing them before society is locked into a path “from which it will be difficult to turn back from.” This includes setting clear and broadly-based policy goals and guiding principles which define rules of the game moving forward.

In other words, no amount of technology or data will overcome the need for sound public policy, proportionate planning and regulation and good governance of the transition to new forms of mobility. It is the role, indeed duty, of Government and public agencies to provide the latter, resisting the mantra of unquestioned faith in innovation in favour of a balanced approach, and a proportionate partnership with the private sector, which recognises the need for evidence, trials and demonstrations, prioritisation of public value, and looks to the tough questions and trade-offs which lie ahead.

5.5. Implications for Low- and Middle-Income Countries

5.5.1. Focus on High Income Countries

Although most discussion of future transport technologies and service models is carried out in relation to advanced (high-income) economies, it is important to identify examples and advice on the potential for developing and adopting innovative applications in Low- and Middle-Income Countries (LMICs). The implementation of new mobility technologies and services in this context presents unique challenges.

There is limited material on new mobility technologies and service models specifically focused on LMICs identified in the literature reviews undertaken by either TF 2.1 or TC 1.1. The majority of publications identified refer to High-Income Countries in terms of mega-trends, technology applications and roadmaps.

Nevertheless, examples can be found, such as the use of Advanced Air Mobility in rural areas of Malawi, Electric Vehicle Taxi and Motorcycle Services in Rwanda and the Contactless M-Pesa payment in Nairobi. Similarly, Yulu Micromobility in India, electric ride-hailing services in Gabon and the rapid take-up and emerging manufacture of EVs in Vietnam or the Philippines provide further cases which could be studied further. Some instances identified are highlighted below.

5.5.2. Distinctive Issues for LMICs

The benefits, business cases and public policy aspects of such innovations may be very different than High-Income Countries, as may be the roles and capacities of the public and private sectors in driving and regulating new forms of mobility. Consideration also needs to be given to NGOs and IFIs in supporting innovation; agencies such as the World Bank, ADB, OECD, UNDP and African Development Bank need to be engaged in this context.

LMICs face distinctive obstacles when it comes to infrastructure development and technology adoption. The high costs of upgrading infrastructure create challenges, as does the capacity and skill limitations on public sector planning and regulatory organisations. Ensuring fair access to new mobility services for lower-income populations in LMICs is essential. Developing local talent and appropriate expertise is also crucial for fostering industry growth. Balancing job displacement in the trucking industry with the demand for skilled workers in the automated vehicle sector is a significant concern. Overcoming challenges related to costs, infrastructure upgrades, equitable access, and workforce development is crucial for building inclusive, sustainable, and resilient transportation systems.

C-ITS may be considered necessary for LMICs, for example where disaster prevention or mitigation measures in road infrastructure are inadequate. C-ITS benefits for LMICs include improving road safety, identifying deficiencies in road design, deploying video surveillance, detecting incidents in rural areas, warning pedestrians of danger, and developing applications to improve road user behaviour. Information communication and dissemination of real-time updates are also important aspects which will be highly relevant.

Digital technologies have the advantage of “leapfrog” deployment and extensive scalability at low cost compared with physical infrastructure, making them suitable for supporting climate resilience in developing economies. Thus, emerging technology may be expected to proliferate rapidly in developing countries once minimum viable products and services, adapted to local circumstances, are achieved.

Implementing MaaS initiatives in LMICs presents unique challenges. Limited transportation infrastructure, the digital divide, and affordability issues are important considerations that need to be addressed. Barriers in terms of institutional silos, lack of professional skills and capacity, and financial resilience of operators, may also be considerable. Strong policy frameworks and regulations, innovative business models, along with collaboration between stakeholders, are crucial for successful MaaS implementation. Despite the challenges, MaaS across a range of vehicle types and services has the potential to improve mobility, accessibility, and quality of life in LMICs.

Finally, it is important to exercise caution when projecting the results of technology trials, for example autonomous microtransit or truck platooning, from a European or North American setting to other markets. The outcomes may vary depending on the underlying circumstances and transit patterns, and certain aspects, such as fuel consumption, may be specific to High Income Countries. Broader conclusions and models should be localised to the specific circumstances, policies and capacities of LMICs.

Case Study: Gozem's Ride-Hailing Service Goes Live in Cameroon

Founded in 2018 in Togo, Gozem operates an app that offers transportation, logistics, e-commerce, and financial services in primarily-francophone African countries. Gozem aims to be the super app for Africa and is modelled after the success of Gojek, Zalo, Grab and WeChat in Southeast Asia and China. While it is only one of many super app candidates in Africa, geographic expansion is a signal of strong intent.

The App has been downloaded one million times and supported seven million trips since its launch. Gozem expanded to Cameroon at the end of 2021 and now operates across 12 cities also in Togo, Benin and Gabon. DR Congo is also being explored. Beyond moving into new countries to enable taxis however, Gozem plans to make its other verticals compete with incumbents in the markets they currently operate.

Gozem's ride-hailing offer works in Gabon and Cameroon like a standard app-enabled taxi booking service. Users download, sign up and input their destination to request rides. The driver accepts and the fare is calculated by distance. Users can pay in cash, with Airtel Money or Moov Money, or by credit card. Work is ongoing to expand the shared mobility service to motor cycle and tuk tuk taxis.

Case Study: Yulu Micromobility in India

Yulu is a technology-driven mobility platform, enabling integrated urban mobility across public and private modes of transport across India. It was founded in 2017 in Bengaluru, India, with operations now in Bengaluru, Delhi, Gurugram, Mumbai, Ahmedabad, Pune, and Bhubaneswar with 18,000 single-seater vehicles across 2.5 million users.

Yulu is an example of the increasing number of micromobility operators in Low and Middle-Income Countries and features e-scooters and bicycles adapted to the road and traffic conditions of Indian cities.

Micro mobility is seen as having enormous opportunity for Indian cities and service providers that can collectively help to address some of the most complex transportation challenges for urban areas such as traffic congestion, fossil fuel emissions, and air quality, and uneven access to transit.

Yulu connects micro mobility vehicles to users through an app, enabling first and last-mile connectivity. The technology-driven platform uses IoT and AI for demand-supply management and efficient operations. The user installs the Yulu app from the Play Store or App store and creates an account, followed by addition of money to the Yulu Money account using Google Pay, Paytm, PhonePe, BHIM UPI, credit card or debit card.

The Yulu app tracks and displays, via GPS, the vehicles available nearby or at any Yulu Zone. Users can search for their destination and see the estimated time to reach it. The user scans the QR code given on the vehicle to begin the trip. To end the trip, the user parks their Yulu at a (dockless) zone nearest to their destination, upon which, the cost of the trip is deducted from the user's Yulu Money wallet. The Yulu platform works on a pay-per-use model.

Case Study: The Rise and Fall of NopeaRide Electric Taxi Service in Nairobi, Kenya

Finnish company EkoRent, which was founded in Helsinki in 2014, aimed to establish a new e-taxi service, NopeaRide, in Nairobi, Kenya, to address local pollution and decarbonise the urban transport sector.

NopeaRide ran a pilot phase, August 2018 to March 2019, which allowed the company to test its business case and showcase the business plan to potential investors with real trip data.

Whilst the case was proven and initial operations based on three vehicles grew positively, NopeaRide was hit hard by the COVID-19 Pandemic. Operations resumed, but took some time to return to pre-COVID levels as customers continued to work from home.

NopeaRide had firm plans expand its fleet in Nairobi which were partially executed. Since the launch five years ago, the company had imported 70 electric vehicles to Kenya which had driven more than 4 million Km by June 2022, saving over 650 tons of carbon emissions. During that time, NopeaRide also operated the largest EV charging network in East Africa with proposals introducing renewable (solar) energy sources and battery swapping.

Unfortunately, EkoRent declared insolvency in Finland in late 2022, meaning the Nairobi operation was unable to finance continued operations and expansion. Barriers have included financing, regulatory uncertainties, gaps in technical standards, limited availability of charging/swapping stations and limited awareness of low-carbon mobility solutions across different groups of stakeholders. Discussions are ongoing for how shared electric transport services may continue to be provide in Kenya.

Case Study: Contactless Payments on Nairobi's Matatu Networks

Used by 70% of the population in Kenya, matatu buses are a dominant transport mode across the country in which passengers traditionally pay in cash. The automated fare collection provider has announced an initiative to drive contactless payments across bus services. The pilot was designed to reduce the use of cash in response to the COVID-19 pandemic. The platform removes unnecessary tickets and cash payments, offering an accessible payment solution that consumers already use, via a device already in their hand (Intelligent Transport, 2020).

The automated fare collection platform utilises the M-Pesa mobile wallet, which is used by 90% of the population in Kenya. Passengers enter a code on their phone and a debit is made on their wallet, which can be instantly seen by drivers to grant access to the bus. The platform is also built to make fare collection more transparent between the bus owners and drivers. Buses and routes are privately owned by several operators who 'lease' to drivers who must meet daily financial fare targets, before generating their own earnings. Fare pricing differs depending on the route and a range of factors, so digitising the transactions enables visibility and reliability of fare data. With heavily congested routes in Nairobi, digitising fare collection also serves to remove the friction of exchanging money and time taken for drivers to pick up passengers.

M-Pesa is Africa's most successful mobile money service and the region’s largest fintech platform. M-Pesa is the preferred way to make payments across the continent both for the banked and unbanked due to its safety and unmatched convenience. It also provides financial services to millions of people who have mobile phones, but do not have bank accounts, or only have limited access to banking services. Now, M-Pesa provides over 42 million people with a safe, secure, and affordable way to send and receive money, top-up airtime, make bill payments, receive salaries, get short-term loans and much more.

6. CONCLUSIONS

This Chapter presents Task Force 2.1's conclusions and recommendations regarding new mobility and its effects on road infrastructure and transportation. These conclusions are drawn from the work carried out between July 2022 and July 2023, and presented in the Interim Report, as well as incorporating insights gained from discussions and roundtable sessions at the PIARC World Road Congress in Prague in October 2023.

Additionally, these recommendations aim to inform the activities of the new Technical Committee 2.5, Road Infrastructure for Connected and Autonomous Mobility, which has now been activated and commenced its work during the PIARC Strategic Planning Cycle 2024–2027.

6.1. Findings from the External Questionnaire Survey

The Task Force designed and published a questionnaire survey to evaluate different aspects considered to be of great interest in relation to the impact of new mobility technologies, concepts and services on road infrastructure and transport. Responses were received online from a range of countries, representing different income levels. Of the four focus areas of the survey:

- **Autonomous Vehicles** present opportunities for road design and construction, digital infrastructure, communications network and traffic operations as well as for investments. Aspects such as cybersecurity and regulation are a serious challenge. The scale of system change is expected to be major in all aspects considered in the survey, although slightly lesser for current infrastructure, traffic operations, maintenance and transport revenue.
- **Connected Vehicles** raise challenges for road design, data management and cybersecurity. For aspects such as existing infrastructure, road maintenance and transport revenue the impact is considered neutral. The scale of system change is considered in most cases as significant.
- **Electric Vehicles** will probably have neutral impacts, except for new infrastructure and transport revenue. A significant scale of impact is considered in the aspects of network design, new roads, digital infrastructure and transport investment, although to a lesser extent than connected and automated concepts.
- **Shared Vehicles and Services** are expected to have a neutral impact on most aspects analysed, while data management and sharing is considered as a challenge. The answers related to the scale of system change are more dispersed, between negligible and significant scale of change, although this may be an underestimate in the instance of significant take-up of shared autonomous, connected and electric mobility models.

A positive impact is expected for social equity, accessibility, public health, citizen acceptance and experience, wellbeing and quality of life and economic competitiveness and prosperity. For climate change, a very positive and positive impact is evident. Just for gender equality, most respondents mark a neutral impact, although this requires further exploration.

6.2. Findings from the Literature Review

6.2.1. Overall Conclusions and Impacts on Road Infrastructure

New mobility initiatives will have a significant impact on the planning, design, construction, and operation of road infrastructure. Although this is not a new conclusion, by considering these implications, offering practical Operational Design Domains, and adapting to the changing transportation landscape, RNOs can contribute to the development of more efficient, sustainable, and resilient transportation systems.

The precise form and timescale of adaptation of physical road infrastructure to Automated, Connected, Electric and Shared (ACES) Mobility is subject to considerable uncertainty, technical and professional debate, with a need for development and validation of practical design and operational concepts. In the near-term, it appears that roads will look and operate much like today, with minimal changes to enable early safe deployment. However, scaling up ACES Mobility concepts against various vehicle types, functional trip and service propositions and business models, offers the long-term potential for fundamentally re-engineering of how roads are built, managed and maintained.

The adoption of new mobility initiatives does not necessarily change the number of vehicles on the roads, although demand management strategies may be enabled (and required) by technology deployment. Paradoxically, scaling up of CAVs may require comprehensive and effective demand management measures, including dynamic pricing, if a smaller number of driverless vehicles, used more intensively than manual operation, is not to result in the same or increased volume of traffic on the network with resulting congestion, carbon emissions, severance and other undesirable externalities. In the long-term, this is an urban design as well as a road infrastructure issue.

6.2.2. Mobility-Specific Findings

Turning to the specific mobility concepts, Cooperative Intelligent Transport Systems (C-ITS) offer numerous benefits for improving expressway network operation. They play a pivotal role in enhancing safety and smoothness by providing advanced traffic information, empowering drivers to take appropriate actions. To maximize the effectiveness of C-ITS, it is recommended that public-private initiatives and implementation strategies are established to collect and utilize data from road users, ultimately leading to improved road safety, reduced emissions, and traffic efficiency.

Moreover, ensuring the functionality of interconnected infrastructure requires careful consideration of communication design, resource allocation, and redundancy in system-crucial components. Addressing legal concerns related to IT systems, data interchange, accountability, and openness is important. Furthermore, the introduction of CAVs necessitates the development of new approaches to traffic management, and thorough studies should be conducted to establish appropriate regulatory structures. It is highly recommended for decision-making authorities to harmonize with EU legislation to ensure effective and informed decision-making processes.

Platooning has shown promise in reducing fuel consumption and CO2 emissions. To facilitate platooning formation and cost-sharing, the implementation of mediating services and careful planning are necessary. It is important to avoid long platoons and large time gaps near highway entries to prioritize safety. Notably, truck platooning can effectively increase road capacity, particularly in areas with a high proportion of truck traffic.

When considering Mobility-as-a-Service (MaaS) solutions, several key considerations come into play. These include enhancing road safety, promoting sustainable mobility, prioritizing convenience, and fostering collaboration among stakeholders. Compliance with regulations, standards, and obligations is crucial to ensure reliability and standardized dissemination of information. Understanding consumer demands, addressing social implications, and conducting comprehensive research are vital to meet user needs and achieve desirable impacts.

6.2.3. Implications for CAVs

In development and operation of CAVs and associated connected, electric and shared use mobility systems, collaboration among stakeholders is crucial. By fostering collaboration, stakeholders can pool resources, share knowledge, and work towards common goals, including agreed ODDs, accelerating the advancement of CAV technology. Knowledge sharing allows researchers, engineers, policymakers, and industry professionals to exchange insights, match technology with regulation, and avoid duplicating (or conflicting) efforts. Appropriate levels investment in infrastructure at different stages of technological maturity and scale of deployment is necessary to ensure the seamless integration of Avs with roads safely, reliably and allowing the full theoretical benefits of autonomous technology to be realised in reality. Equitable access to AV technology is also important to ensure that its benefits are accessible to all segments of society. Comprehensive regulatory frameworks are necessary to establish guidelines and standards, striking a balance between innovation, market penetration and safety. Regular evaluation and monitoring facilitate improvement, adaptation, and optimization of AV technologies.

Upgrading standards and operating procedures related to vehicle safety, cybersecurity, traffic and environmental impact will ensure that CAVs meet rigorous requirements and contribute to sustainable transportation. Maintenance practices will also be essential for optimal performance and reliability, as well as ensuring that road infrastructure is safe for CAV deployment. Promoting intermediate CAV segregation, simplifying physical road infrastructure, and designing and implementing an effective transition plan are further considerations that will support scaling up of CAV technology in the medium- to long-term.

6.3. Overall Conclusions on Technical Issues

Overall TF 2.1 concludes that in the evolving landscape of modern transportation, the integration of Digital Infrastructure, C-ITS, Platooning, MaaS, and Automated Vehicles signifies a significant step towards enhancing road efficiency, safety, and sustainability. Drawing insights from the literature review in particular, this conclusion explores the transformative potential of each component, underscoring collaborative and innovative approaches that set the stage for a seamlessly connected future. The mobility ecosystem has undergone substantial changes in recent years, embracing connectivity, cooperative systems, automated driving, MaaS, micromobility, and low- or zero-emission vehicles. These emerging technologies and use cases, as discussed in the WRC in Prague, underscore the imperative of addressing challenges and opportunities comprehensively.

6.3.1. Digital Infrastructure: A Foundation for Smart Mobility

Digital Infrastructure serves as the bedrock for intelligent transportation, demonstrating its efficacy through various facets. Cooperative Intelligent Transport Systems (C-ITS) stand out as a pivotal force in enhancing the operational efficiency of expressway networks. Through the strategic dissemination of advanced traffic information, C-ITS ensures safer and smoother driving experiences. The efficiency in data collection, facilitated by public-private initiatives, emerges as a key strategy for optimizing infrastructure functionality.

The WRC session in Prague underscored the need for robust communication design and redundancies in system-crucial components for digital infrastructure. Additionally, insights into machine detection of road markings for connected and automated vehicles are crucial for enhancing road safety in adverse weather conditions.

Robust communication design and redundancies in system-crucial components are deemed necessary for ensuring the functionality of this intricate network. Unmanned Aerial Vehicles (UAVs) contribute significantly to road safety and infrastructure management, utilizing advanced imaging technologies. However, the integration of these technologies brings legal considerations, necessitating meticulous attention to IT systems, data interchange, and accountability. Comprehensive research becomes imperative in areas like traffic environments, and legal aspects to establish performance standards for efficient and sustainable transportation.

Challenges such as high initial costs, regulatory complexity, cybersecurity, and data exchange and management were identified during the WRC session in Prague. These challenges underscore the importance of addressing legal concerns and conducting comprehensive research, aligning with the recommendations in this report.

The transformative impact of automated vehicles on traffic management and regulatory structures is undeniable. The integration of decision-making authorities with EU legislation is emphasized for consistent regulatory frameworks across European countries.

6.3.2. Cooperative Intelligent Transport Systems (C-ITS): Navigating the Future

The experience gathered from diverse pilot projects worldwide underscores the effectiveness of a gradual and iterative approach in launching C-ITS. Starting small and learning progressively emerges as the most practical method. C-ITS services, particularly those utilizing hybrid communication channels, exhibit a significant positive impact on road safety. They achieve this by mitigating harsh braking, instances of speed limit violations, and reaction times. Certain services contribute to emissions reduction, enhance fuel efficiency, and improve overall traffic efficiency, resulting in reduced travel times. It is crucial to acknowledge that not all services yield positive outcomes in these domains.

Insights from the WRC session in Prague emphasize the importance of initiating small-scale pilot projects and overcoming integration challenges, aligning with the recommendations for a gradual and iterative approach.

The widespread availability of C-ITS stations underscores the importance of the short-range ITS-G5 approach, which complements long-range cellular communication in a hybrid communication model within the harmonized communication profile of the European C-Roads Platform. The emergence of automated vehicles, equipped with advanced sensory capabilities and High-Definition (HD) maps, necessitates a profound paradigm shift in transportation. This shift extends to innovative traffic management approaches, with C-ITS playing a pivotal role in providing essential infrastructure support for automated vehicles operating within specific Operational Design Domains.

The utility of C-ITS extends beyond the day-to-day management of road infrastructure. Its effectiveness becomes evident even in times of disasters, offering valuable insights for countries susceptible to such crises. C-ITS aligns seamlessly with broader policy goals, encompassing road safety, traffic efficiency, sustainability, and the evolution of Vehicle-to-Everything (V2X) technology. Achieving a high penetration rate of connected vehicles remains a prerequisite for realizing the full spectrum of benefits associated with C-ITS.

The positive aspects of new mobility, including various business models and reducing externalities, align with the broader policy goals of C-ITS. Insights into data transmission challenges and the need for data management are consistent with the emphasis on addressing legal concerns and conducting comprehensive research.

6.3.3. Platooning: Redefining Fuel Efficiency

Platooning introduces a paradigm shift by presenting substantial potential in reducing fuel consumption and CO_2 emissions. The importance of waiting for reasonable platooning opportunities is highlighted, along with the need for mediating services to facilitate effective platoon formation and equitable cost-benefit sharing. Various methods for implementing platooning systems are explored, with promising results in terms of comparable fuel consumption and emissions, especially with the Platooning Support Function. The study presented in Prague about the impact of platooning on pavements aligns with the emphasis on developing mediating services and exploring various methods for implementing platooning systems. Truck platooning emerges as a strategic avenue to increase road capacity, particularly in areas characterized by a significant proportion of truck traffic.

Insights on the impact of platooning on pavements and the need for optimization resonate with the focus on optimizing platoon configurations and facilitating platooning formation.

6.3.4. Mobility as a Service (MaaS): Shaping the Future of Transportation

Enhancing road safety and promoting sustainable mobility are the cornerstones of Mobility as a Service. The emphasis on convenience and user-centric design underscores the fundamental principles driving the success of MaaS solutions. Collaboration and partnerships play a pivotal role in seamlessly integrating digital infrastructure within the MaaS ecosystem.

Compliance with regulations, standards, and obligations becomes imperative for establishing trust, reliability, and standardized information dissemination.

Challenges such as high initial costs, regulatory complexity, cybersecurity, and data exchange and management were identified in the WRC session in Prague. These challenges underscore the importance of addressing legal concerns and conducting comprehensive research, aligning with the recommendations in this report.

Understanding consumer demands and addressing social implications are fundamental considerations for meeting user needs in the context of MaaS. Recommendations focus on continuous improvement, collaborations, advocacy for standards, comprehensive research, targeted campaigns, and the establishment of shared purposes.

6.3.5. Automated Vehicles: Paving the Way for Autonomy

Collaboration and knowledge sharing are paramount for the deployment of AVs, emphasizing the need for coordination among mobile network operators, neighboring countries, and road operators. This collaboration extends to stakeholders in the automated driving industry, urging them to work together in developing and implementing new mobility solutions.

Infrastructure and technology investment emerge as critical factors for Spain to catch up with leading countries in connected and automated vehicle development. Increased investment in AI, communication infrastructure, sensors, and traffic management systems is essential. Developing local talent and expertise in autonomous vehicle technology is identified as crucial for industry growth.

Equitable access and social considerations are highlighted, urging efforts to ensure that new mobility solutions are accessible to vulnerable populations. Planning and implementation should address social issues, focusing on the needs of marginalized riders to improve accessibility and safety.

Data exchange and optimization are emphasized to enhance route planning, traffic flow management, and overall system efficiency. Stakeholders are encouraged to foster collaboration for real-time data and insights, enabling more efficient investment decisions.

Challenges and opportunities for Low- and Middle-Income Countries (LMICs) are recognized, with a call to address challenges such as initial investment costs, infrastructure upgrades, and workforce development. Tailored solutions are recommended to address the unique challenges faced by LMICs.

The regulatory framework and safety considerations are crucial elements, urging governments to establish comprehensive regulations ensuring safety and compliance for the deployment of automated vehicles and systems. Regular evaluation and monitoring of new mobility solutions are deemed crucial, with findings informing future planning, design, construction, and operation of road infrastructure.

6.4. Conclusions on Horizontal Issues

6.4.1. Overview

The combined work by TF 2.1 and TC 1.1 shows that new mobility technologies, products and services exhibit a range of horizontal, or cross-cutting, challenges beyond the immediate capability, deployment profiles or operational feasibility of the assets, infrastructure or user propositions themselves. These issues, however, are not straight-forward with limited empirical evidence to define a clear way forward and without a single approach or technical solution likely to be applicable in all locations and all circumstances.

There are relatively few sources on new mobility technologies which refer to wider economic and social effects, the choices available to public sector decision makers and the societal processes for how innovation and technology development should be organised.

6.4.2. Social Impacts

New technologies and service models, individually and in combination will have a range of far-reaching impacts on individuals, communities, businesses, industry, public agencies and civil society. Generally, these impacts are seen as positive, such as reduced traffic congestion, enhanced network resilience, fewer accidents and less pollution, but the scale, roadmap, timeline and direction of the full spectrum of effects is subject to great uncertainty, complexity and debate.

There are questions over the distribution, equity, ethics and inclusiveness of benefits of new technologies between different groups within society, including gender, income level, age, urban vs rural and disability, as well as impacts on vulnerable road users. There is a general desire to “leave no one behind” as new concepts are developed, deployed and scaled up, but achieving this in practice may be challenging, with a need for proportionate regulation of private sector actors.

6.4.3. Financial Issues and Business Models

The implementation of innovative mobility solutions brings forth both financial challenges and the need for sustainable business models. Over time, the commercial viability and economics of new mobility concepts will improve, but there are current investment needs, as well as financial and business model risks to overcome in the transition. Again regulation needs to be proportionate to balance the need for private sector return on risk taken and wider public value and interest.

Effective partnerships between the public, academic and private sectors are therefore essential to identify, progress, appropriately regulate and realise the benefits from new technologies. Fair and equitable approaches to management of externalities must also be established.

6.4.4. Low and Middle-Income Countries

New mobility technologies and services exist in, and impact, Low and Middle-Income Countries although the pace and form of innovation is focused to particular applications and locations. More evidence is needed beyond individual case studies. Planning, regulatory and business models, cost-benefit evaluations, as well as the capacities and skills of the respective public and private sectors, and roles of IFIs and NGOs, will also differ markedly from High-Income Countries.

6.5. Recommendations

In the rapidly evolving landscape of intelligent transportation, the following recommendations are crucial for establishing a robust foundation, ensuring effective implementation, and fostering collaboration among stakeholders. New mobility will have several impacts on RNOs encompassing planning, design, procurement, operation, and maintenance.

Overall, it can be stated that future-ready RNOs need to be open-minded and build up their own knowledge. The investment in RNO's staff is seen as crucial for all new mobility solutions. This creation of in-house know-how includes a broad expertise in IT, data processing and data management, as well as in traffic management. This grow in importance, as digitalization and automation will help to ease and quicken processes in Traffic Management Centers.

It is important to cooperate, especially with other RNOs, to harmonize priorities and to ensure interoperability. This applies to the services provided as well as to digital interfaces with other stakeholders. Having several RNOs committed to the provision of specific use-cases enables private actors to invest in these services to support travelers. The same applies to the digital interfaces to be used, which should be harmonized at RNO level and agreed with private stakeholders.

It is also important to be open to discuss and cooperate with other (including industrial) stakeholders. New mobility solutions are built upon a harmonized multi-actor understanding. This includes the agreement on responsibilities. This cooperation forms the basis for adaptations to physical infrastructure and implementation of digital interfaces/services in digital infrastructure.

Where updates or upgrades of RNO infrastructure is required, have emerging and approaching mobility solutions in mind. This includes both, the physical as well as the digital infrastructure; as both are addressed through the mobility solutions discussed. Usually, it is cheaper overall to consider additional requirements during regular updates/upgrades.

For the specific technical new mobility solutions, the following recommendations are given:

6.5.1. Digital Infrastructure

Ensure, that RNO staff are well skilled and trained

Proper training needs to be prepared and provided to RNO staff to ensure the proper operation and maintenance of the digital infrastructure. The availability of trained and skilled staff will reduce dependency on industrial suppliers and will help to operate, maintain and develop the digital infrastructure in accordance with all needs and user expectations.

Establishing Resilient Communication Design

A resilient digital infrastructure requires a design that incorporates fail-safe elements in system-crucial components. This ensures the reliability and resilience of the overall system, minimizing the risk of disruptions and data losses.

Addressing Legal Concerns

To mitigate legal concerns related to IT systems and data interchange, stakeholders must engage in a proactive dialogue with legal experts and data protection officers. This includes thorough assessments and adherence to evolving data protection regulations to ensure compliance and foster trust among users.

Conducting Comprehensive Research

Conducting comprehensive research in traffic environments, including legal aspects is essential. This research will inform the development and enhancement of intelligent transport systems, addressing challenges and identifying opportunities for improvement.

Collaborating with International/Regional Legislation

Collaboration with International or regional legislation is vital to establish consistent regulatory frameworks. This ensures seamless integration and interoperability across borders, promoting a unified and standardized approach to intelligent transport.

6.5.2. C-ITS (Cooperative Intelligent Transport Systems)

Initiating Small-Scale Pilot Projects

Kickstarting C-ITS implementation through small-scale pilot projects allows for practical testing and refinement before broader deployment. Collaboration between, and cooperation with, all stakeholders involved – including public and private organizations – will enable the full potential of C-ITS to be realised. This approach enables stakeholders to identify challenges and fine-tune solutions in a controlled environment.

Focus on Use cases

When discussing C-ITS the communication technologies often form the basis for discussions. While communication technologies will evolve over time, it is highly recommended that use-cases are considered first and then how communication technologies can support those use-cases.

Use C-ITS to improve existing Traffic Management Systems

When investing in C-ITS, applications need to be integrated into the overall Traffic Management System and not created as a separate system. RNOs will receive data from Connected Vehicles that act as mobile sensors along the transport network. This data should be used to improve existing Traffic Management procedures.

Overcoming Integration Challenges

Proactively overcoming challenges in integrating new technologies is essential. Stakeholders should invest in research and development to identify and address barriers, ensuring a smooth transition to advanced transportation systems.

6.5.3. Platooning

Developing Mediating Services

Stakeholders should invest in the development of mediating services to facilitate effective platoon formation. These services act as intermediaries, optimizing communication and coordination among vehicles in a platoon.

Exploring Implementation Methods

Exploring various methods for implementing platooning systems is crucial. This includes evaluating technological options and considering factors such as vehicle compatibility, communication protocols, and infrastructure requirements.

Ensure that physical infrastructure is prepared to operate Platoons

Platoons have several requirements on the physical infrastructure that need to be met by RNOs. This includes that bridges need to be prepared to carry platoons. The dynamic creation of platoons requires road sections of at least 10 km; shorter sections are unlikely to be able to allow platooning.

6.5.4. MaaS (Mobility as a Service)

Continuous Improvement of MaaS Platforms

Stakeholders should focus on the continuous improvement and innovation of MaaS platforms. This involves regular updates, enhancements, and user-centric improvements to provide seamless and efficient mobility services.

Fostering Collaborations and Partnerships

Building strong collaboration and partnerships among stakeholders is essential for the success of MaaS. This includes cooperation between public and private entities, fostering an ecosystem that supports the growth of intelligent transportation solutions.

Advocating for Standards and Regulations

Advocacy for the adoption of standards and regulations is crucial. Establishing a regulatory framework ensures consistency and reliability in MaaS platforms, fostering public trust and widespread adoption.

Conducting Comprehensive Research and Analysis

Continuous research and analysis are imperative to keep abreast of evolving mobility trends and user preferences. This information informs the ongoing development of MaaS platforms, ensuring they remain relevant and responsive to user needs.

Implementing Campaigns and Educational Initiatives

Implementing targeted campaigns and educational initiatives is essential for raising awareness and promoting the benefits of MaaS. This encourages user adoption and builds a positive perception of intelligent transportation solutions.

Establishing a Shared Purpose

Establishing a shared purpose among stakeholders is vital for the sustained growth of MaaS. This involves aligning objectives, values, and goals to create a cohesive and collaborative community dedicated to advancing intelligent transportation.

6.5.5. Automated Vehicles (AV)

Encouraging Collaboration and Knowledge Sharing

Encouraging collaboration and knowledge sharing among stakeholders is key to overcoming challenges and accelerating the development of AV technology. This includes open communication channels, collaborative research, and shared best practices.

Increasing Investment in AI and Technological Infrastructure

A significant increase in investment in AI and technological infrastructure is essential to drive advances in AV technology. This financial commitment supports research, development, and the implementation of cutting-edge solutions.

Ensuring Equitable Access and Addressing Social Considerations

Ensuring equitable access to AV technology and addressing social considerations is paramount. Stakeholders must actively work to prevent disparities in access and consider the broader societal impacts of AV implementation.

Fostering Data Exchange and Collaboration

Fostering data exchange and collaboration is crucial for optimizing AV performance. This involves creating standardized protocols for data sharing and collaboration among AV systems to enhance overall efficiency and safety.

Establishing Comprehensive Regulatory Frameworks

Establishing comprehensive regulatory frameworks is vital for the safe and responsible deployment of AVs. These regulations should address technical standards, safety protocols, and ethical considerations to build public trust.

Regularly Evaluating and Monitoring New Mobility Solutions

Stakeholders should commit to regularly evaluating and monitoring new mobility solutions, ensuring that AV technology evolves responsibly. This includes continuous assessments of safety, performance, and societal impacts.

6.5.6. Horizontal Issues

Assessing Social Impacts Comprehensively

As well as their technological capability, maturity and operational readiness, new mobility technologies should be assessed for the distribution, equity, ethics and inclusivity of benefits versus costs between different groups in society, including vulnerable road users, gender and age. As far as reasonably possible, there should be a requirement to “leave no on behind” in terms of development, deployment and scaling up of initiatives, including recognising risks around unconscious bias.

Developing Viable Business Models

Development and deployment of new mobility concepts should be accompanied, and supported, by sustainable funding and financing models as well as effective business models. The latter should include proportionate and agile regulation by public agencies which recognises the legitimacy of private sector return on investment in line with risk and relative to the need to protect and enhance public value.

Focusing on Low- and Middle-Income Countries

To date the new mobility technology debate has been very much on High Income Countries. Yet there are many needs and potential use cases in LMICs which must be developed more comprehensively, including through assistances of IFIs and NGOs. This includes designing appropriate applications based on differing user bases and needs, varying the business case in terms of costs and benefits and recognising variations in the capacity of RNOs in these circumstances to make rapid progress. PIARC has a key role to play in facilitating progress in this respect.

6.6. Technical Committee 2.5

The key topics examined by TF 2.1 will now be taken forward by the new TC 2.5 – Road Infrastructure for Connected and Autonomous Mobility – over the 2024 – 2027 Cycle, focused on three main lines of enquiry:

- Roads for connected, cooperative and automated mobility, considering both physical and digital infrastructure;
- Automated driving and infrastructure; and
- Architectures and business models for public authorities, including partnerships with industry and the private sector.

Task Force 2.1 is grateful to the efforts of its members, contributions from other Task Forces and Technical Committees, as well as colleagues across PIARC for the evidence and analysis presented and commends its work to TC 2.5 and other PIARC groupings for future use in the 2024 – 2027 Strategic Planning Cycle.

7. GLOSSARY

Term	Definition
ACES	Automated, Connected, Electric and Shared
ADB	Asian Development Bank
ADS	Advanced Driving System
AI	Artificial Intelligence
AV	Automated Vehicle
CAM	Connected and Automated Mobility
CAV	Connected and Automated Vehicle
C-ITS	Cooperative Intelligent Transport System
CO_2	Carbon Dioxide
CV	Connected Vehicle
DDT	Dynamic Driving Task
EM	Electric Mobility
ETC	Electronic Toll Collection
EU	European Union
EV	Electric Vehicle
GNI	Gross National Income
GPS	Global Positioning System.
HD Maps	High Definition Maps
HLN	Hazardous Location Notification
ICE	Internal Combustion Engine
IFI	International financial institution
IoT	Internet of Things
ITS	Intelligent Transport System
IVS	In-vehicle Signage
LAI	Look-ahead Information
LMIC	Low- and Middle-Income Countries
MaaS	Mobility as a Service
MEC	Multi-Access Edge Computing
NGO	Non-Governmental Organization
ODD	Operational Design Domain
OECD	Organisation for Economic Co-operation and Development
OEM	Original Equipment Manufacturer
PVD	Probe Vehicle Data
RNO	Road Network Operators/Operations

Term	Definition
RSU	Road Side Unit
RWW	Road Works Warning
SAE	Society of Automotive Engineers
SECAV	Shared, Electric, Connected and Automated Vehicle
SI	Signalised Intersection
SNL	Split to Leader
SPaT	Signal Phase and Time
TC	Technical Committee
TF	Task Force
TMC	Traffic Control Centres
UAVs	Unmanned Aerial Vehicle
UNDP	United Nations Development Programme
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to everything
WRC	World Road Congress
ZEV	Zero Emission Vehicle

ANNEX A – LITERATURE REVIEW – KEY REFERENCES

Task Force 2.1 – Internal Survey

1. Connected Vehicles – Challenges and Opportunities for Road Operators and Authorities - 2019R11EN – PIARC TF B.1
2. Automated Vehicles – Challenges and Opportunities for Road Operators and Authorities – 2021R03EN – PIARC TF B.2 2021
3. C-Roads Working Group 3 – Evaluation and Assessment - Final Report - 2021
4. Project 5G Mobix in Spain – 2022
5. Report on Connected and Automated Vehicles. National Vehicles Manufacturer – Spain 2022
6. Case Set for Automated Driving Industry Applications – China 2022
7. Report on Japanese National Laws Related to Automated Driving – Japan 2023
8. Automated Driving Mobility Services in Regional Communities – Japan 2023
9. Main Axes around the Deployment of Automated Driving in Spain – Spain 2022
10. Facilitating Automated Driving – Requirements of Network Operators – Europe 2020
11. INFRAMIX - Evaluation, Impact Analysis and New Safety Performance Criteria – Europe 2020
12. MANTRA: Making Use of Automation for National Transport and Road Authorities – Europe 2020
13. A Rhode Trip. Lessons from Little Roady Automated Microtransit pilot – RIDOT USA 2022
14. French National Automated Vehicle Strategy – France 2023
15. French National Regulation on AV – France 2023
16. Acceptability of the automated vehicle: bibliographical review of work – France 2021
17. DGT 3.0 Connected Vehicle Platform – Spain 2022
18. The effect of connected and automated vehicles on traffic management. Central System project – Hungary 2023

Technical Committee 1.1 – Previous Reporting and Literature Review

1. The Role of Transport Agencies in Shaping Disruptive Technologies and Service Models – Technical Report – 2023R01EN – PIARC TC 1.1 2023
2. The Role of Transport Agencies in Shaping Disruptive Technologies and Service Models – Private Sector Roundtable – 2022R19EN – PIARC TC 1.1 2023
3. The Role of Transport Agencies in Shaping Disruptive Technologies and Service Models Literature Review – Unpublished – PIARC TC 1.1 2021
4. UK Government Office for Science. (2019). The Future of Mobility: A Time of Unprecedented Change in the Transport System
5. Arthur D. Little. (2018). Future of Mobility 3.0
6. KPMG. (2019). Mobility 2030: Transforming the Mobility Landscape
7. Oxford Institute for Energy Studies. (2018). Disruptive Change in the Transport Sector: Eight Key Takeaways
8. Spear, J. (2020). Micrombility - Perspectives on the Mess and Success of a New Form of Urban Mobility
9. Marsden, G., Reardon, L. (Ed) (2018): Governance of the Smart Mobility Transition
10. Curtis, C., Stone, J., Legacy, C., & Ashmore, D. (2019). Governance of Future Urban Mobility: A Research Agenda (In Urban Policy and Research)

ANNEX B – RESULTS OF EXTERNAL SURVEY

SECTION 1 – ORGANISATIONAL INFORMATION

First section complies seven general questions about the main characteristics of the respondents.

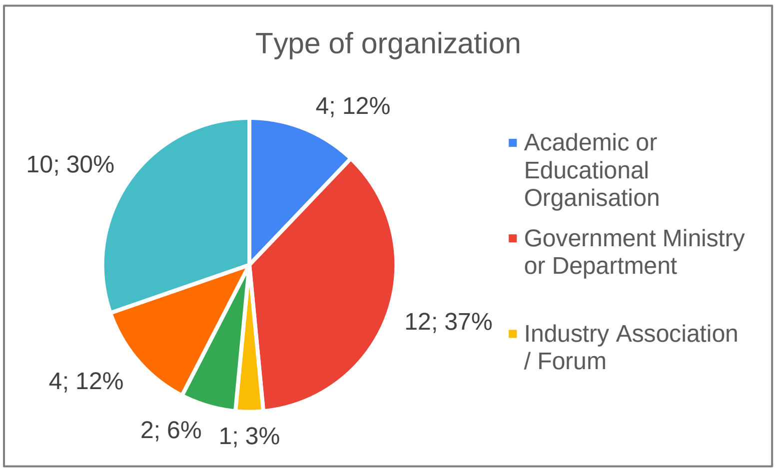

Figure B.1: Characteristics of the respondents. Type of organization.

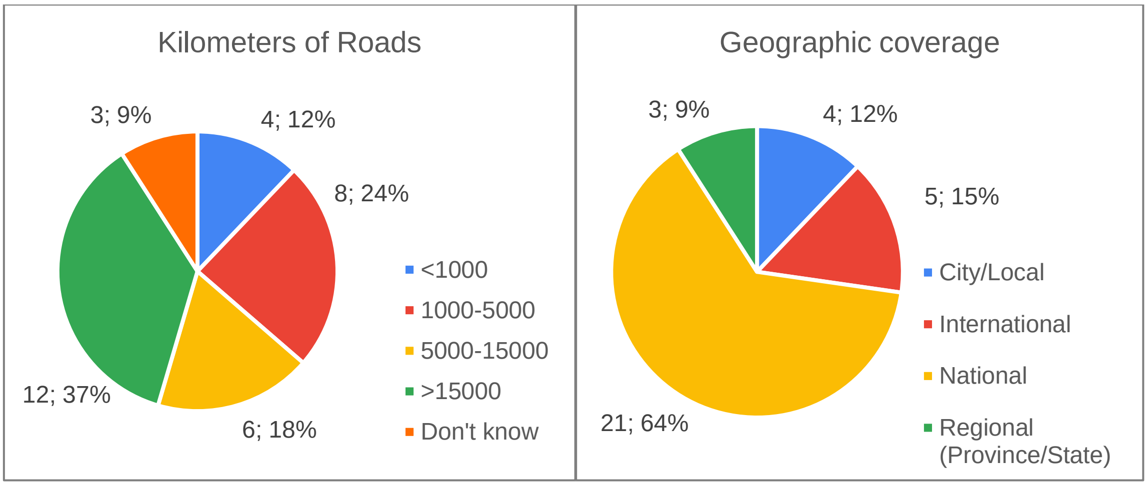

Figure B.2: Characteristics of the respondents. Kilometers of roads and geographic coverage.

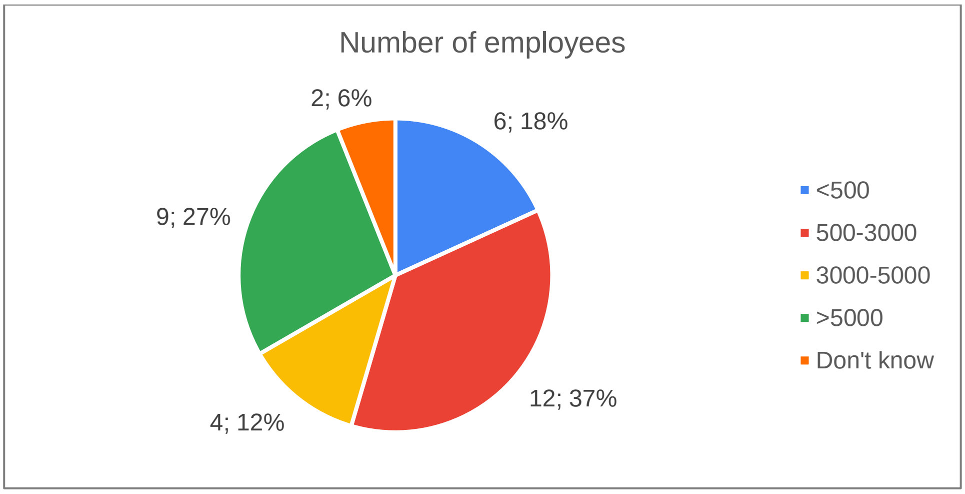

Figure B.3: Characteristics of the respondents. Number of employees.

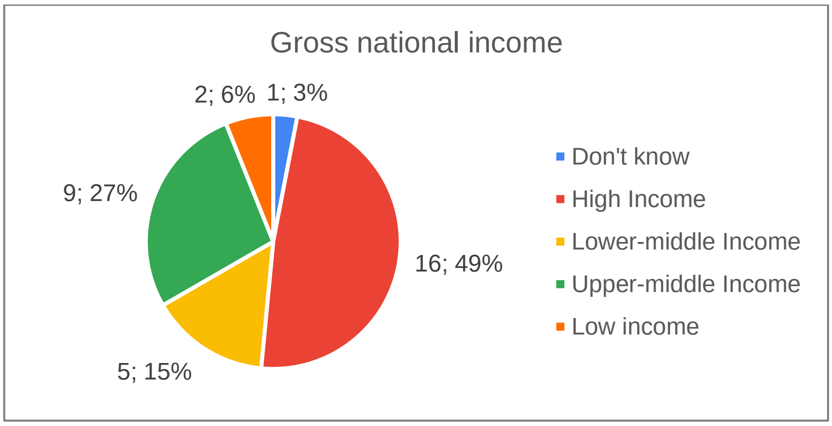

Figure A.4: Characteristics of the respondents. Gross national income.

SECTION 2 – IMPACT OF NEW MOBILITY TECHNOLOGIES AND SERVICES

2. How would you classify the following new mobility technologies and services in terms of their PREDOMINANT IMPACT on road administration in your jurisdiction over the next 30 years?

	Very Positive		Positive		Neutral		Negative		Very negative		No Opinion		No Answer		Total
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº
Automated/ Autonomous vehicles	6	18%	14	42%	7	21%	3	9%	0	0%	2	6%	1	3%	33
E-deliveries and automated logistics	10	30%	11	33%	6	18%	1	3%	1	3%	3	9%	1	3%	33
Connected vehicles	9	27%	14	42%	8	24%	1	3%	0	0%	0	0%	1	3%	33
Platooning	4	12%	5	15%	6	18%	9	27%	1	3%	7	21%	1	3%	33
Electric vehicles	11	33%	12	36%	8	24%	0	0%	0	0%	1	3%	1	3%	33
Alternative fuel vehicles (e.g. hydrogen)	6	18%	15	45%	9	27%	0	0%	0	0%	2	6%	1	3%	33
Micromobility (e-scooters, e-bikes, etc.)	7	21%	8	24%	12	36%	1	3%	2	6%	2	6%	1	3%	33
Mobility as a Service	10	30%	16	48%	6	18%	0	0%	0	0%	0	0%	1	3%	33
Digital highways and next generation ITS	11	33%	10	30%	6	18%	1	3%	1	3%	3	9%	1	3%	33

Table B.1: Summary of number and percentage of answers on the predominant impact of new mobility technologies on road administration over the next 30 years.

3. How would you classify the PREDOMINANT IMPACT new and emerging Automated/Autonomous, Connected, Electric and Shared technologies and services are expected to have on the following road transport outcomes in your jurisdiction over the next 30 years?

	Very Positive		Positive		Neutral		Negative		Very negative		No Opinion		No Answer		Total
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº
Network efficiency and congestion	8	24%	19	58%	4	12%	0	0%	0	0%	1	3%	1	3%	33
Road safety	16	48%	10	30%	3	9%	3	9%	0	0%	0	0%	1	3%	33
Accessibility	7	21%	13	39%	11	33%	1	3%	0	0%	0	0%	1	3%	33
Environmental sustainability / Climate change	10	30%	17	52%	4	12%	0	0%	0	0%	1	3%	1	3%	33
Resilience	2	6%	13	39%	11	33%	4	12%	0	0%	2	6%	1	3%	33
Security	8	24%	10	30%	7	21%	5	15%	0	0%	2	6%	1	3%	33
Economic development	8	24%	15	45%	6	18%	1	3%	0	0%	2	6%	1	3%	33
Energy efficiency	11	33%	17	52%	2	6%	1	3%	0	0%	1	3%	1	3%	33

Table B.2: Summary of number and percentage of answers on the predominant impact of new and emerging Automated/Autonomous, Connected, Electric and Shared technologies and services expected on road transport outcomes.

4. How would you rate the following new mobility technologies and services in terms of SCALE OF EXPECTED IMPACT on road transport activity in your jurisdiction over the next 30 years?

	Very Low Impact		Low Impact		Medium Impact		High Impact		Very High Impact		No Opinion		No Answer		Total
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº
Automated/ Autonomous vehicles	2	6%	2	6%	5	15%	12	36%	8	24%	1	3%	3	9%	33
E-deliveries & automated logistics	0	0%	7	21%	8	24%	14	42%	3	9%	0	0%	1	3%	33
Connected vehicles	1	3%	7	21%	7	21%	10	30%	7	21%	0	0%	1	3%	33
Platooning	3	9%	7	21%	9	27%	6	18%	2	6%	5	15%	1	3%	33
Electric vehicles	1	3%	3	9%	9	27%	11	33%	7	21%	1	3%	1	3%	33
Alternative fuel vehicles (e.g. hydrogen)	2	6%	4	12%	10	30%	7	21%	6	18%	2	6%	2	6%	33
Micromobility (e-scooters, e-bikes, etc.)	4	12%	5	15%	9	27%	8	24%	3	9%	1	3%	3	9%	33
MaaS	2	6%	7	21%	9	27%	8	24%	5	15%	1	3%	1	3%	33
Digital highways and next generation ITS	2	6%	2	6%	6	18%	11	33%	9	27%	2	6%	1	3%	33

Table B.3: Summary of number and percentage of answers on the impact of new mobility technologies and services on road transport administration.

5-A. How would you CLASSIFY THE IMPACT Automated/Autonomous Vehicles are expected to have on the following aspects of the road transport system in your jurisdiction over the next 30 years?

	Serious Challenge		Challenge		Neutral		Opportunity		Significant Opportunity		No Opinion		No Answer		Total
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº
Network design, technical standards and manuals	5	15%	7	21%	6	18%	8	24%	6	18%	0	0%	1	3%	33
Existing road infrastructure	4	12%	9	27%	7	21%	7	21%	5	15%	0	0%	1	3%	33
New road infrastructure	0	0%	7	21%	5	15%	15	45%	5	15%	0	0%	1	3%	33
Digital infrastructure (ITS and back office)	5	15%	6	18%	6	18%	7	21%	7	21%	1	3%	1	3%	33
Communications network	4	12%	9	27%	4	12%	10	30%	5	15%	0	0%	1	3%	33
Data management/ sharing	4	12%	11	33%	2	6%	10	30%	5	15%	0	0%	1	3%	33
Cybersecurity	10	30%	8	24%	2	6%	5	15%	6	18%	1	3%	1	3%	33
Network and traffic operations	4	12%	8	24%	3	9%	10	30%	7	21%	0	0%	1	3%	33
Road maintenance	6	18%	2	6%	13	39%	4	12%	7	21%	0	0%	1	3%	33
Transport revenue	3	9%	5	15%	8	24%	7	21%	5	15%	4	12%	1	3%	33
Transport investment	5	15%	4	12%	5	15%	8	24%	7	21%	3	9%	1	3%	33
Regulation	8	24%	7	21%	2	6%	7	21%	7	21%	1	3%	1	3%	33

Table B.4: Summary of number and percentage of the impact classification of Automated/Autonomous vehicles expected to have on road transport system aspects.

5-B. How would you CLASSIFY THE IMPACT Connected Vehicles & Services are expected to have on the following aspects of the road transport system in your jurisdiction over the next 30 years?

	Serious Challenge		Challenge		Neutral		Opportunity		Significant Opportunity		No Opinion		No Answer		Total
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº
Network design, technical standards and manuals	3	9%	8	24%	8	24%	6	18%	7	21%	0	0%	1	3%	33
Existing road infrastructure	5	15%	7	21%	9	27%	4	12%	7	21%	0	0%	1	3%	33
New road infrastructure	2	6%	3	9%	8	24%	13	39%	6	18%	0	0%	1	3%	33
Digital infrastructure (ITS and back office)	4	12%	8	24%	2	6%	11	33%	6	18%	1	3%	1	3%	33
Communications network	6	18%	7	21%	4	12%	9	27%	6	18%	0	0%	1	3%	33
Data management/ sharing	3	9%	11	33%	2	6%	8	24%	8	24%	0	0%	1	3%	33
Cybersecurity	7	21%	9	27%	6	18%	6	18%	4	12%	0	0%	1	3%	33
Network and traffic operations	1	3%	4	12%	6	18%	9	27%	12	36%	0	0%	1	3%	33
Road maintenance	3	9%	3	9%	12	36%	7	21%	7	21%	0	0%	1	3%	33
Transport revenue	2	6%	3	9%	11	33%	6	18%	6	18%	4	12%	1	3%	33
Transport investment	3	9%	2	6%	8	24%	10	30%	5	15%	4	12%	1	3%	33
Regulation	4	12%	8	24%	3	9%	10	30%	6	18%	1	3%	1	3%	33

Table B.5: Summary of number and percentage of the impact classification of Connected vehicles and services expected to have on road transport system aspects.

5-C. How would you CLASSIFY THE IMPACT Electric Vehicles are expected to have on the following aspects of the road transport system in your jurisdiction over the next 30 years?

	Serious Challenge		Challenge		Neutral		Opportunity		Significant Opportunity		No Opinion		No Answer		Total
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº
Network design, technical standards and manuals	2	6%	7	21%	12	36%	8	24%	3	9%	0	0%	1	3%	33
Existing road infrastructure	3	9%	5	15%	11	33%	9	27%	4	12%	0	0%	1	3%	33
New road infrastructure	4	12%	4	12%	8	24%	10	30%	6	18%	0	0%	1	3%	33
Digital infrastructure (ITS and back office)	1	3%	2	6%	20	61%	5	15%	3	9%	1	3%	1	3%	33
Communications network	1	3%	4	12%	17	52%	8	24%	2	6%	0	0%	1	3%	33
Data management/ sharing	1	3%	7	21%	13	39%	9	27%	2	6%	0	0%	1	3%	33
Cybersecurity	2	6%	9	27%	14	42%	6	18%	1	3%	0	0%	1	3%	33
Network and traffic operations	2	6%	3	9%	18	55%	5	15%	4	12%	0	0%	1	3%	33
Road maintenance	1	3%	6	18%	15	45%	6	18%	3	9%	1	3%	1	3%	33
Transport revenue	1	3%	6	18%	9	27%	10	30%	2	6%	4	12%	1	3%	33
Transport investment	2	6%	5	15%	10	30%	7	21%	5	15%	3	9%	1	3%	33
Regulation	1	3%	7	21%	13	39%	6	18%	3	9%	2	6%	1	3%	33

Table B.6: Summary of number and percentage of the impact classification of Electric vehicles expected to have on road transport system aspects.

5-D. How would you CLASSIFY THE IMPACT Shared Vehicles & Services are expected to have on the following aspects of the road transport system in your jurisdiction over the next 30 years?

	Serious Challenge		Challenge		Neutral		Opportunity		Significant Opportunity		No Opinion		No Answer		Total
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº
Network design, technical standards and manuals	1	3%	6	18%	16	48%	7	21%	1	3%	1	3%	1	3%	33
Existing road infrastructure	1	3%	3	9%	16	48%	8	24%	3	9%	1	3%	1	3%	33
New road infrastructure	1	3%	1	3%	15	45%	10	30%	4	12%	1	3%	1	3%	33
Digital infrastructure (ITS and back office)	0	0%	6	18%	14	42%	10	30%	0	0%	2	6%	1	3%	33
Communications network	1	3%	10	30%	10	30%	8	24%	2	6%	1	3%	1	3%	33
Data management/ sharing	1	3%	12	36%	6	18%	8	24%	4	12%	1	3%	1	3%	33
Cybersecurity	4	12%	9	27%	13	39%	4	12%	1	3%	1	3%	1	3%	33
Network and traffic operations	1	3%	6	18%	11	33%	7	21%	6	18%	1	3%	1	3%	33
Road maintenance	1	3%	3	9%	18	55%	6	18%	3	9%	1	3%	1	3%	33
Transport revenue	1	3%	6	18%	7	21%	9	27%	3	9%	6	18%	1	3%	33
Transport investment	1	3%	2	6%	12	36%	9	27%	3	9%	5	15%	1	3%	33
Regulation	1	3%	9	27%	10	30%	5	15%	4	12%	3	9%	1	3%	33

Table B.7: Summary of number and percentage of the impact classification of Shared vehicles and services expected to have on road transport system aspects.

6-A. How would you rate the SCALE OF SYSTEM CHANGE expected to be brought by Automated/Autonomous Vehicles on the following aspects of the road transport system in your jurisdiction over the next 30 years?

	Negligible		Minor		Moderate		Significant		Major		No Opinion		No Answer		Total
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº
Network design, technical standards and manuals	2	6%	3	9%	5	15%	10	30%	11	33%	1	3%	1	3%	33
Existing road infrastructure	1	3%	5	15%	5	15%	10	30%	10	30%	1	3%	1	3%	33
New road infrastructure	1	3%	5	15%	8	24%	7	21%	10	30%	1	3%	1	3%	33
Digital infrastructure (ITS and back office)	0	0%	3	9%	6	18%	10	30%	11	33%	2	6%	1	3%	33
Communications network	0	0%	2	6%	8	24%	7	21%	12	36%	3	9%	1	3%	33
Data management/ sharing	0	0%	2	6%	7	21%	7	21%	14	42%	2	6%	1	3%	33
Cybersecurity	0	0%	2	6%	7	21%	9	27%	13	39%	1	3%	1	3%	33
Network and traffic operations	0	0%	2	6%	5	15%	15	45%	8	24%	2	6%	1	3%	33
Road maintenance	1	3%	8	24%	7	21%	8	24%	6	18%	2	6%	1	3%	33
Transport revenue	2	6%	4	12%	4	12%	10	30%	3	9%	9	27%	1	3%	33
Transport investment	0	0%	4	12%	2	6%	9	27%	11	33%	6	18%	1	3%	33
Regulation	0	0%	1	3%	8	24%	7	21%	15	45%	1	3%	1	3%	33

Table B.8: Summary of number and percentage of the scale of system change expected to be brought by Automated/Autonomous Vehicles.

6-B. How would you rate the SCALE OF SYSTEM CHANGE expected to be brought by Connected Vehicles & Services on the following aspects of the road transport system in your jurisdiction over the next 30 years?

	Negligible		Minor		Moderate		Significant		Major		No Opinion		No Answer		Total
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº
Network design, technical standards and manuals	3	9%	2	6%	6	18%	11	33%	7	21%	2	6%	2	6%	33
Existing road infrastructure	2	6%	2	6%	8	24%	11	33%	7	21%	1	3%	2	6%	33
New road infrastructure	1	3%	4	12%	11	33%	9	27%	5	15%	1	3%	2	6%	33
Digital infrastructure (ITS and back office)	0	0%	4	12%	3	9%	14	42%	8	24%	2	6%	2	6%	33
Communications network	0	0%	2	6%	5	15%	17	52%	6	18%	1	3%	2	6%	33
Data management/ sharing	0	0%	1	3%	5	15%	13	39%	11	33%	1	3%	2	6%	33
Cybersecurity	0	0%	5	15%	5	15%	11	33%	9	27%	1	3%	2	6%	33
Network and traffic operations	1	3%	2	6%	10	30%	9	27%	8	24%	1	3%	2	6%	33
Road maintenance	4	12%	7	21%	6	18%	8	24%	5	15%	1	3%	2	6%	33
Transport revenue	2	6%	6	18%	6	18%	8	24%	2	6%	7	21%	2	6%	33
Transport investment	0	0%	5	15%	7	21%	7	21%	6	18%	6	18%	2	6%	33
Regulation	2	6%	2	6%	8	24%	7	21%	10	30%	2	6%	2	6%	33

Table B.9: Summary of number and percentage of the scale of system change expected to be brought by Connected vehicles and services.

6-C. How would you rate the SCALE OF SYSTEM CHANGE expected to be brought by Electric Vehicles on the following aspects of the road transport system in your jurisdiction over the next 30 years?

	Negligible		Minor		Moderate		Significant		Major		No Opinion		No Answer		Total
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº
Network design, technical standards and manuals	4	12%	7	21%	8	24%	9	27%	3	9%	1	3%	1	3%	33
Existing road infrastructure	3	9%	9	27%	7	21%	6	18%	6	18%	1	3%	1	3%	33
New road infrastructure	3	9%	9	27%	6	18%	9	27%	4	12%	1	3%	1	3%	33
Digital infrastructure (ITS and back office)	6	18%	6	18%	8	24%	8	24%	3	9%	1	3%	1	3%	33
Communications network	9	27%	4	12%	10	30%	5	15%	4	12%	0	0%	1	3%	33
Data management/ sharing	5	15%	7	21%	11	33%	5	15%	4	12%	0	0%	1	3%	33
Cybersecurity	8	24%	4	12%	11	33%	5	15%	4	12%	0	0%	1	3%	33
Network and traffic operations	6	18%	7	21%	8	24%	7	21%	4	12%	0	0%	1	3%	33
Road maintenance	6	18%	8	24%	9	27%	6	18%	3	9%	0	0%	1	3%	33
Transport revenue	4	12%	6	18%	7	21%	7	21%	3	9%	5	15%	1	3%	33
Transport investment	1	3%	7	21%	5	15%	11	33%	5	15%	3	9%	1	3%	33
Regulation	3	9%	7	21%	10	30%	7	21%	4	12%	1	3%	1	3%	33

Table B.10: Summary of number and percentage of the scale of system change expected to be brought by Electric vehicles.

6-D. How would you rate the SCALE OF SYSTEM CHANGE expected to be brought by Shared Vehicles & Services on the following aspects of the road transport system in your jurisdiction over the next 30 years?

	Negligible		Minor		Moderate		Significant		Major		No Opinion		No Answer		Total
	№	%	№	%	№	%	№	%	№	%	№	%	№	%	№
Network design, technical standards and manuals	9	27%	9	27%	3	9%	5	15%	5	15%	1	3%	1	3%	33
Existing road infrastructure	8	24%	9	27%	4	12%	9	27%	1	3%	1	3%	1	3%	33
New road infrastructure	9	27%	8	24%	4	12%	6	18%	4	12%	1	3%	1	3%	33
Digital infrastructure (ITS and back office)	4	12%	11	33%	6	18%	4	12%	5	15%	2	6%	1	3%	33
Communications network	5	15%	9	27%	5	15%	8	24%	4	12%	1	3%	1	3%	33
Data management/sharing	3	9%	9	27%	6	18%	9	27%	4	12%	1	3%	1	3%	33
Cybersecurity	8	24%	4	12%	6	18%	7	21%	5	15%	2	6%	1	3%	33
Network and traffic operations	8	24%	4	12%	7	21%	8	24%	4	12%	1	3%	1	3%	33
Road maintenance	11	33%	5	15%	7	21%	6	18%	1	3%	2	6%	1	3%	33
Transport revenue	7	21%	4	12%	5	15%	9	27%	1	3%	6	18%	1	3%	33
Transport investment	5	15%	8	24%	5	15%	8	24%	0	0%	6	18%	1	3%	33
Regulation	7	21%	5	15%	6	18%	9	27%	3	9%	2	6%	1	3%	33

Table B.11: Summary of number and percentage of the scale of system change expected to be brought by Shared vehicles and services.

7. Please indicate any activities that your organisation has undertaken or is planning to undertake to ADDRESS THE TECHNICAL CHALLENGES AND OPPORTUNITIES associated with new and emerging Automated/Autonomous, Connected, Electric and Shared technologies and services.

9 blank responses and 24 responses with activities related to the identification of technical challenges and associated opportunities were collected.

8. Please indicate any activities your organisation has undertaken or is planning to undertake to IDENTIFY GOOD PRACTICES associated with adopting new and emerging Automated/Autonomous, Connected, Electric and Shared technologies and services.

3 blank responses and 20 entities that did provide activities carried out and/or planned in this area.

SECTION 3 – SOCIAL IMPLICATIONS

9. How would you rate the predominant impact of emerging technologies on the following social problems in the next 30 years?

	Very Positive		Positive		Neutral		Negative		Very Negative		No Opinion		Total
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº
Social equity	5	15%	8	24%	7	21%	5	15%	3	9%	5	15%	33
Gender equality	1	3%	8	24%	17	52%	1	3%	1	3%	5	15%	33
Disability outcomes / Accessibility	7	21%	19	58%	5	15%	0	0%	0	0%	2	6%	33
Environmental sustainability / Climate change	13	39%	13	39%	1	3%	1	3%	2	6%	3	9%	33
Public health	7	21%	17	52%	5	15%	2	6%	1	3%	1	3%	33
Customer/citizen acceptance	5	15%	16	48%	6	18%	2	6%	2	6%	2	6%	33
Customer/citizen experience	4	12%	18	55%	6	18%	2	6%	1	3%	2	6%	33
Wellbeing and quality of life	6	18%	16	48%	6	18%	1	3%	2	6%	2	6%	33
Economic competitiveness and prosperity	5	15%	15	45%	7	21%	1	3%	2	6%	3	9%	33

Table B.12: Summary of number and percentage of answers on the predominant impact of emerging technologies on social problems.

SECTION 4 – REQUEST FOR CASE STUDIES AND FURTHER INFORMATION

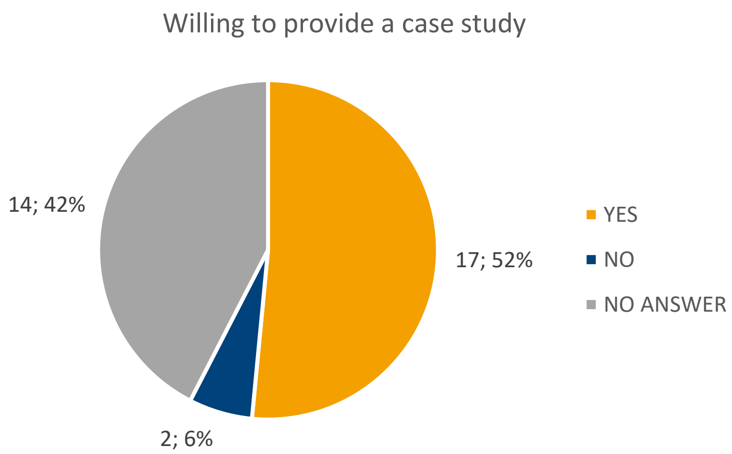

Figure B.12: Characteristics of the respondents. Willing to provide a case study.

ANNEX C – CONCLUSIONS OF TF 2.1 SESSION AT WRC

Date: 3/10/2023

Authors: Ana Luz Jiménez, Abdelmenane Hedli, Antonio Granado and Ignacio González Rodríguez

Keywords

Disruptive mobility, Mobility as a Service (MaaS), Automated driving, Cooperative Connected and Automated Mobility (CCAM), Autonomous Vehicles (AV), Micromobility, Platooning, Electric Vehicle (EV), literature review, Intelligent Transport System (ITS), Road Infrastructure, Connected vehicles, E-Delivery, Cybersecurity, Shared Mobility, Digital Highways and Next Generation ITS.

Topic of the Session

The mobility ecosystem has experienced significant change in recent years: connectivity, cooperative systems, automated driving, mobility as a service (MaaS), micromobility, low emission vehicles - new technologies and use cases that need new approaches and answers from road authorities, agencies and Road Network Operators.

The session was organized in two parts, including 7 presentations in total. In the first part, the 4 presentations were developed by members of the task force and were based on the findings of the analysis developed in the literature review and the survey developed by the Task Force. The second part of the technical session was reserved to 3 experts that had submitted papers that were selected by the expert panels due to their interest for PIARC.

Technical Findings

The topics presented during the first part of the session were:

- Results of the external survey launched by the TF to PIARC members and sector stakeholders regarding the likely impacts and responses to new mobility technologies in different regions, and expectations for the future.
- Mobility innovations impacting Road Network Operators, focused on six main topics: Autonomous and Connected Vehicles, Cooperative ITS, Digital Highways, Platooning, MaaS (Mobility as a Service) and Electric Vehicles.
- Horizontal Issues related to mobility technologies overall, including financial issues, social impacts and implications for Low- and Middle-Income Countries (LMICs).
- Conclusions obtained by the TF through the analysis of the bibliographical sources, use cases and case studies, including those of specific relevance and interest to the PIARC new cycle.

This highlight the need for a comprehensive approach to addressing the challenges and opportunities posed by new mobility technologies. Cooperation among different regions and a focus on social and financial impacts are crucial for success.

During the second part, these were the main topics:

- Evaluation of machine detection of road markings for connected and automated vehicles under adverse weather and light conditions with camera and lidar.
- The effect of Connected and Automated Vehicles on Traffic Management observed through a national project in Hungary.
- The effect of truck platooning on rutting formation of flexible pavements.

During the session, it was pointed out that current mobility is changing every day. There are new business opportunities, improved connectivity, and opportunities for road administrations. Here are some of the opportunities that the new mobility presents:

- Various business models involve revenue generation through fees, partnerships, and funding.
- Reducing externalities like congestion, pollution, or accidents.

- Provide a more inclusive mobility (people with disabilities, young or elderly people).
- Increase road capacity trough digitalization.

This highlights the positive aspects of new mobility, where technology not only offers economic benefits but also promotes inclusivity and sustainability. Embracing digitalization can lead to more efficient road networks.

On the contrary, there are also challenges to face:

- High initial costs for implementing innovative mobility.
- Complexity of regulations.
- Cybersecurity.
- Data exchange and management.

These challenges underline the need for robust cybersecurity measures, streamlined regulations, and efficient data management systems to ensure the successful integration of innovative mobility solutions.

The Task Force launched a survey to mobility related actors to learn about their expectations, concerns and solutions to come. From the initial survey, we can conclude that almost every organization finds that the predominant impact for AV, E-deliveries, Connected vehicles, EV, Alternative fuel vehicles and MaaS will be positive. These positive impacts are expected in terms of efficiency and congestion, accessibility, climate change, resilience, economic development, and energy efficiency. In the case of road safety, a very positive impact is expected.

From the experience presented in the national Hungary project, it was discussed how a transport system using the highest-level state of the art technology to develop and demonstrate a holistic solution to support and operate autonomous vehicles in cooperation with infrastructure elements can be developed. The Hungary project exemplifies the potential for close collaboration between infrastructure and autonomous vehicle technology, paving the way for more efficient and advanced transportation systems.

Additionally, it was highlighted that platooning is expected to have a negative predominant impact on pavements if it is not corrected. The study about the effect of Platooning in flexible pavements was presented during the second part of the session presented from a Gustave Eiffel University Research Group and concluded that if the truck's path is deviated 20 cm between them, it will help distribute the load in the pavement. Also, if the distance between trucks is increased, it will help to reduce the effects of the platoon in the pavement. ..The results show that truck platoon configurations can be optimised to reduce the impact of this new type of load on pavement structures. It emphasizes the importance of optimizing platoon configurations to minimize pavement wear and tear, which is crucial for the long-term sustainability of road networks The study aims to help transport policymakers in the definition of policies to allow a proper deployment of platoons without impacting the current performance of pavement structures

Regarding CCAM, Administrations are going to play a big role, so it is very important to define ways to cooperate with the market. Road administrations need to be familiar with short- and long-range communication systems and edge computing. To be able to deploy this new mobility concepts, private sector needs to have the Administration's support. Cooperation between road administrations and the private sector is vital for the successful deployment of Connected and Cooperative Automated Mobility (CCAM) solutions. It underscores the importance of staying updated with communication technologies and fostering collaboration between the public and private sectors.

Concerning, camera and LIDAR vision for road markings, which is a key element for CCAM, an study was presented in the second part of the session. The study concluded that for camera vision, it is needed at least 0,5 contrast for the camera to properly detect the road markings. Contrast is much greater at night, and it gets lower as we get farther from the camera. Also, with heavy rain or the sun against the camera, the contrast will decrease drastically. Regarding LIDAR, contrast will not change much during the day or with heavy rain, so this technology will always help to detect the road markings in different conditions. The findings about camera and LIDAR vision emphasize the need for robust and versatile sensor technologies to ensure the safety of Connected and Cooperative Automated Mobility systems under varying conditions. Preparing for situations where both sensors fail is crucial to maintain road safety. The conclusion is drawn that CAV could benefit from the combined use of camera and lidar detection under certain adverse driving conditions. Finally, the future demand for innovative road markings when both sensors fail in critical situations is discussed.

During the session, there were some questions from the audience. These are the questions and answers registered:

Q: What needs to be considered for data transmission in ITS regarding Artificial Intelligence?

A: We need to know how to manage this information. We don't know which sources we can trust. We have to figure out how to use data more efficiently. For a road administrator, it's best to look at what others are doing. We need to educate ourselves and learn from these new technologies and artificial intelligence.

Q: When do the necessary transitions occur regarding CAVs?

A: There are studies indicating that with a 15% penetration rate of CAV (Connected and Autonomous Vehicles), traffic significantly improves. It's very difficult to get all vehicles to switch at once. We need to prepare for the coexistence of vehicles with different levels of automation. We will have 100% mixed traffic; the issue to deal with is how it can be managed.

Q: What aspects do you consider most important from an infrastructure perspective to ensure vehicles perform properly?

A: It's important for the infrastructure to be well-maintained so that sensors can detect everything accurately. Traffic management is also crucial. The infrastructure side and traffic management will always be necessary.

Q: What has been the most challenging aspect to define in traffic management (Hungarian project)?

A: It's always very difficult to deal with vehicle operators. They don't articulate their needs for testing. They are collaborating with a major Hungarian company, and they still don't know what they need.

Q: In this project, will you also communicate with commercial vehicles (Hungarian project)?

A: Yes, having a receiver is crucial. For the implementation of these connections, we need a security layer.

Q: In platooning, similar tire tracks occur, but could this same study also be conducted for autonomous vehicles (Platooning study)?

A: Since road behavior is measured with heavy vehicles, no study has been conducted. It will likely behave similarly.

Recommendation for Decision Makers

From the session, some recommendations for decision makers regarding new mobility concepts were obtained:

- **Regulation for Public Value** : Policy makers and public administrations must regulate to ensure public value and societal benefits. Economic profit vs public services had to be balanced.

- **Risk Identification and Management:** Policy makers and public administrations must identify and manage risks, externalities, and market failures.
- **Balanced Partnerships :** Stress the importance of sound public policy and balanced partnerships with the private sector.
- **Operational Design Domain (ODD):** Offering practical ODD (Operational Design Domain), and adapting to the changing transportation landscape, RNOs can contribute to the development of more efficient, sustainable, and resilient transportation systems. Roads may look similar in the near term, but, scaling up Automated, Connected, Electric and Shared Mobility concepts offers the long-term potential for fundamentally re-engineering of how roads are built, managed, and maintained.
- **Demand Management Measures for CAVs:**If a smaller number of driverless vehicles will be used more intensively than manual operation, with resulting congestion, carbon emissions, severance, and other undesirable externalities, scaling up of CAVs may require demand management measures, including dynamic pricing. In the long-term, this is an urban design issue.
- **Benefits of C-ITS:**C-ITS offer numerous benefits for improving expressway network operation. To maximize the effectiveness of C-ITS, it is recommended that public-private initiatives and implementation strategies are established to collect and utilize data from road users. Addressing legal concerns related to IT systems, data interchange, accountability, and openness is important. Furthermore, the introduction of CAVs necessitates the development of new approaches to traffic management, and thorough studies should be conducted to establish appropriate regulatory structures.
- **Facilitating Platooning Formation:** To facilitate platooning formation and cost-sharing, the implementation of mediating services and careful planning are necessary.
- **MaaS Solutions:** When considering MaaS solutions, enhancing road safety, promoting sustainable mobility, prioritizing convenience, and fostering collaboration among stakeholders are included in key considerations. Compliance with regulations, standards, and obligations is crucial to ensure reliability and standardized dissemination of information.
- **Role of RNOs:** RNO’s will have a crucial role to deploy new mobility concepts. Decision makers need to define the different roles and stablish cooperation with the different stakeholders. It is important to have a constant training in new mobilities and build a knowhow.
- **Gender equality issues need to be considered in the deployment and development of new technology and its application.**
- **Positive Social Impacts:** Positive social impacts could help decision makers guarantee acceptance.

Recommendations for PIARC and International Organisations

For PIARC and international organisations, there are some recommendations as well:

- It is important to clearly define the roles of each stakeholder regarding CCAM.
- Enhance cooperation among stakeholders related to new mobility is a key topic.
- **Provide training and expertise** in cybersecurity and Artificial Intelligence.
- Continue to conduct research and disseminate information.
- Need to share knowledge already applied for LMIC.
- Assists countries with lower incomes to develop new mobility concepts avoiding failures experimented in other countries yet. Learning from best practices.

- Sustain ongoing analysis of the evolution of new mobility to try to anticipate and avoid possible negative effects and optimize positive potential for transport efficiency, road safety and the decarbonisation of the transport sector.
- Establish a Technical Committee regarding new mobility for next PIARC cycle.

Preparation of the Session

The session was prepared among the TF members playing different roles. Ana Luz Jimenez acted as organizer, moderator and chair of the technical session.

Presentations from the Task Force were prepared by Abdelmename Hedli, Paolo Maltese, Martin Böhm, Carmen Postigo, Jean François Rioux, Suzuki Soichi and Antonio Granado and were presented by the members indicated in the Session Program. Ignacio Rodriguez acted as secretary of the technical session.

Task Force received the support for preparing the technical session from our technical theme PIARC advisor, Jeayoun Kim.

Session Programme

Chair: Ana Luz Jiménez, TF 2.1 Chair (Spain)

Moderator: Ana Luz Jiménez, TF 2.1 Chair (Spain)

Time (Mins)	Topic/Presentation Title	Speaker
0-10	Welcome and introduction	Ana Luz Jimenez
10-25	External Survey launched by TF 2.1	Antonio Granado & Jean François Rioux
25-40	Mobility Innovations Impacting RNO	Martin Böhm
40-55	Horizontal Issues: Business Model and Financial issues regarding new technologies	Carmen Postigo Arce
55-70	Conclusions and Recommendations from TF 2.1 Literature Review	Suzuki Shoichi
70-90	Questions & Answers	Ana Luz Jimenez
	Coffee break	
0-15	0311 - Evaluation of machine detection of road markings for connected and automated vehicles under adverse weather and light conditions with camera and lidar.	Amogh Sakpal
15-30	0382 - The Effect of Connected and Automated Vehicles on Traffic Management.	Tamás Attila Tomaschek
30-45	0297 – Effect of truck platooning on rutting formation of flexible pavements.	Paulina Leiva Padilla
60-80	Questions & Answers	Ana Luz Jimenez
80-90	Session conclusion	Ana Luz Jimenez

World Road Association (PIARC)

La Grande Arche, Paroi Sud, 5e étage, F-92055 La Défense cedex