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THE ROLE OF TRANSPORT AGENCIES IN SHAPING DISRUPTIVE TECHNOLOGIES AND SERVICE MODELS

A PIARC TECHNICAL REPORT

TECHNICAL COMMITTEE 1.1 *PERFORMANCE OF TRANSPORT ADMINISTRATIONS*

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 nominated 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.

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

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A PIARC TECHNICAL REPORT

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AUTHORS/ ACKNOWLEDGEMENTS

This Final Report is written within the mandate of PIARC Technical Committee (TC) 1.1 (Performance of Transport Administrations) and the activities of Working Group 2 (WG2) which, between 2020 and 2023, has been studying The Role of Transport Agencies in Shaping Disruptive Technologies and Service Models.

The working group consists of: Co-leaders, Jonathan SPEAR (United Kingdom) and Anne-Séverine POUPELEER (Belgium), and the following members, Manuel CERVERO (CAF – Uruguay), Kian Keong CHIN (Singapore), Wee Shann LAM (Singapore), Alice MATTHEW (South Africa), Seonha LEE (South Korea), Jihyun PARK (South Korea), María Dolores JIMÉNEZ MATEOS (Spain), Mª Eugenia MARTÍNEZ DONAIRE (Spain), Oleksandr GUSTIELIEV (Ukraine), Sami ALHASHMI (United Arab Emirates), Matthew W. DAUSS (USA), Nathan HIGGINS (USA), and Christos S. Xenophontos (USA).

The following individuals have directly contributed during the writing process of this Report with their feedback and recommendations: Jonathan SPEAR (United Kingdom), Anne-Séverine POUPELEER (Belgium), Mª Eugenia MARTÍNEZ DONAIRE (Spain), Nathan HIGGINS (USA), Matthew W. DAUSS (USA), Alice Mathew (South Africa) and Christos S. XENOPHONTOS (USA).

The Report was peer reviewed by: José Manuel BLANCO SEGARRA (Spain).

The Technical Committee is chaired by Mr. Christos S. XENOPHONTOS (USA). Mr. Alan COLEGATE (Australia), Mr. Joseph AHISSOU (Benin) and Mr. José Manuel BLANCO SEGARRA (Spain) are respectively the English, French and Spanish-speaking Secretaries.

The Working Group wishes to acknowledge the positive contributions of the International Association of Transport Regulators (IATR), and in particular the President of IATR and Associate Member of TC 1.1, Matthew W. DAUSS, as well as Slalom Consulting, and in particular Nathan HIGGINS, for their respective activities which assisted in the production of this Report as part of PIARC TC 1.1.

In addition, the Working Group wishes to acknowledge the constructive contributions and feedback of other members of TC 1.1 and wider PIARC roads and transport community in discussing, shaping, challenging and evolving the material set out in this Report.

EXECUTIVE SUMMARY

2023R01EN

THE ROLE OF TRANSPORT AGENCIES IN SHAPING DISRUPTIVE TECHNOLOGIES AND SERVICE MODELS

A PIARC TECHNICAL REPORT

Overview

The World Road Association, PIARC, aims to foster and facilitate global discussion and knowledge sharing on road and transport policies and practices. Within this remit, the objective of Technical Committee 1.1 (TC 1.1 – Performance of Transport Administrations), through its Working Group 2 (WG2), is to identify and document policy, regulatory and organisational challenges, and emerging responses and good practice, for transport agencies in understanding and successfully responding to, and shaping, disruptive technologies and service models.

Between 2020 and 2023, WG2 undertook an extended investigation of a number of key questions and research issues relating to disruptive technologies and service models impacting the roads and transport sector, and how transport agencies are responding, using a range of data collection and analytical methods:

- Development of Key Terminology and Definitions;
- An in-depth Literature Review;
- A Global Questionnaire Survey of Transport Organisations;
- Engagement, including a Private Sector Roundtable organised jointly with IATR;
- Analysis of 12 detailed Case Studies of policies and practices of specific transport agencies;
- Development of Key Concepts, Frameworks and Checklists, based on the preceding evidence; and
- Preparation of Conclusions and Recommendations for transport agencies and for PIARC itself.

The outputs of a number of these methodologies have been published by PIARC as separate Reports, whilst other outputs are either included within this, or available separately alongside, this Final Technical Report.

Key Findings

WG2's research has produced a number of firm findings within a robust evidence base. First amongst these is that disruptive technologies and service models will have a major future impact on the transport and mobility sector, and its associated entities, individually and in combination. Generally, this impact of what is termed as the "Future Mobility Ecosystem" is seen by practitioners as positive in such areas as operational efficiency, sustainability, user convenience and safety. However, there is an urgent need for robust and objective research, and empirical evidence, to support many of the claims made by technology advocates, identify and manage risks, as well as ensure public value, fairness and equity in outcomes.

Many key issues are not specifically focused on technology and individual technical solutions themselves," but are questions of appropriate public policy, regulation and governance to deliver the optimum balance of benefits to people, communities, civil society and sustainability of natural ecosystems. It is therefore important to take an approach focused not on technology per se, but the future vision, objectives and guiding principles for development, deployment and scaling up of different transport assets, infrastructure and services.

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Whilst transport agencies are responding in a variety of ways to technological disruption, most believe they are not yet fully prepared to develop and implement comprehensive, policy-aligned, informed and effective solutions, and require substantial assistance and capacity building to address emerging challenges. Many agencies also view innovation as a broader theme to address within their organisations. This covers other aspects beyond technology, such as people and process, and may often be in response to a range of everyday operational and practical problems faced by customers, managers, employees and stakeholders, as well as longer-term programmes for technological disruption and transformation.

Moving forward, a number of overarching roles are available to transport agencies in shaping disruptive technologies and service models. These include (i) Policy Maker and Regulator (ii) Researcher and Developer (iii) End User, Operator and Manager and (iv) Convener, Enabler and Integrator. Application of these roles is highly context specific and varies across organisations, as does the extent of public sector intervention (and regulation) desired across technology development and deployment coming predominantly from the private sector.

Indeed, the private sector is key to a high proportion of the elements making up the Future Mobility Ecosystem. However, contrary to expectations, the private sector does not generally wish, or expect, a complete laissez-faire approach to innovation. There is a recognition that a strong public sector should lead, provide a clear policy and regulatory framework, balance competing interests, level the playing field and set the rules of the game. Only if these conditions are in place will innovators and their financial backers have confidence to plan ahead, understand the public policy context and impacts of their activities, and invest to secure long-term rewards.

The necessary regulation from the public sector should be proportionate, agile, informed, investor-friendly, and ethical, seeking to reflect the evolving benefits and risks of new technologies, as well as balancing the legitimate search for private profit and return, with consideration of wider public safety, equity and value.

Within the roles that transport agencies may play, there is a wide range of specific strategies which can be applied to make progress, as documented in this Final Report. At present, the actions of transport agencies tend to focus more on policy, strategy and technical dimensions than broader governance, regulatory or organisational change which may be seen as more complex, political, intangible and uncertain, and best tackled in the longer-term.

Not every transport agency takes on the available roles and strategies in the same way. There are leaders, early adopters as well as those which choose to take a more conservative approach. In this context, we have identified a Future Mobility Maturity Curve with benchmarks in facing disruptive change. Agencies may assess themselves against this Maturity Curve and the extent and nature of organisational change under way or required in future.

As well as the leadership and regulatory role of transport agencies themselves, collaboration across a wide range of organisations is recognised as key in making progress in successfully delivering the Future Mobility Ecosystem. This collaboration spans the public, private and academic sectors in terms of research, initial deployment, accountability, consultation and long-term delivery. However, the level of engagement currently taking place, especially between the public and private sectors, is not yet sufficient to enable or support actions in all required dimensions. Greater levels, and smarter methods, of joint working are needed. In addition, most transport agencies believe they need further external support to make progress, with professional associations and industry bodies such as PIARC well-placed – and indeed expected – to provide such support.

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A significant proportion of future mobility services, even if accessed, managed and operated by the private sector, will continue to run on public infrastructure, especially roads, associated rights of way and across the public realm. The availability of modern, flexible, future-proofed and well-maintained public road and right of way infrastructure, including digital as well as physical assets, and the resources to adequately fund these over coming decades, appears to be one of the major constraints holding back progress. In addition, new infrastructure design and operating standards, guidelines and regulations will be required to reflect new vehicle types, modes of operation and deployment approaches, but have yet to be (or start to be) substantially prepared.

New transport and mobility technologies and service models appear to be impacting Low and Middle-Income, as well as High-Income, Countries, with a few use cases and examples identified by WG2. However, the pace and scope of innovation appears more limited to particular applications, with the balance of benefits and risks, and therefore the business case, likely to be significantly different. There is an urgent need for further evidence on application of disruptive technologies and service models within LMICs, and how roadmaps, capacity building, enabling strategies and approaches by transport agencies may need to differ from more advanced economies.

Recommendations and Associated Reports

Building on the conclusions above, and following discussions within WG2 and TC 1.1 as a whole, a number of recommendations have been made to transport agencies as well as to PIARC itself in shaping disruptive transport technologies and service models. This include considerations under future PIARC Strategic Plans with areas for further research including road transport electrification, digital connectivity, developing the transport agency of the future, and fostering innovation as a broader theme and organisational culture.

This Final Technical Report is supported by three Reports previously published by PIARC as follows:

- A Global Technology and Service Model Survey Report (2022R18EN, July 2022);
- A Private Sector Roundtable (2022R19EN, July 2022); and
- A Case Study Summary Report (2022R27EN, November 2022).

WG2's findings on *Disrupting the Disruptors: The Impact of COVID-19 on Emerging Transport Technologies and Service Models* is set out in an article in Routes and Roads (Number 390), published in October 2021.

Finally, a Literature Review Report (August 2021) is also available on request as a separate document, with the key findings summarised in this Final Technical Report.

CONTENTS

1. INTRODUCTION

1.1. CONTEXT

The best way to predict the future is to create it.

Peter Drucker

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 Technical Committee 1.1 (TC 1.1 Performance of Transport Administrations) Working Group 2 (WG2) is to identify and document policy, regulatory and organisational challenges, and emerging responses and good practice, for transport agencies in understanding and successfully shaping disruptive technologies and service models.

The combination of new technologies and service models, for example autonomous and electric vehicles, micromobility or new transit systems, is dramatically altering the landscape of how people view mobility, how they travel, and their associated travel attitudes, behaviour and expectations. The convergence of new technologies with the shared economy to connect people, places and things to each other, 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, customer-service concepts and their organisational structures, skills and capacities.

This is an area which is very rapidly moving in terms of technological and service-concept development, testing and adoption, but also highly Volatile, Uncertain, Complex and Ambiguous (VUCA[1]) in terms of public policy and regulatory approaches, including required decision-making through governance structures and processes. The fact that much innovation is being driven by private entrepreneurs, start-ups and other corporate entities only adds to this uncertainty. Some public agencies are seeking to develop proactive policies and plans to enable and guide new forms of mobility, whilst others are resisting adoption until more is known about the implications for public safety and interest; many more are taking an agnostic “wait and see” stance, leaving initiatives to the market, or narrowly reacting to media debate and public opinion as it emerges.

Looking forward, it is important that such dynamic change is fully anticipated, understood, managed and implemented in a structured manner in order to provide certainty and confidence within government, the private sector, customers and civil society more widely. In particular, the implementation of governmental controls and regulations without a considered assessment of the technology landscape and stakeholder environment, could result in stifling or misdirecting innovation, whilst their absence could lead to unforeseen intrusions on public safety, privacy and security. In achieving an appropriate balance, transport agencies need the pre-requisite skills, capacity, culture, management and organisation to make informed and proportionate decisions appropriate to the pace and direction of change. They also need to understand the requirements of private sector innovators and mobility providers and balance the legitimate expectations for return on private investment with public value and social equity. WG2 is therefore seeking to

[1] The term VUCA is an acronym coined in 1987, based on the leadership theories of Warren Bennis and Burt Nanus, to describe the volatility, uncertainty, complexity and ambiguity of general conditions and situations. The U.S. Army War College introduced the concept of VUCA to describe the more volatile, uncertain, complex and ambiguous multilateral world perceived as resulting from the end of the Cold War. It has subsequently taken root in emerging ideas in strategic leadership that apply in a wide range of organizations and situations and can be summarised by the phrase “It’s crazy out there!” More recently, VUCA has been used in the context of the unpredictable and chaotic global events during and immediately following the COVID-19 Pandemic.

ascertain whether these policy, governance and organisational arrangements are in place, whether gaps exist in knowledge and established practice and what more needs to be done.

1.2. Terms of Reference and Scope

In undertaking research into the subject matter outlined above, WG2 has taken the following scope adapted from the objectives set out in the PIARC Strategic Plan for 2020 – 2023:

- Defining the role, responses, required and actual transformation of transport agencies in the face of disruptive technologies and associated ownership and service models;
- Understanding the role of transport agencies within a wider stakeholder ecosystem which includes the wider public sector, private sector, academia and roads and transport profession;
- Putting this analysis in the context of the work between 2016 and 2019 by the former PIARC TC A1 on change management and its identification of new technologies as major change drivers on transport agencies in policy and organisational terms;
- Encouraging coordination with other PIARC Technical Committees and Task Forces such as with TC 2.1 – Mobility in Urban Areas, TF.B.2 – Automated vehicles and TF 2.1 – New Mobility, Roads and Transport; and
- Encouraging coordination with NCHRP Project 08-127 / B-12 Emerging Issues: Impact of New Disruptive Technologies on the Performance of (US State) DOTs.

It is emphasised that the primary focus of WG2 enquiry is policy, regulation and organisational response, leaving narrow technical issues such as technology standards, specifications, management and deployment of products and concepts to other PIARC Committees, Task Forces as well as various external fora. In developing its Programme, WG2 has sought to answer the following questions:

- What are the transport and mobility technologies and service models having the greatest external potential impact on transport agencies, in which ways and over which timescales?
- What is the current level of awareness, willingness to respond and leadership to these technologies and service models and wider sector innovation across transport agencies and how well-equipped are they to manage disruption and change?
- In taking these steps, how are agencies adapting their organisations, for example through building skills and capacity, changing organisational processes, or recruiting new talent?
- What partnerships are emerging, and may be needed, to support technological change, within the public sector, but also across the private and academic sectors, and how should these partnerships be best managed?
- What guidance, decision support tools and other actions are needed to improve transport agencies' capacity to respond to and manage change in ways which balance the complex factors at play and deliver public value?

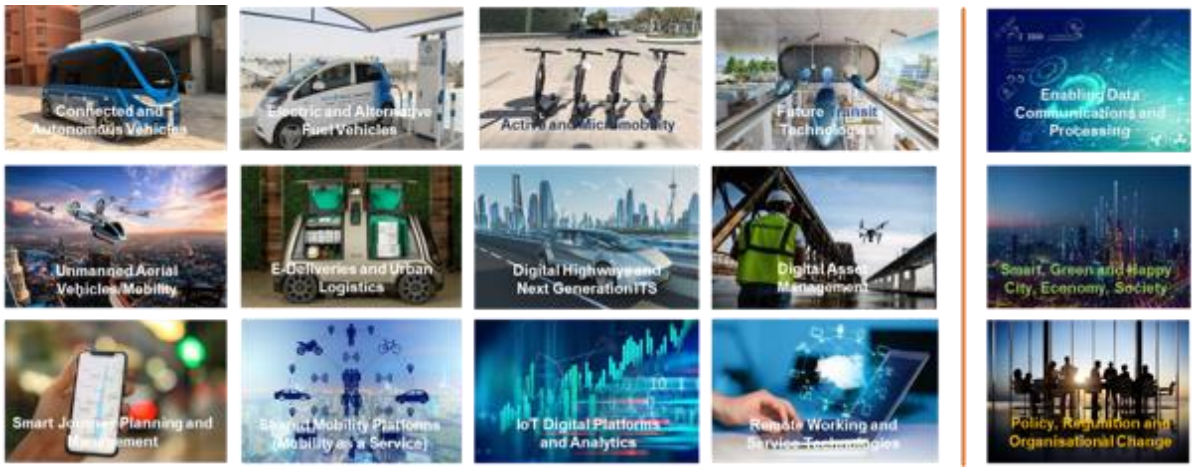
WG2 has adopted a work programme to answer these questions commencing in February 2020 with the TC 1.1 Kick-Off Meeting in in Paris and ultimately reporting its outputs in October 2023 at the World Road Congress in Prague. The evidence base and methods include definition of key terminology, a Literature Review, a global Questionnaire Survey of transport organisations, investigation of in-depth case studies and engagement with private sector innovators. These sources of evidence have led to the development of conceptual frameworks, proposals and recommendations. In addition, WG2's participation in TC 1.1 has generated ongoing discussions between transport professionals which have prompted new lines of enquiry.

The focus of WG2 is on technological and service model change drivers external to transport agencies. These include, but are not confined to, automated and electric vehicles, digital highways, personalised journey management, transport brokerage, micromobility and advanced air mobility, along with associated data, communication, artificial intelligence, cybersecurity, and other digital enablers. In addition, these components are supporting, and being preceded by, the shift from the inflexible private ownership of transport assets to a new paradigm offering users multiple options for shared access and use.

Figure 1.1 below sets out the key disruptive technology and service model categories which have informed WG2's data collection, analysis and reporting. They are defined more fully in Chapter 2 with key terminology defined in Chapter 9.

Digital transformation of internal functions and processes for transport and infrastructure planning and design, such as Building Information Modelling (BIM), Digital Twins and 3D Printing, are not directly relevant to WG2's enquiries and have been largely excluded from examination, although should be considered for their potential to prompt wider changes to transport agencies' internal skills sets, wider approach to innovation, organisational structures, processes, culture and learning.

Figure 1.1: Categories of Transport Technologies and Service Models within Scope



WG2 has sought to investigate key trends by time, geography and countries at different stages of development. Most focus has been on those countries most impacted by, and responding to, disruptive technologies and service models, with a presumption in favour of evidence from High-Income Countries in North America, Europe, the Gulf, East Asia, and Australasia. This is where most advanced technology development, demonstration and early adoption appear to be under way.

The applicability of disruptive technologies to Low- and Middle-Income Countries (LMICs) is relevant, however, and has been explored. For example, given the poor performance of LMICs in the field of road safety, the application of connected and autonomous vehicle technology to shared and public transport may have a major beneficial impact. Similarly, drone technology has already been deployed to some LMICs for delivery of medicines and light goods as a substitute to the road network. Such considerations are relevant and may be developed further in subsequent work.

1.3. Key Definitions and Terminology

Key definitions in terms of acronyms and terminology around transport and mobility technology, service models and associated concepts, are set out below in Chapter 9 of this Report and are being reported separately to PIARC's Terminology Committee.

1.4. Approach, Methodology and Programme

The main stages of WG2's work programme between 2020 and 2023 as agreed at the Paris Kick-Off Meeting are shown conceptually in Figure 1.2 below.

Figure 1.2: Working Group 2 Approach and Methodology

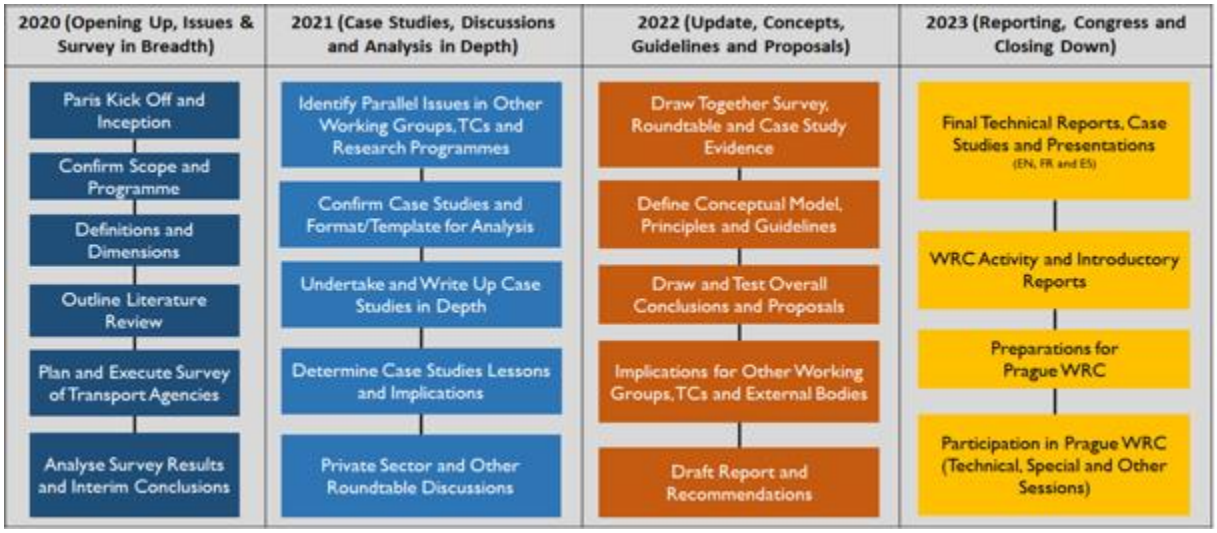
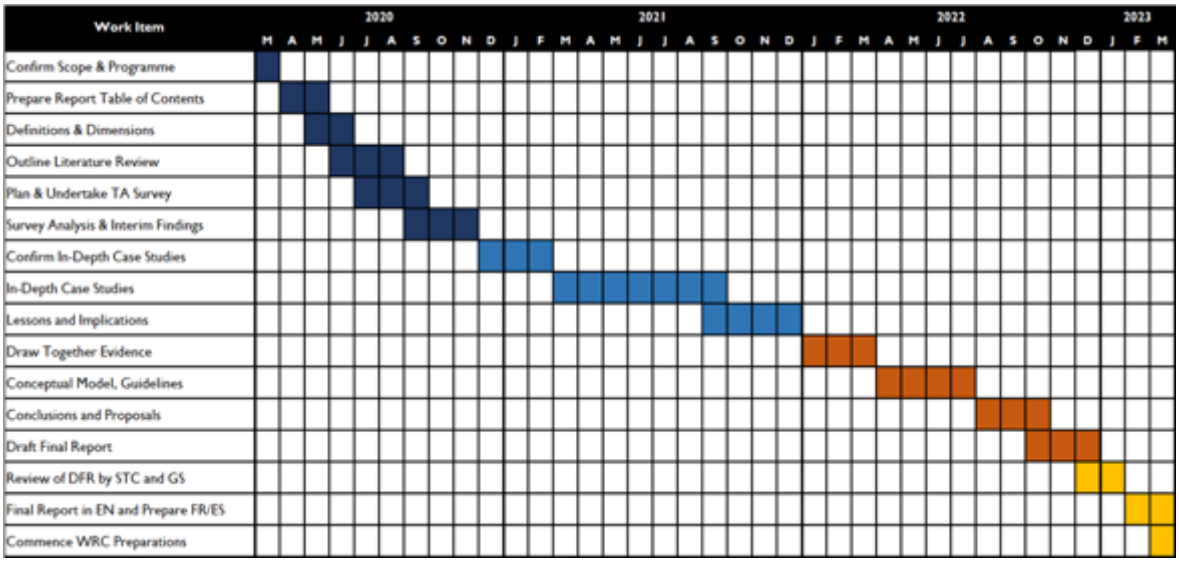


Figure 1.3 translates this programme into a more precise timeline. Whilst various factors, not least the global COVID-19 Pandemic, have led to individual tasks diverging from this plan, WG2 has ensured the completion of all data collection, assessment of evidence and development of proposals in order to produce final reporting outputs by the end of 2022 in preparation for the World Road Congress and the end of the PIARC 2020 – 2023 Strategic Planning Cycle.

Figure 1.3: Working Group 2 Programme



1.5. Other TC 1.1 Working Groups and Broader Considerations

WG2 has undertaken its work programme jointly and in parallel with activities from the two other Working Groups within TC 1.1, within the overall context of public value, as follows:

1.5.1. Working Group 1: Transport Agencies, Customer Experience and Public Value Creation

Working Group 1 is focusing on identifying best practices for measuring the efficiency and effectiveness of transport agencies, including the establishment of assessment indicators,

evaluation indexes and benchmarking, with particular focus on customer experience and communication of performance information. All this is being done considering the impact of the shared economy and other disruptions in respect of customer facing levels of service underpinning asset management, models and frameworks in use, value capture and creation and understanding decisions and practices around communicating, engaging and activating the community.

1.5.2. Working Group 3: Organisation of Staff and Human Resources

Working Group 3 is exploring matters of diversity, whether gender, ethnicity, culture, disability, age, religion, socio-economic status, political ideas, ideology, income or other factors perceived to represent disadvantage in achieving personal and community opportunities. Approaches include positive discrimination, setting of targets for recruitment or career progression, professional networks, publicity around role models or selective support for educational or training opportunities. The scope includes approaches for defining and promoting diversity in opportunity, including how to attract and retain a greater diversity of employees, especially, young professionals.

Transport technology and service model issues have been considered within plenary sessions at all TC 1.1 meetings involving all Working Groups, whilst WG2 has presented key outputs and deliverables to wider TC review, comment and discussion as its work outputs have progressed.

WG2 has also incorporated a number of items of specific interest to WG1 and WG3 into its data gathering and analysis. For example, the Questionnaire Survey incorporated questions developed by WG1 (on involvement of customers) and WG3 (on development of new job descriptions and recruitment activity within agencies) into questionnaire design, analysis and reporting. The responses to these questions are set out in the relevant Working Group Report.

WG2 has also collaborated on a range of broader debates across the whole of TC 1.1, for example in organising workshops and seminars, including:

- Developing the Transport Agency of the Future; and
- Models and Initiatives for Organisational Innovation as a Broader Theme.

Finally, WG2 is represented on, and is fully supporting, the new PIARC Task Force 2.1, which kicked off in Paris in July 2022, on New Mobility, Roads and Transport. The Task Force commences with the same technology and service model concepts as TC 1.1, but will give more focus to the implications for the future design, construction and operation of road and transport infrastructure. This Task Force is expected to report through a two-year cycle in mid-2024.

1.6. Impact of the COVID-19 Pandemic

WG2 finalised its scope and programme following its Kick Off Meeting in February 2020, immediately before the onset of global disruption of the COVID-19 Pandemic. Inevitably, given the scale and duration of the crisis, this has resulted in disruption to the Working Group's activities. There have been no major impacts on the original Terms of Reference, however, and therefore no need to notify the General Secretariat of major change in planned scope, deliverables or outputs.

As the Pandemic progressed, and the depth and the longevity of the crisis became apparent, WG2 responded to COVID-19 as follows:

After the initial Kick-Off Meeting in Paris, shifting WG Meetings to an online format via Zoom, resuming face-to-face activities (in a hybrid format) from late 2021;

- Using the opportunity of the online meeting format and platform to broaden involvement of a wider range of WG members and associate members from around the World in a way which would have been more difficult to achieve through physical meetings alone;

- Making some additions or re-emphasis to disruptive technologies and models within scope of inquiry to focus on those brought forward or accelerated by the Pandemic, for example Remote Working, Smart Deliveries and Micromobility;
- Adding relevant articles on COVID-19 and transport to the ongoing Literature Review;
- Adding a specific COVID-19 item to the Questionnaire Survey;
- Minor changes to the Table of Contents for this Final Report; and
- Close tracking of Work Programme and early remedial actions to address any slippage resulting from Pandemic disruption.

In summary, the COVID-19 Pandemic has added a degree of complexity to WG2's research and activities, but has not fundamentally changed the original Terms of Reference. Indeed, it is likely that the transition to new transport technologies and service models will be accelerated in the medium to long-term by the Pandemic. The impacts of WG2 outputs have been fully manageable with good planning, lateral thinking as well as flexibility and responsiveness in work programming.

The Pandemic has therefore formed an additional line of enquiry in its own right. Based on the Literature Review and Questionnaire Survey, this resulted in a focused article in a Routes and Roads COVID-19 Special Edition (Number 390) in October 2021 on *Disrupting the Disruptors: The Impact of COVID-19 on Emerging Transport Technologies and Service Models*.

Three TC 1.1 members, including the Chair and one WG2 Co-Chair, have also been active on the *PIARC COVID-19 Response Team*, convened as the Association's principal response to the Pandemic, undertaking a range of activities and outputs between March 2020 and December 2021.

Figure 1.4: PIARC COVID-19 Response – Working Group 2 Online Meeting via Zoom

1.7. Structure of this Report

Following this Introduction, the remainder of this Final Technical Report is structured around specific methodologies and sources of evidence as follows:

- **Chapter 2** summarises the findings of the Literature Review undertaken between 2020 and 2021, with the full Review available as a separate document on request;
- **Chapter 3** summarises the findings of the Questionnaire Survey, undertaken also between 2020 and 2021, with the full Survey Report published by PIARC in July 2022;
- **Chapter 4** summarises the findings of the Case Studies, undertaken between 2021 and 2022, with further details published separately by PIARC in November 2022;
- **Chapter 5** summarises the findings of the Private Sector Roundtable co-hosted by PIARC and IATR at the end of 2021, published separately by PIARC in July 2022;
- **Chapter 6** brings the preceding evidence base and analysis together to set out the roles of transport agencies in shaping disruptive technologies and service models moving forward, based on conceptual models, activities and maturity assessments;
- **Chapter 7** looks at strategies for how transport agencies should strengthen their adoption of future roles through a range of different initiatives, including policy and regulatory development, technical studies, testing and demonstration, internal organisational change, capacity building and stakeholder collaboration;
- **Chapter 8** sets out our final conclusions and recommendations based on our analysis, for transport agencies themselves and for PIARC itself, including the development of key themes for the next Strategic Planning Cycle, 2024 – 2027; and
- **Chapter 9** documents acronyms and technical definitions used within this Report and for consideration by PIARC's Terminology Committee.

1.8. Associated Reports

This Report represents the final output of WG2 on its mandated subject matter. It is supported by a number of associated reports and articles which have been separately published by PIARC over the 2020 – 2023 Strategic Planning Cycle. These include:

- PIARC Routes and Roads Edition 390 – *Disrupting the Disruptors: The Impact of COVID-19 on Emerging Transport Technologies and Service Models (October 2021);*
- 2022R18EN – *The Role of Transport Agencies in Shaping Disruptive Transport Technologies and Service Models : A PIARC Survey Report (July 2022);*
- 2022R19EN – *The Role of Transport Agencies in Shaping Disruptive Transport Technologies and Service Models : A Private Sector Roundtable (July 2022);* and
- 2022R27EN - *The Role of Transport Agencies in Shaping Disruptive Transport Technologies and Service Models : A PIARC Case Study Summary Report* (November 2022).

In addition, as noted, WG2 is represented on the new PIARC Task Force 2.1 (New Mobility, Road Infrastructure and Transport) which commenced in July 2022 and is considering the road design, management and operational implications of new transport technologies and modes, and which is expected to report in 2024. WG2 has put its evidence base at TF 2.1's disposal for the development of early conclusions and to support the development of key concepts.

2. EXISTING EVIDENCE – LITERATURE REVIEW

2.1. INTRODUCTION

Aside from the development of a glossary of key terminology, which is outlined in Chapter 9, an early activity for WG2 was a Literature Review of the subject matter, undertaken and updated between February 2020 and August 2021. The full Literature Review, available as a separate document, aimed to outline the context, challenges, and potential roles of transport agencies in directing technologies and service models that will shape the future mobility system.

The Review starts with the definition of what is called the "Future Mobility Ecosystem," the key technologies and service models which make it up and their potential impacts within the transport sector. It then focuses on what evidence is specifically available on transport agencies, their potential roles, activities and organisational development and transformation to keep pace with innovation. Finally, some conclusions are presented which will inform subsequent work. Specifically, a number of concepts presented in the literature which are further articulated and developed, combined with other sources of evidence, in Chapters 6 and 7 of this Final Report.

2.2. THE FUTURE MOBILITY ECOSYSTEM

Mobility is traditionally defined as the ability to travel from point A to point B, regardless of mode or purpose (Moveco, 2018). The "Mobility Ecosystem" includes different transportation modes, their users and the way they affect and interact with each other and their physical environment. Recently, with the advancement of technology and user-focused operating models this ecosystem is becoming more connected and integrated allowing safer and faster mobility (Moveco, 2018). Deloitte (2020) classifies the forces affecting the Mobility Ecosystem into five broad trend categories: societal, technological, economic, environmental, and governmental trends.

Extending this definition, the "Future Mobility Ecosystem" is defined as the combination of new technologies, systems, infrastructure, data, service models and customer propositions which are converging to offer integrated, automated, personalised on demand and sustainable mobility for people and goods. The concept includes policy, regulatory, stakeholder and governance conditions required to create the system, make it efficient, sustainable, and equitable, and support its future development.

For the National Academies of Sciences, Engineering and Medicine (2019), the critical issue driving the Future Mobility Ecosystem is the array of revolutionary changes in technology. Conversations among policy makers, industry and citizens about how transportation can evolve and adapt to changes in society, technology, the environment, and public policy, are therefore urgently needed (National Academy of Sciences, Engineering or Medicine, 2019).

In contrast, according to Arthur D. Little (2018), societal evolution is the main driver for the Future Mobility Ecosystem. Changes in customer expectations, mobility usage and behaviour trigger many opportunities predominantly for the private sector, but present challenges for transport agencies.

In a more general sense, the Future Mobility Ecosystem could be defined as the sum of all the mobility options that will be available for people and goods to move faster, cheaper, cleaner and safer, benefiting individual travellers, governments, businesses, and society at large (Deloitte, 2018). These different modes and key components are often complementary, and their enabling technologies provide data, processing, communications, and materials for the main use cases.

Table 2.1 below defines 12 technologies and service models which WG2 believe are key components of the Future Mobility Ecosystem and form the basis for general and specific analysis.

Table 2.1: Key Definitions of Key Components of the Future Mobility Ecosystem

No.	Category	WG2 Definition and Examples
1.	Connected and Autonomous Vehicles (CAVs)	Road vehicles able to sense their environment, control motion and trajectory and communicate with infrastructure and other equipment without the need for intervention of a human driver. Associated terms include Self-Driving Transport, Driverless Vehicles or the Internet of Vehicles (IoV).
2.	Electric and Alternative Fuel Vehicles	Road vehicles powered by electric motors, electric batteries, or other forms of traction such as Compressed Natural Gas or Hydrogen, rather than a petrol or diesel Internal Combustion Engine. Associated terms include E-Mobility, Low Emission Vehicles, New Energy Vehicles and Low Carbon Transport.
3.	Micromobility	A range of small, lightweight vehicles, privately owned or for hire, operating at speeds typically below 25 kph and driven by users personally. Micromobility devices include bicycles, E-bikes, electric scooters, electric skateboards, shared bicycles, and electric pedal assisted bicycles.
4.	Shared Mobility Platforms (Mobility as a Service)	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.
5.	Smart Journey Planning and Management	Use of smart devices, search protocols and databases to receive personalised information on travel by different modes, including adjustments due to congestion and other network conditions, allowing users to make better travel choices.
6.	Digital Highways and 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
7.	Digital Asset Management	Management and maintenance of road and transport assets through application of technology to collect and analyse data, optimise planning, allocate resources, understand performance and deliver operations, for example through machine learning, use of drones and embedded sensors to monitor conditions and performance.
8.	Unmanned Aerial Vehicles (UAVs)	An aircraft which is controlled to transport people and goods without the need for a human pilot on board. The aircraft may have varying degrees of autonomy and/or be part of a broader Unmanned Aerial System which includes a ground-based controller and system of

No.	Category	WG2 Definition and Examples
		communication between them. Associated terms include Drones, Flying Cars or Aerial Taxis.
9.	E-Deliveries and Logistics	Use of technologies and service models for the movement and delivery of freight, as part of wider supply chain management. The concept, sometimes called smart logistics, includes online ordering of goods and services for delivery at home, workplaces or other destinations selected by the customer. Associated terms include Associated Terms: Smart Logistics, Logistics as a Service and Smart Freight Management.
10.	Future Transit Technology	A range of new mass and personalised transit technologies, with varying degrees of autonomy, alternative powertrains, and dynamic control, beyond traditional metro and transit systems, such as Hyperloop, Small Transit Systems, Pods or E-Shuttles.
11.	Big Data Platforms and Analytics	Systems and processes which collect, store, analyse and allow management of large and complex datasets, for example through machine learning and artificial intelligence, which can be used to support transport infrastructure, equipment and services. Associated Terms include Data as a Service, Data Services and Artificial Intelligence.
12.	Remote Working Technologies	Also known as teleworking or telecommuting, the use of Information and Communications Technology to facilitate activities or maintain contact with businesses and customers electronically without the need for physical interaction and mobility.

Figure 2.1: Components of the Future Mobility Ecosystem (McKinsey, 2016)

2.3. Relevant Concepts and Models

2.3.1. How Technologies are Disrupting the Transport Sector

"Disruption" describes a process whereby a smaller organisation with fewer resources can successfully challenge established incumbent organisations (Christensen, Raynor, & McDonald, 2015). A new technology is disruptive to a given industry if it eventually supplants the incumbent technology, and significantly changes the behaviour of most of the stakeholders in the industry (Muller, 2020).

"Disruptive technology" applied to the transport and mobility sector is defined as an innovation that significantly alters the way that consumers, businesses, suppliers and eventually policy makers and regulators, operate. It has attributes that are recognisably different and potentially superior, eventually resulting in bringing larger market share and economies of scale in production, as well as driving cost and other measures of competitiveness. It overturns traditional business models challenging established organisations and public agencies.

Innovation can be classified based on two dimensions, the technology it uses and the market it operates in, differentiating: Incremental innovation, sustaining innovation, disruptive innovation, and radical innovation (Vilma, 2019).

In transportation, traditional methods of overcoming critical challenges are increasingly subject to technology-based disruptions (EBRD, 2019). The accelerating pace of technology diffusion and its updates, the convergence of multiple technologies towards human-centric goals or common applications, and the emergence of global platforms are disrupting traditional transport and infrastructure development models (EBRD, 2019) including through the concepts and products outlined in Table 2.1 above.

2.3.2. Strength and Nature of Future Impacts

There is extensive literature around the negative externalities and impacts of the current transport system and how the Future Mobility Ecosystem will deal with these impacts (KPMG, 2019).

According to KPMG (2019), mobility transformation will be driven by three key technology-driven disruptive trends that will significantly challenge the status quo and disrupt the mobility sector: Electric Vehicles and alternative powertrains, Connected and Autonomous Vehicles and Mobility as a Service (MaaS). These three drivers will combine to disrupt the road, automotive and transport sectors in a way not seen since the invention of the Internal Combustion Engine in the early twentieth century.

The UK Government Office for Science (2019) lists a long set of technologies, overlapping and consistent with Table 2.1, which will prove significant in the long-run including their reported inception dates and stage of development showing how government decisions and social values could impact the adoption of these technologies.

Figure 2.2: Technology Development and Deployment Milestones (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)

Taking the case of Connected and Autonomous Vehicles (CAVs), Arthur D Little (2018) states that if properly regulated and priced, fully autonomous 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, increase of road capacity (Curtis, Stone, Legacy, & Ashmore, 2019) as well as improve road safety. They may also decrease mobility and maintenance costs while increasing the productivity of infrastructure and services. However, they may also threaten existent jobs, put in doubt the resilience and sustainability of some existing modes of transport such as public transport, and raise several challenges in fields such as data protection, privacy and cybersecurity. They may also perpetuate car dependence and urban sprawl. The development of CAVs may affect specific industries. While positive impacts are expected for policing, healthcare and media and advertising, the demand for air and rail transport could decrease (KPMG, 2019).

Overall, new forms of mobility have the potential to radically transform transportation although it is difficult to predict with certainty what the impacts will be as well as if and when they will reach a critical mass in providing benefits. Similar discussions over positive and negative impacts are seen in recent debates over micromobility in many cities across the world. (Spear, 2020).

Detailed investigation, forecasting, further empirical evidence and debate is needed to arrive at an informed viewpoint. The precise range of outcomes in any given city or locality may also be highly context specific, as might be the policy and regulatory responses.

2.3.3. Challenges to the Future Mobility Ecosystem

Much of the literature on the Future Mobility Ecosystem is positive about the future possibilities that new technology and service models present to solve current problems. It also sees innovation in the transport sector as matching wider technological progress across society. This is in line with the paradigm of "technological optimism" (Docherty, 2018).

Other researchers are more sceptical in their perspectives. For example, Marsden & Rearden (2018) consider that to ensure positive outcomes for society, stronger policy analysis, a robust governance framework and mechanisms for strong regulation are needed. The Hype Cycle, proposed by American advisory firm Gartner claims to provide a graphical and conceptual presentation of the maturity of technologies through five phases at varying degrees of optimism, claimed benefits, scepticism and disillusionment before commercial products and services become established.

Recently some technology actors are challenging the traditional role of Government as transport planner, regulator or provider. They also increasingly generate and support mobility services and customer demand and determine how infrastructure is used, challenging existing policy and regulatory frameworks. This challenge has been seen clearly in the development of shared micromobility systems in cities around the World since 2017, as well as the early introduction of car-based ride-hailing from firms like Uber, creating "facts on the ground" which city and regional governments have struggled to understand, respond to and appropriately regulation (Spear, 2021).

This raises the question over the role of Government in the Future Mobility Ecosystem. A "hands-off" mindset amongst policy makers and an uncritical faith in technology could be dangerous, since private sector innovators and mobility providers are motivated by maximising consumption of their product and ultimate profitability, whilst externalising costs onto others. (Docherty, 2018). Thus, the State should provide a regulatory counterweight to market forces, ensuring that public value is secured, that society benefits from the mobility transition and "no one is left behind." In other words, no amount of technology or data will overcome the need for sound public policy, proportionate regulation and good governance of the transition to new forms of mobility.

2.3.4. Implications of the COVID-19 Pandemic

COVID-19 has been an unprecedented global health, economic, and social crisis which has created entirely new challenges for the roads and transport sector with major impacts on the future of transport and mobility, including the disruptive technologies and service models.

During early stages of the Pandemic demand for travel fell across all modes, with self-isolation and social distancing created a plethora of operational challenges. Over the long-term, COVID-19 could have a lasting impact on mobility as it drives change in the macroeconomic environment and business environment, regulatory trends, technology, and consumer behaviours (McKinsey, 2020).

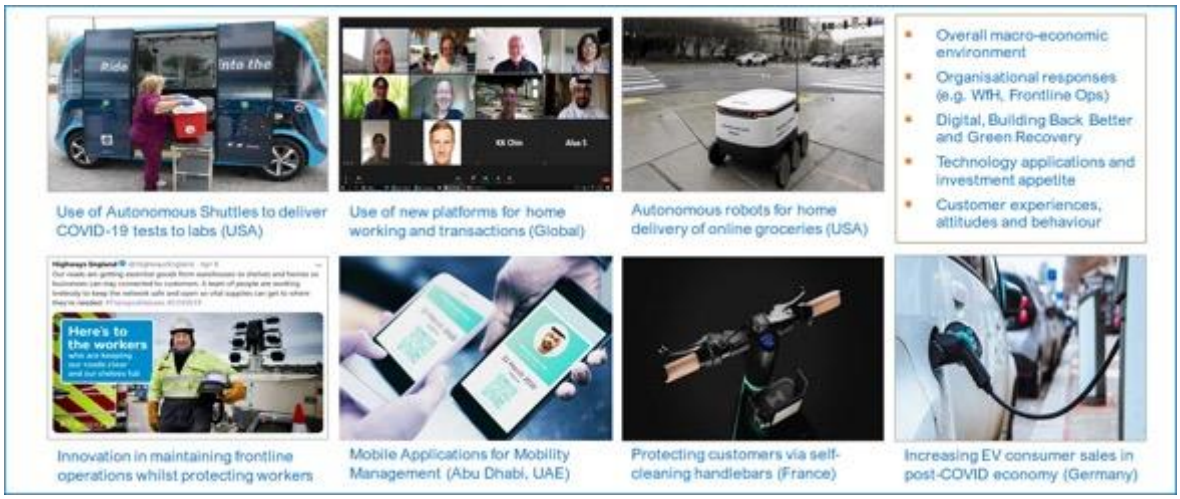
For Deloitte (2020), there are differing dimensions on how the post-COVID-19 environment will play out: the role of the public sector in leadership the Future Mobility Ecosystem, noting that the crisis has increased State intervention in many places. Individual freedom and choice has been curtailed by societal or systemwide-benefits, with safeguarding of the many overriding the rights of the individual. Government regulation has also countered market liberalisation to satisfy competing policy objectives, whilst data collection and surveillance has impacted privacy and security. The impacts on the Future Mobility Ecosystem may also be trip substitution via digitization, a new and

expanded definition of transport safety, growing reliance on e-commerce and delivery and the reconfiguration of the mobility landscape with new players, partnerships and alliances.

Another longer-term implication is the move of work, retail, and other activities to a virtual format. Transport agencies will have to forecast the future distribution of travel demand for the delivery of infrastructure and services and change their own organisational structures and processes as a result, not least embracing concepts such as Triple Accessibility Planning (Atkins Acuity, 2021).

With recovery to 2025 and beyond, there is an opportunity to organize the transport system in a better way as regulators, innovators and consumers look towards cleaner environments, decarbonisation of transport, flexible and personalised digital services on demand, as well as fostering innovation as a source of competitive advantage and wealth creation. Enabling and reconfiguring future mobility technologies and services will be a key aspect by investing in research and development for Connected and Autonomous Vehicles, Micromobility, E-Mobility and Shared Mobility, enacting regulations that encourage and enable innovation rather than continuing to unconditionally support incumbents and legacy business models (Atkins Acuity, 2021).

Figure 2.3: Examples of Technological Innovation During the COVID-19 Pandemic (Atkins, 2021)



2.3.5. Roadmaps for Preparing for Future Mobility

Understanding, anticipating and being comfortable with new technology and innovation is crucial for making decisions on transport, developing regulation, and leading transformational change for the sector (Deloitte, 2017).

For organisations looking to derive maximum impact from the future of mobility, it is helpful to pursue several steps: plan for future scenarios; establish desired roles; current state assessment; adopt new ways of working and mature capabilities in line with new roles.

McKinsey (2017) sets out an equivalent road map to eventual organisational maturity by outlining five core capabilities to which transport agencies must implement changes in order to acquire the necessary skills and transform its practices towards the future: strategy, portfolio planning, resources model, project planning and delivery, and performance measurement.

2.4. Transport Agencies Support For Technological Change

Most of the literature on disruptive technology in transportation covers technical aspects while there are relatively few sources which refer to governance, institutional structures, public sector policy, and processes for how innovation and technology development should be organised.

The question is what the respective roles of Government, private sector and other players in civil society in the rollout of future mobility should be (Curtis, Stone, Legacy, & Ashmore, 2019).

Currently, most technology and service model development is coming from the private sector, either through new start-ups or from established companies and with the direction and funds from private sector lenders, investors and advisory firms. This is explored more fully in Chapter 5 of this Report through the Private Sector Roundtable organised by TC 1.1 and IATR in late 2021.

However, despite the dominance of the private sector, Government intervention could (and should) play a significant part mitigating market failures and maximising equitable benefits (UK Government Office for Science, 2019). For Deloitte (2017) the role of the public sector goes beyond merely providing guidance, it also links to wider business and industrial strategy on the grounds that a country (or region or city) leading in the race for mobility innovation potentially gains a powerful source of competitiveness and reputation within the global economy.

At a national level, according to Deloitte (2017), the roles that Governments may play in technology development and roll-out can be associated with three key functions: as policy maker and regulator, as researcher and developer and as end user.

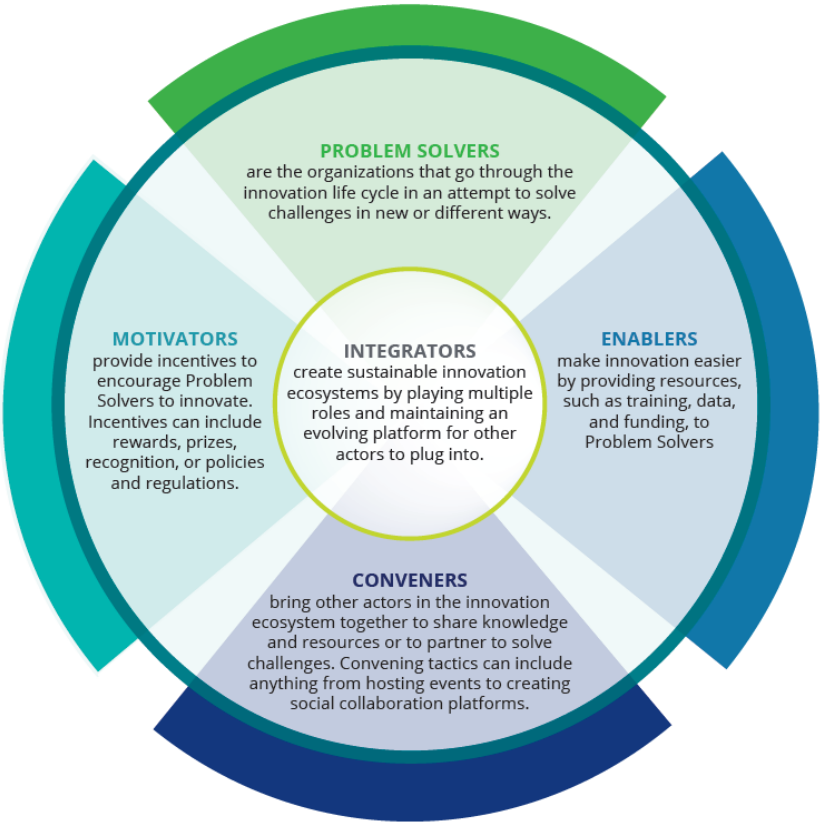
As for transport agencies, Deloitte (2018) has set out four roles in the Future Mobility Ecosystem: strategist, shaping the transport system, convener and catalyst stimulating the mobility ecosystem, regulator setting rules to deliver transport system outcomes and operator delivering an integrated transport system.

Nevertheless, these roles may be applied with differing degrees of ambition, rigour and leadership. For the Urban Transport Group (2020), cities are taking various approaches: Laissez faire: direction left to the market (some states in US), Partnership: Public/ Private (UK) and Guiding Hand (Singapore).

According to the UK Government Office for Science (2019), Government and public agencies can also intervene at different points in a technology lifecycle: Early intervention: Catalyser, Innovative facilitator and Skills planner; Market framing: Regulator, Standard Setter and Fiscal Incentiviser and Adoption and Integration: Intelligent Customer, Platform Provider.

Each organisation therefore needs to decide which role it can most effectively and appropriately play in the innovation process (Deloitte, 2017). In particular, public agencies may be central to problem solving, enabling, convening, motivating or integrating solutions (Figure 2.4 and Table 2.2).

Figure 2.4: Public Sector Innovation Roles and Decision Tree. (Deloitte, 2017)



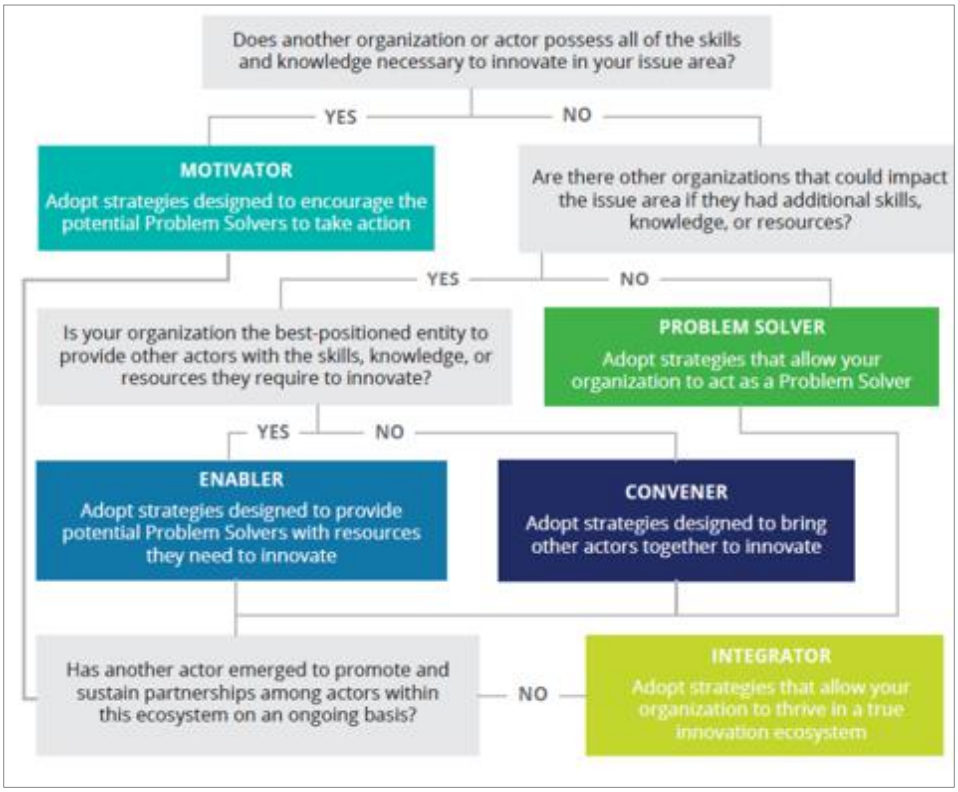


Table 2.2: Strategies for Supporting Public Sector Innovation Roles (Deloitte, 2017)

Role	Problem Solver	Enabler	Motivator	Convener
Description	Problem Solvers are the groups or individuals who are most often identified as "innovators" – Actors who come up with a solution to a public sector challenge	Enablers seek to make innovation easier – or in some cases possible – by providing other actors with necessary resources	Motivators provide incentives to encourage potential Problem Solvers to innovate	Conveners bring actors in the innovation ecosystem together to share knowledge and resources, or develop partnerships
Strategies	Design Thinking and human-centred design techniques Ideation sessions Diverging and converging techniques (e.g. Double Diamond) which combine concepts into solutions Scenario planning and futurist techniques that project the potential benefits of new solutions being applied to a specific problem area	Training sessions that equip Problem Solvers with new skills sets Releasing data-sets for use in solving particular challenges Facility-sharing sessions One-time investments in new innovation projects	Challenges and competitions that award prizes or recognition to new innovators The use of games or gamification to encourage participation in problem-solving	Organising conferences, hackathons and other events that bring organisations and individuals together Use wikis and crowd-sourcing tools to leverage knowledge and skills to solve a problem
Initiatives	Establish Innovation Groups responsible for idea generation, piloting and incubation Use Innovation Programmes to bring in external Problem Solvers Establish Innovation Committees or Governance Groups to guide solution development	Build an infrastructure for technology and web-based projects through Wi-Fi or broadband initiatives Launch open data initiatives Provide testbeds and sandbox opportunities for trialling innovation Provide online toolkits to support Problem Solvers Establish grant schemes Support training programmes and facilities	Establish competition platforms that allow Problem Solvers to vie for recognition and funding Provide awards with confer status in exchange for successful innovation Establish policies and regulations that encourage, reward or require new approaches Provide financial incentives for demonstrated social impacts and benefits	Develop social collaboration and crowdsourcing platforms that allow innovators to share knowledge and exchange ideas Establish physical spaces and event that bring innovators and other players together
Integrator	A hybrid role which serves to align actors in the other four roles and enhance the effectiveness of the ecosystem as a whole Integrators articulate the innovation ecosystem's goals and create processes and platforms that allow the ecosystems actors to work effectively together on an ongoing basis, including identifying actors who can partner with each other, making connections between them and selecting the right tools to create value amongst the ecosystem's various members Integrators often begin by playing one of the other four roles and evolve as they take steps to identify other actors, develop platforms and help other participants partner effectively In weak or immature policy and regulatory environments, or in respect of early innovations, private sector organisations may also act as Integrators.			

2.4.1. Towards a Maturity Model and Toolkit of Responses

Whilst potentially strongly positive in terms of impacts, emerging mobility trends can aggravate some of the challenges that Governments are already facing with growing user expectations for responsive and personalised mobility services. The management of the Future Mobility Ecosystem at scale requires focus, leadership, and a fundamental change in mindset. (Deloitte,2017)

Deloitte (2018) developed the Future Mobility Maturity Curve which allows organisations to assess how prepared they are for the Future Mobility Ecosystem and the extent of changing requirements. The curve ranges from Stage 1: Aware, an organisation with no dedicated capabilities, resources, nor strategy to Stage 5: Embedded, an organisation that places the opportunities and challenges of the Future Mobility Ecosystem at the heart of policy and strategy. Moving up the curve involves change on two fronts: i) external policy through new regulation, and ii) internal operations, through the organisational and cultural transformation including new ways of doing business and a new mindset. (Deloitte, 2017)

In a similar vein, Arthur D. Little (2018) defined three pathways to progress and strategic directions for transport authorities: 1. Establish sustainable core to invent new sustainable mobility solutions; 2. Rethink the system towards more common and sustainable solutions and 3. Network the system by fully integrating mobility solutions.

Figure 2.5: Future Mobility Organisational Maturity Curve (Deloitte. 2017)

2.4.2. The Transport Agency of the Future

Traditional transportation agencies are not built for rapid innovations and could hinder their ability to thrive in future. The Transport Agency of the Future therefore requires a change of mindset, shifting to a perspective focused on the entire mobility ecosystem, in which both the private and public sector work in partnership. It must rapidly adapt to be in a better position to proactively shape the evolving mobility ecosystem, rather than only reacting to it (Deloitte, 2020) by:

- Developing strategies that maximize the potential benefits of new technologies (CTDOT, 2021) establishing objectives and actions within the agency;

- Policy making, supporting concepts and products based on the benefits these technologies bring to travellers and society, the costs and disruption of change, while ensuring safety, security and immediate public value (Spear, 2017);
- Creating a regulatory framework for the introduction of more sustainable mobility solutions (Arthur D Little, 2018) in partnership with central government, manufacturers and service providers (Deloitte, 2017);
- Implementing organisational practices which are more connected, with lower transaction costs, higher automation and fundamental societal shifts (McKinsey, 2021);
- Acquiring new key skills, capabilities and attributes to move up the maturity curve cited above (aware- engaged- uneven-holistic- embedded); and
- Generating workforce changes which replace existing work and generate new work. Changes are to be expected in roles and job titles, responsibilities, and workforce training. These changes must be complemented with institutional innovation (MIT,2020).

This vision of the entire Future Mobility Ecosystem, in which both the private and public sector work in partnership is supported by the concept of a public value chain in which public and private actors constitute necessary linkages, which can be of a mixed nature.

2.4.3. National and city indices

A number of indices have been developed across the World to compare and benchmark how countries and cities stand in relation to key aspects of transport and mobility, including the adoption of innovative planning concepts and technologies. The objective is to provide insights that can help city leaders and transport authorities to define priorities and improve their decision making. Examples include Arthur D. Little's Urban Mobility Index, KPMG's Autonomous Vehicles Readiness Index (AVRI) and Deloitte's City Mobility Index (DCMI).

Although the various indices have different variables and arrive at slightly differing rankings, there are several countries and cities which consistently score highly, for example Singapore, Germany and Norway. These cases, and the basis of the indices themselves, may be useful for further in-depth examination.

2.5. Applications in Low- and Middle-Income Countries

Most discussion of future transport technologies and disruptive service models in literature is carried out in relation to advanced economies. However, in line with PIARC's priorities, it is important to identify examples on the potential for innovative mobility applications in Low- and Middle-Income Countries (LMICs). There is limited in-depth literature on this topic with most references being confined to brief citations in trade journals, press and online bulletins.

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 provide further cases which could be studied further. Some instances identified during the Literature Review are highlighted below. The benefits, business cases and public policy aspects of such innovations may be very different than High-Income Countries, however, 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 the NGOs and IFIs in supporting innovation and agencies such as the World Bank, ADB and African Development Bank should be engaged in this context.

Case Study: Advanced Air Mobility (Drones) in Malawi

Drones are increasingly being used to help foster development. This has led efforts in piloting and using various applications including launching, in collaboration with the Government of Malawi, the first humanitarian drone testing corridor in Africa. Drones transport health supplies and medical equipment, monitor infrastructure programmes, combining drone-acquired imagery with AI for emergency response and supporting development of the national regulatory framework.

A cadre of drone pilots and technicians are being trained, and the Government is supporting the integration of drones into the national disaster preparedness and response framework (UNICEF, 2020).

The testing corridor is located at the Kasungu Aerodrome, in Central Malawi, it has a 40 km radius covering some 5,000 km² allowing drones to travel up to 400 meters above ground level and beyond visual line of sight. The corridor is designed to test drone technology in three main areas: (i) imagery – generating and analysing aerial images; (ii) connectivity – exploring the possibility for drones to extend telecommunications connectivity across difficult terrain; (iii) transport – delivery of low weight supplies such as medicines (UNICEF, 2018).

This corridor is the first in Africa and one of the first globally with a focus on humanitarian and development use. It is designed to provide a controlled platform for the private sector, universities, and other partners to explore how UAVs can help deliver services that benefit communities and schools. All data generated by the flights is used to inform the Government's plans for the use of drones in the future.

Drones, data and artificial intelligence are leapfrog technologies that allow more informed and agile development response and potentially accelerate economic growth in the region. However, to achieve this, Malawi and neighbouring countries lack qualified and skilled personnel needed to seize the opportunities offered by drone and data technology. To respond to the skills deficit, UNICEF established the first African Drone and Data Academy (ADDA) in January 2020.

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 tricycle (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 and the economy recovered.

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.

2.6. Conclusions and Key Transferable Lessons

The literature reviewed by WG2 on disruptive transport and mobility technologies and service models shows that:

- New technologies and service models will have a great impact in transport sector, but the scale, direction and timeline of change are subject to a great level of uncertainty, volatility and debate amongst researchers and commentators, as well as claim, counter-claim and controversy between private sector innovators and those focused on public value and interest. This uncertainty has increased further due to the impacts of the COVID 19 Pandemic.
- Most of the literature on disruptive technology in transportation covers technical aspects of development, use cases and applications. Some sources, such as the Gartner Hype Cycle, cover different stages of technology development, rollout and adoption at varying degrees of optimism, industry claim and scepticism. There are relatively few sources referring to institutional structures and processes for innovation and technology development, or the wider internal organisation of transport agencies.
- Nevertheless, the literature suggests transport agencies can play several roles in supporting and enabling new technologies and service models: Policy Maker, Strategist, Researcher, Regulator, Stakeholder Manager, Integrator, Convener, as well as direct procurer or operator of transport infrastructure and mobility services.
- A key role of the public sector is to ensure that new technologies and service concepts are safe, equitable and align with, rather than work against, public policy objectives, as well as identifying and tackling negative externalities and safeguarding against market failure.
- Transport agencies will need to develop new skills, capacity, competencies, structures and processes to fulfil these roles effectively. At the same time, agencies will be subject to wider disruption of their workforces and working environment, with new job roles and forms of working, including remote and hybrid working, and digitisation of organisational processes, emerging.
- New transport technologies and service models are also impacting Low and Middle-Income Countries, although the pace and form of innovation appears more limited to particular applications and use cases, making progress may be less resilient, there are greater skill and capacity limitations, and further research and examination is needed in this area.
- There is little detailed literature on what constitutes good practice in transport agency governance and organisation to shape future technologies and service models. Responses are, in many ways, still to emerge. Clearly, ongoing work by PIARC including this Report may assist in shaping future approaches.

In summary, this Literature Review has found that transport agencies have a fundamental role to play in the development of the Future Mobility Ecosystem acting as Policy Maker and Regulator; Researcher and Developer; Operator and Manager; Convener, Enabler and Integrator.

When considering the different stages of the technology lifecycle, transport agencies could also act as facilitators or catalysts at the early stage, policy maker and standard setter during the market framing and as a platform provider and guardian of public interest during adoption and integration.

These concepts are explored and developed more fully in Chapter 6 and 7 of this Final Report.

3. ANALYSIS IN BREATH – QUESTIONNAIRE SURVEY

3.1. Approach to The Survey

The Questionnaire Survey (of global transport organisations) forms part of the research of disruptive technologies and service models impacting the transport sector and how public agencies are responding to them. It was developed and implemented by the WG2, in cooperation with the International Association of Transport Regulators (IATR), whose President is a Correspondent Member of TC 1.1. The full Survey Report has been published separately by PIARC in July 2022.

The Survey aimed at a range of transport organisations in the public, private and academic sectors. It was produced in three languages (English, French and Spanish) and disseminated via TC 1.1 members, PIARC's General Secretariat, AASHTO, IATR, IRF (Geneva) and the China Highway Transportation Society (CHTS). The Survey's objectives were to identify:

- The most significant and pressing technologies, models and perceptions around impacts;
- Level and form of awareness and knowledge around technology and service models;
- Importance and form of response (e.g. pioneers or followers) to the technologies;
- Transport agencies' preparedness and responses (e.g. policies, structures, skills, culture);
- Most relevant partnerships and collaborations; and
- Requirement for support tools and identification of potential In-Depth Case Studies.

The Survey was carried out online via Survey Monkey from September to December 2020 and reporting was completed in March 2021. It consisted of 35 questions in six sections as follows:

- Section 1 – Organisational Information;
- Section 2 – Development (Impacts) of Technologies and Service Models;
- Section 3 – Organisational Responses to Technologies and Service Models;
- Section 4 - Stakeholder Relations in Progressing Technologies and Service Models;
- Section 5 – Support Needed by Organisations in their Responses; and
- Section 6 – Request for Case Studies and Further Information.

Most questions included in the Survey covered WG2's scope and areas of interest as outlined in Chapter 1. However, a small number of questions were also included at the request of the other two Working Groups in TC 1.1, WG1 (Customer Experience) and WG3 (Organisation of Human Resources).

During preparation and piloting, it was recognised that the Survey was long and complex, requiring time and a strong subject matter and organisational knowledge to complete fully. The purpose, and deliberate decision made, was to seek a more limited number of in-depth responses across a range of related topics rather than a shorter survey attracting more returns, prioritising quality over volume.

The Survey was undertaken whilst the global COVID-19 Pandemic was continuing to cause disruption to the transport sector. Although there was one specific question attempted to capture perceptions of COVID-19 impacts, respondents were asked to take a medium- and longer-term perspective of technological and service model development beyond the Pandemic.

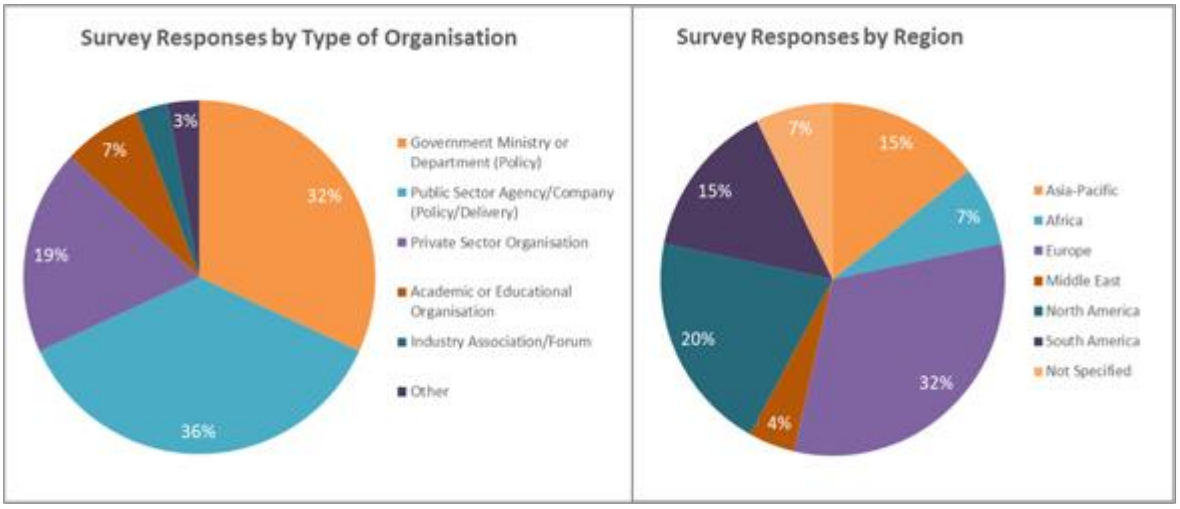
3.2. Survey Findings

3.2.1. Response to the survey

There was a solid global response to the Survey, with 69 fully completed questionnaires and a further 16 partially completed responses on generic impacts. The responding organisations covered a diverse range of geographical region, scale, type and modal jurisdiction, and the results are considered representative of the PIARC's membership and constituency.

The remainder of this Chapter describes the key findings of the Survey, with the full Survey Report available as a separate document already published by PIARC in July 2022. Responses to questions raised by WG 1 (Customer Experience) and WG3 (Human Resources) are documented in the respective WG Final Technical Reports.

Figure 3.1: Survey Responses by Region and Type of Organisation



3.2.2. Main findings

3.2.2.1. Organisational information

More than half the responding organisations have a formal mandate and function beyond purely transportation, with a wide range of functions and activities such as planning (62%), research and development (62%) and programme management (59%).

Over two-thirds of respondents are public agencies and almost a fifth are private sector. Over half are from Europe and North America. There was a relatively low response from Low- and Middle-Income Countries despite the strong outreach via TC 1.1 members and PIARC First Delegates.

3.2.2.2. Development of New Transport Technologies and Service Models

New transport technologies and services are seen as having high future impact on society. However, the strength of impact varies between the different technologies and service models. Impact is especially high for CAVs (74%), EVs and Alternative Fuels (77%), Remote Working (75%), Data Platforms and Analytics (72%). By contrast, UAVs (33%) and Micromobility (22%) are seen as having a more uncertain impact at this stage.

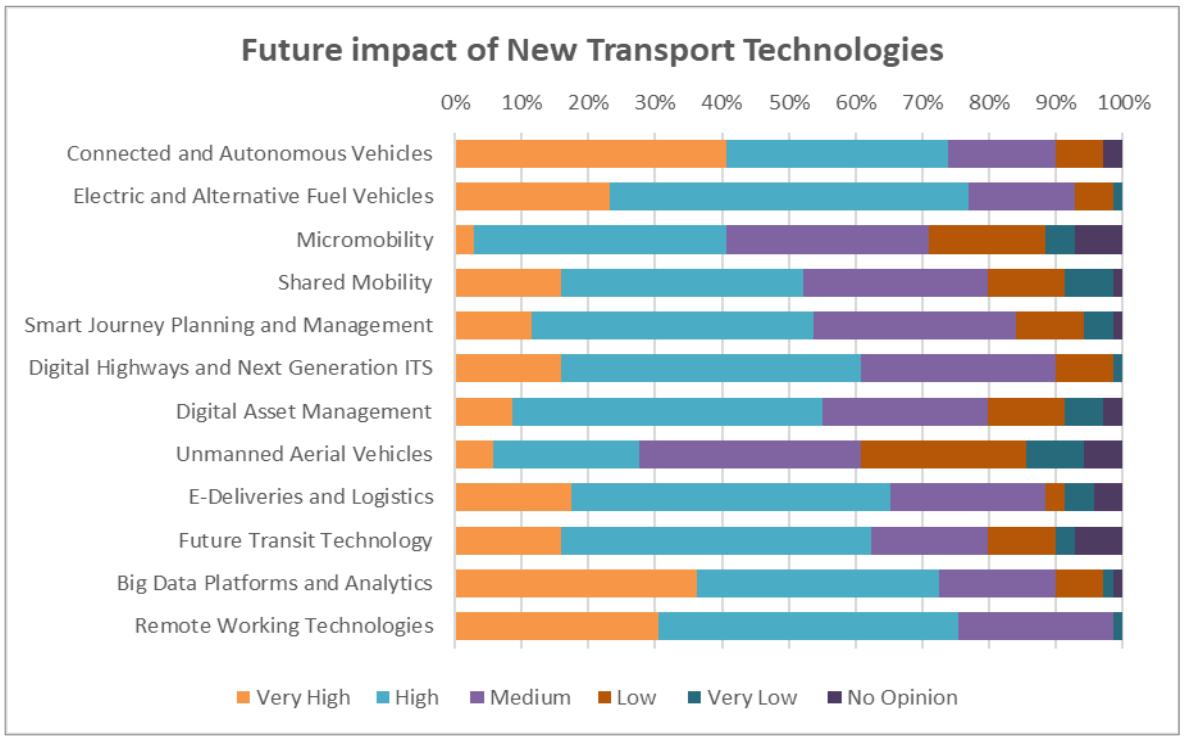
Taken as a whole, new technologies and services are seen as positive for various policy objectives, especially in respect of transport system efficiency (100%), environmental sustainability (91%) and operational resilience (80%). There is a more uncertain or potentially negative impact in terms of social equity (52%) and (city) brand and reputation (57%).

Looking ahead, there is a belief that there will be considerable variation in timescales over which different technologies and service will mature and achieve societal adoption. Remote Working Technologies (86%), Micromobility (72%) and Data Platforms and Analytics (80%) will develop faster than other concepts. Significantly, road vehicles are seen as likely to be fully electric or powered by alternative fuels much sooner than they become autonomous.

There is a perception that barriers to technological adoption outweigh current enablers. Public policy and budgets are the areas of greatest concern, although with differing views on the extent to which transport sector skills, competencies and culture hold back or support progress at the current time. By contrast the strongest enablers are private sector innovation and investment, stakeholder collaboration and the securing the right environment for testing and research.

Whilst recognising uncertainty, the COVID-19 Pandemic is seen as having had and having a negative impact on new technology development over the next couple of years, but with a far more positive outlook in the medium- to long-term. A substantial minority perceive a positive initial impact.

Figure 3.2: Future Impact on Society of Transport Technologies and Service Models (n=69)

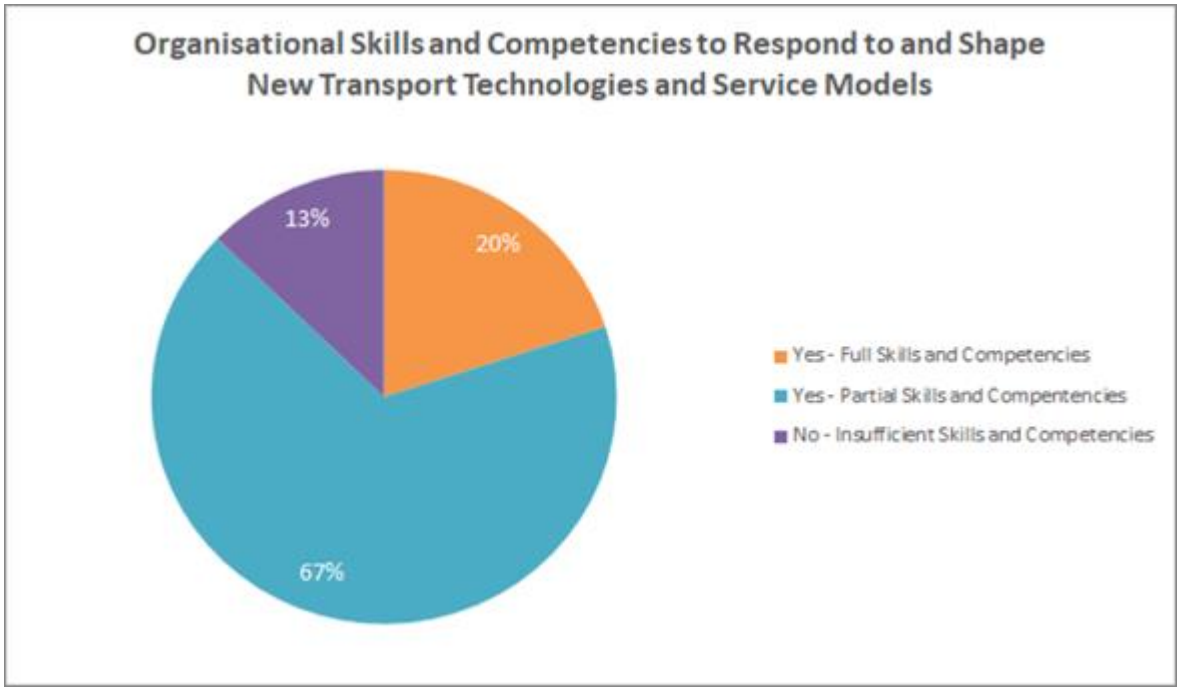


3.2.2.3. Organisational Responses

Technologies and service concepts command different levels of importance, support and desire for leadership within organisations. There appears to more focus on EVs and Alternative Fuels (58%), Digital Highways/Asset Management (65%), Remote Working Technologies (65%) and CAVs (54%) compared to UAVs (42%), Micromobility (40%) and Future Transit (26%).

The vast majority of organisations feel that they have at least partial skills and competences to respond and shape new technologies and service models. However, four out of five organisations require additional development of skills and competencies to make progress and 13% report having insufficient skills. A number of public agencies note that they will acquire the skills needed through collaboration with academia and industry and by employing consultants or external service providers. In reality, the proportion of organisations with insufficient skills is likely to be more than 13% - since these organisations have less likely responded to the survey

Figure 3.3: Organisational Competencies to Shape New Transport Technologies and Service Models (n=54)



Within this context, organisations have undertaken a wide range of activities to adapt to the challenges of new transportation technologies and service models. Some 32 activities were suggested in the Survey under four groups of (i) Data Gathering, Strategy Development and Engagement (ii) Legal, Regulatory and External Governance (iii) Technical activities and (iv) Internal Organisational Changes. While it is also recognised that most organisations are uncertain about future activities on new technologies, there appears to be slightly greater focus on data gathering, strategy development, engagement and technical activities compared to legal, regulatory, governance and internal organisational changes which may be challenging, complex, unstructured and political. These activities are considered further in Chapter 7 of this Report.

Questions aligned with the work programmes of WG1 (Customer Experience) and WG3 (Human Resources) show that half of our responding organisations (49%) have full ability and acceptance of responsibility to engage with citizens and customers on new transport technologies and service models. In addition, over half of organisations have identified key competencies, and adapted job descriptions and educational requirements to address new technologies, although far fewer have yet to make changes to their recruitment processes.

Around half of organisations responding to the Survey have appointed a dedicated director, manager or equivalent post for progressing new technologies and services. Examples given of positions appointed with such responsibility include:

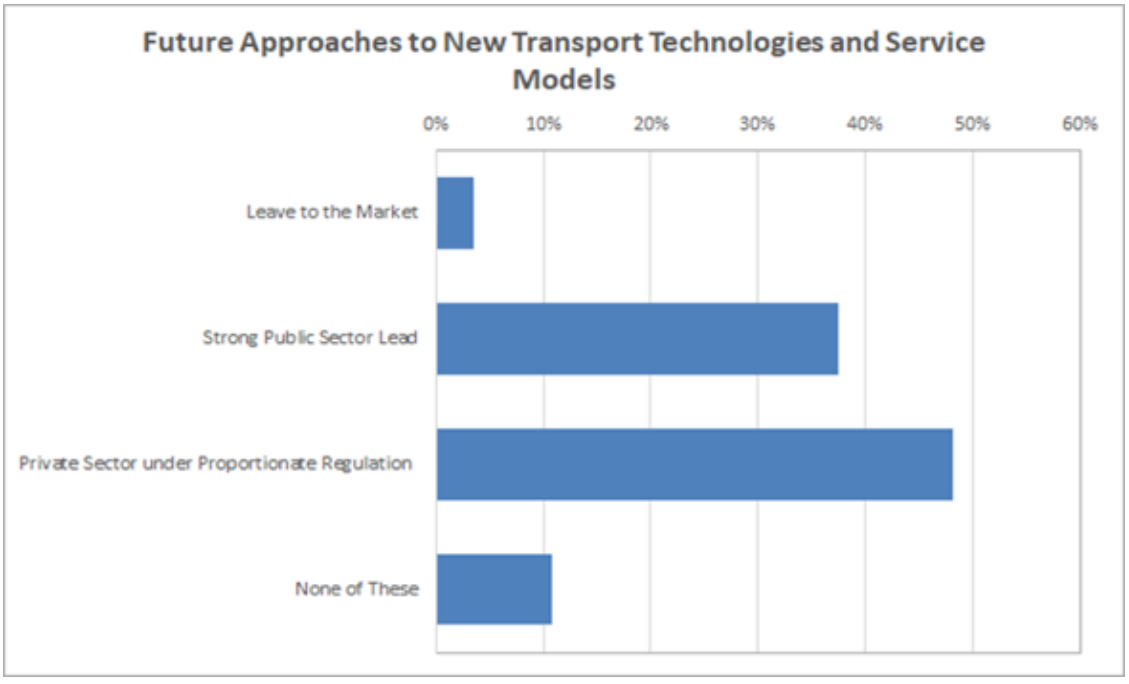
- Executive Lead for Future Transport and Technology;
- Chief Digital Officer;
- Technology Director;
- Director, Intelligent Mobility; and
- Head of Technical Innovation.

Figure 3.4: Activities to Adapt to Transport Technologies and Service Models (n=47-50)

ACTIVITIES	UNDERTAKEN			PLANNED				AVERAGE UNDERTAKEN	AVERAGE PLANNED
	Yes	No	Don't Know	Yes - Definitely	Yes - Possibly	No	Don't Know		
DATA GATHERING, STRATEGY DEVELOPMNENT AND ENGAGEMENT									
Technical Studies & Investigations	82%	12%	6%	38%	22%	4%	36%	71%	33%
Development of Strategies & Road Maps	72%	16%	12%	44%	18%	4%	34%		
Development of Datasets & Databases	72%	16%	12%	46%	10%	8%	36%		
Engagement with Industry within Transport Sector	90%	8%	2%	40%	20%	6%	34%		
Engagement with Industry outside Transport Sector	64%	24%	12%	20%	24%	12%	44%		
Partnering with Academic or Research Organisations	86%	10%	4%	44%	12%	6%	38%		
Public Surveys	70%	20%	10%	26%	20%	14%	40%		
Hackathons, Brainstorming or Equivalent	50%	30%	20%	24%	38%	12%	26%		
Focus Groups	58%	24%	18%	28%	26%	14%	32%		
Benchmarking and Case Studies	62%	20%	18%	24%	42%	4%	30%		
LEGAL REGULATORY AND EXTERNAL GOVERNANCE									
Reviewing, Amending or Developing New Policies	72%	21%	6%	43%	13%	4%	40%	69%	15%
Reviewing, Amending or Developing New Laws or Regulation	62%	26%	13%	32%	23%	9%	36%		
Reviewing , Amending or Developing New Standards and Gui	70%	19%	11%	49%	11%	4%	36%		
Reviewing or Amending Transport Sector Governance or Stal	62%	30%	9%	36%	11%	6%	47%		
Pursuing Public-Private Partnerships (or Equivalent)	68%	21%	11%	26%	19%	6%	49%		
Pursuing Partnerships with Academia (or Equivalent)	79%	15%	6%	38%	15%	2%	45%		
TECHNICAL ACTIVITIES									
Research and Development	81%	19%	0%	49%	13%	11%	28%	63%	35%
Demonstration Projects	77%	19%	4%	38%	28%	6%	28%		
Innovation Competitions/Challenges	64%	23%	13%	28%	36%	6%	30%		
New Operating Franchises or Concessions	30%	43%	28%	17%	26%	30%	28%		
Technology Testbeds/Sandboxes	45%	43%	13%	17%	40%	19%	23%		
Data Governance and Management	60%	30%	11%	47%	26%	6%	21%		
Implementation/Facilitation of New Infrastructure	70%	28%	2%	40%	19%	9%	32%		
Implementation/Facilitation of New Equipment and Facilities	74%	23%	2%	45%	17%	9%	30%		
INTERNAL ORGANISATIONAL CHANGES									
Changes to Vision, Mission or Objectives	61%	31%	8%	20%	37%	12%	31%	60%	28%
Changes to Strategic Plan	67%	20%	12%	31%	37%	4%	29%		
Changes to Organisational Structure	55%	33%	12%	24%	39%	12%	24%		
Changes to Organisational Processes	53%	33%	14%	31%	37%	12%	20%		
Setting up a New Unit, Department or Division	55%	35%	10%	14%	37%	12%	37%		
Changes to People and Skills	67%	16%	16%	39%	24%	6%	31%		
Changes to Organisational Culture	53%	29%	18%	22%	35%	12%	31%		
Communicating with Citizens on this Topic	67%	18%	14%	43%	20%	12%	24%		

The Survey asked what regulatory approaches should be taken towards new transport technologies and service models. Almost half of organisations agree that new technologies and services should be progressed by the private sector, but within a proportionate regulatory framework set by the public sector. Hardly any (4%) agree that matters should be deregulated in terms of being left to the private sector alone.

Figure 3.5: Future Regulatory Approaches to Transport Technologies and Service Models (n=54)



3.2.2.4. Stakeholder Relations

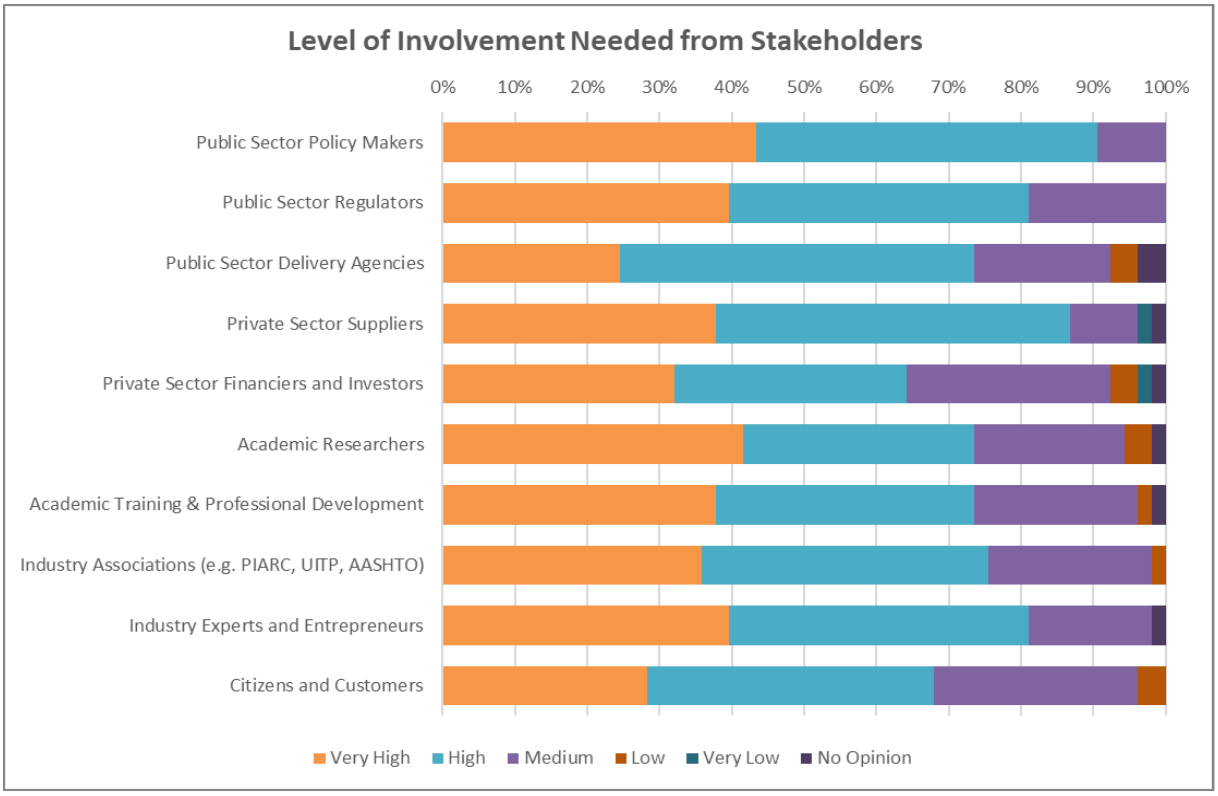
Development of new transport technologies and services will need involvement across a wide range of stakeholders. Within this, the role of Public Sector Policy Makers (91%) and Regulators (81%), Private Sector Suppliers (87%) and Industry Experts and Entrepreneurs (81%) is seen as especially important. However, there are no stakeholder groups of minor importance.

The Survey supports the view that making progress on new technologies and services will require effective collaboration between the public and private sectors, as well as to a slightly lesser extent, academia.

Current levels of engagement fall substantially below those required to make good progress on future development and adoption of new products and services.

Responding organisation have a wide range of mechanisms for engaging with stakeholders. The most popular mechanisms are General Networking (83%), Conferences and Exhibitions (79%) and Dedicated Committees and Working Groups (77%).

Figure 3.6: Stakeholders Involvement to Support Transport Technologies and Service Models (n=53)



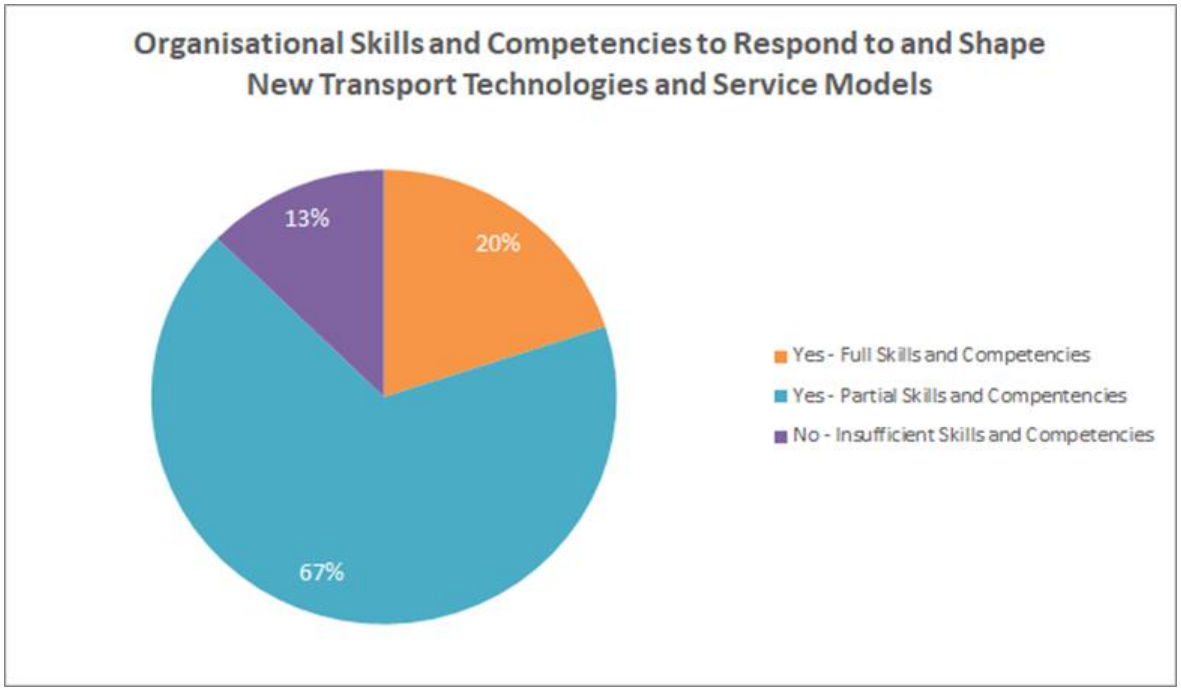
3.2.2.5. Support Needed

Most organisations (85%) require at least some assistance in responding to new technologies and services, correlating with the finding that only a fifth feel they have full skills, competencies and talent management to face this agenda. Less than one in ten feels they need no support at all.

Support is needed across a wide range of technology and service concepts and functions, with CAVs (52%), Digital Highways (49%) and Data Platforms and Analytics (50%) requiring more help than other areas. By function, slightly less support is required on stakeholder relations and engaging with citizens and customers compared to other areas such as policy development (51%), technical development and standards (51%) and skills and capacity building (53%). However, the spread of support required is extensive.

Support needs to be provided by a range of organisations, with National Governments (82%), academia (82%), international and regional bodies such as PIARC (73%) being especially notable.

Figure 3.7: Support Required to Respond to New Transport Technologies and Service Models (n = 53)



3.3. Conclusions and Implications

3.3.1. Qualifications and assumptions

This Survey was undertaken from September to December 2020 and represents a snapshot of transport organisational perspectives, activities and plans on new transport technologies and service models at that time. However, the pace of change in technological and service model development, adoption and take-up continues to be rapid.

The number of organisational responses was reasonable for a Survey of this complexity and length. However, it is suggested that many organisations less supportive, organised or equipped to tackle technological change and innovation did not complete the questionnaire. This may be reflected in the results in that less proactive, less structured and more resistant responses are underestimated.

The Survey was undertaken whilst the global COVID-19 Pandemic was continuing to cause disruption to the transport sector and transport organisations. This may have affected responses to an unknown extent. Further research post-COVID will be required to capture this.

The conclusions of this Survey are generic and high-level. However, organisational change in the face of technological change is highly location and context-specific. This greater level of granularity is explored in the In-Depth Case Studies reported in the next Chapter of this Report.

3.3.2. Conclusions and transferable lessons

The results of the Survey are broadly consistent with the findings of the Literature Review and enables the following conclusions to be drawn:

- New transport technologies and service models are seen as having high future impact, mainly positive, on individuals, communities and society as a whole. There is also the general perception that barriers to technological adoption outweigh current enablers, with public policy, equity and budgets being areas of greatest concern.

- The COVID-19 Pandemic is seen as having had a negative impact on new technology development in the short term, but with a more positive outlook in the medium- to long-term.
- Technologies and service concepts command different levels of importance and support within organisations with CAVs, EVs and Alternative Fuels, Digital Highways/Asset Management and Remote Working being more of a focus than UAM, Micromobility and Future Transit.
- Organisations have undertaken a wide range of activities to adapt their organisations and processes to the new technologies and service models. However, there is less commitment, reflecting greater uncertainty, to planning and undertaking specific activities in the future.
- Four out of five organisations require at least some development of skills and competencies to make progress with new technologies and services. It is emphasised that less supportive and prepared organisations are less likely to have answered this Survey, therefore these numbers may be underestimates of all organisations.
- Organisations are starting to consider broader competencies and skills sets to address new technologies, but have yet to fully operationalise this through recruitment practices.
- Almost half of organisations agree that new technologies should be progressed by the private sector, but within a proportionate regulatory framework set by the public sector. There is little support for a completely market-led approach, nor full public sector delivery.
- Development of new transport technologies and services will need involvement across a wide range of stakeholders and effective collaboration between the public and private sectors, as well as to a slightly lesser extent, academia.
- Four out of five organisations require some assistance in responding to new technologies. Support needs to be provided by a range of organisations, with National Governments, academia, industry associations such as PIARC being especially notable. The latter finding confirms the relevance and mandate of TC 1.1 work programme in this area, as well as other research, knowledge sharing and best practice development.
- The responses to this Survey support developing further advice structured by activity and function aligned against different technologies and service models as a final output of the WG2 programme, as set out in Chapters 6 and 7 of this Report.

Finally, the low response rate from Low- and Middle-Income countries despite strong outreach via TC 1.1 members and PIARC First Delegates, does provide some confirmation that disruptive technologies and service models are considered more of a current agenda for High Income Countries. However, further work is needed to explore whether and how certain dimensions may be applicable to countries at different stages of development, including Low and Middle-Income Countries.

4. ANALYSIS IN DEPTH – CASE STUDIES

4.1. IDENTIFICATION OF CASE STUDIES

Following the broad analysis of the Questionnaire Survey, this Chapter sets out the evidence from a series of in-depth case studies of technological research, development and innovation undertaken by 12 public sector transport agencies, collated by WG2 between March 2021 and July 2022.

The 12 case studies discussed in this summary include the following organisations, grouped with a one-line summary of each agency's area of focus:

- Australia – Main Roads Western Australia – Innovation vision and partnerships;
- Belgium – Flanders Agency for Roads and Traffic – Innovation process and organisational design;
- Italy – ANAS S.p.A. – Smart roads;
- Singapore – Land Transport Authority – Coordination for Autonomous Vehicles;
- South Africa – South African National Roads Agency Ltd (SANRAL) – Processes for research and innovation;
- Spain – Madrid Public Transport Company – Multimodal trip management;
- Spain – Madrid Regional Public Transport Consortium – Centre for Innovation and Training;
- Sweden – Trafikverket – Innovation vision and partnerships;
- United Kingdom – National Highways – Digital roads;
- United States – Minnesota Department of Transportation – CAVs and innovation processes;
- United States – Connecticut Department of Transportation – Planning for EVs and CAVs; and
- United States – Massachusetts Department of Transportation – Enterprise Data Strategy.

The responses of the case study organisations to key issues were collected using a combination of a question-based template sent out for completion in writing and in some cases a structured interview carried out online by members of WG2. The overall findings were then collated, using a Miro Board, to identify key findings, similarities and differences and draw out initial highlights.

The case studies represent varying perspectives of different agencies, groups, or divisions within each country's transport ecosystem. For example, several transport agencies, including Belgium, South Africa, Sweden, and Australia gave agency-level perspectives on where all new technologies fit within the organisation. In contrast, Singapore is focused on the efforts across the Whole of Government to develop, test and deploy Autonomous Vehicles as a specific technology. Similarly, the Massachusetts Department of Transportation case study reflects the perspective of the Chief Data Officer, in the Office of Performance Management and Innovation, around data initiatives in respect of new technologies and service propositions as well as providing a broad perspective on how the rest of the agency is handling other technologies.

The full Case Study Summary Report was published by PIARC as a separate document in November 2022. The key findings are highlighted below. WG2 is grateful to all agencies which provided case study evidence.

Figure 4.1: Final WG2 Case Study Selection

4.2. HIGHLIGHTS FROM THE CASE STUDIES

The following sections follow the structured questions posed by WG2. Key findings and conclusions are highlighted together with selected examples and illustrations from the case studies.

4.2.1. Basic Information

The transport organisations providing the case studies represent a global cross section of national, regional, and municipal level transport agencies that generally include all modes in their portfolios.

- Transport agencies are significant organisations in terms of size and capacity with almost all agencies having 5,000 or more staff;
- Case study agencies include a mix of national and regional agencies; and
- Case studies include a mix of highway, public transport, and multimodal functions.

4.2.2. Technologies and Service Models of Interest

Case study agencies were asked to indicate which technologies they believe will be significant and priorities to focus on over in the coming decade. The results are set out in Table 4.1 and show:

- **Top technologies** of great significance include CAVs, EVs, Digital Asset Management, digital highway/next gen ITS, and data platforms and analytics.
- **Micromobility, Urban Air Mobility and Future Transit Systems** are given relatively less focus at this time, either because of a lower level of technological maturity or being outside the remit of organisations focused predominantly on road infrastructure and services.
- **Remote work technology** is consistently managed at the agency level, including as a response to the Pandemic. In practice, often a central IT organisation has addressed issues with remote work, with implicitly less focus, at this stage, on digital connectivity as a policy instrument for mobility management.

Transport agencies can implement some of these technologies without the influence of the private sector (e.g., agency-owned EVs, ITS, IoT, digital design and construction, digital operations). Some technologies will influence the agency because a substantial population of end users will use them and this broad use will influence how transport agencies need to operate and maintain their systems (e.g., EVs, CAVs, MaaS). Finally, some technologies will influence transport agencies through public-private partnerships (e.g., signal systems, digitized roads, robotic production).

Table 4.1: Transport Technologies and Services of Interest to Case Study Agencies

Technologies	Level of Interest			
	High + Med	High	Med	Low
Connected and Autonomous Vehicles	9	4	5	0
Digital Asset Management	9	8	1	0
Electric and Alternative Fuel Vehicles	8	7	1	1
Digital Highway/Next Generation ITS	8	6	2	0
Data Platforms and Analytics	8	6	2	0
Remote Working Technologies	7	4	3	0
Enabling ICT (5G, IoT, Blockchain)	7	3	4	2
Shared Mobility	5	2	3	3
Smart Journey Planning & Management	4	4	0	4
Urban Air Mobility	3	1	2	2
Micromobility	2	2	0	5
E-deliveries and Urban Logistics	1	1	0	4
Future Transit Technologies	1	1	0	2

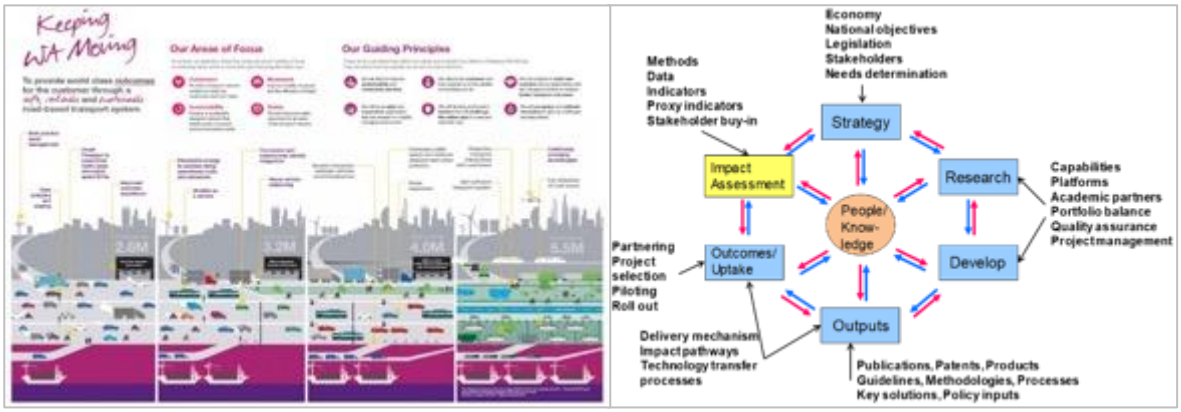
4.2.3. Organisational Considerations

4.2.3.1. Approaches for Organisational Change

There are a range of organisational approaches to innovation and technological change within the case study agencies, including working within existing structures and or revising structures to accommodate new technologies. Approaches, such as those shown in Figure 4.2, include:

- **External Influence:** A political leader creates a direction that requires an organisation to respond to, or implement, a technology in some way;
- **Agency Vision/Strategy:** Agencies address emerging technologies as a fundamental philosophy within overall agency goals and objectives;
- **Organisational Structure: This includes o**ne person shows, new or expanded offices, cross-agency committees, or organisational model reviews;
- **Business Process Redesign:** Agencies create well-defined processes for identifying, implementing and managing innovation;
- **Structured Innovation:** Agencies have structured arrangements for exploring problems and developing solutions, such as design thinking or double diamond models; and
- **Regulations:** Development of guidelines (including for testing ahead of early deployment); executive orders or directives which guide private sector and other actors.

Figure 4.2: Innovation Case Studies – Main Roads Western Australia Vision for Future Road-Based Transport and SANRAL's Systems-Based Model for Innovation Management in the Roads Sector



4.2.3.2. The Transport Agency of the Future

The transport agency of the future will use many techniques to focus on emerging technologies. The agency vision will include technology, the agency will be organised to allow for focus on finding, filtering and implementing new technologies; the agency will have strong partnerships across government, industry, and academia to influence external parties and properly design regulations; the agency will be more automated, agile, and flexible; and the agency will move with greater agility.

4.2.3.3. Approaches To Become the Transport Agency of the Future

To achieve their future organisation, agencies must draw from a range of approaches to organisational change, but in particular emphasising the following:

- **Intellectual Gathering:** Continuing or creating committees, groups, forums, etc. (intra-agency, inter-agency, and cross-industry and with or without executive/decision-making authority);
- **Formal Remit:** Appointing officers or forming groups with remits to progress research, explore technology solutions, consider future standards or pursue broader innovation with the organisation;
- **Reorganising:** Reorganising the agency to better focus on tracking trends, managing an innovation, digitising services and on implementation;
- **Partnerships:** Building relationships among government, industry, and academia, with private sector collaboration being seen as especially important;
- **Skilling Up:** Adding skills required to manage innovation and change, including communications, networking, coalition-building, and digitisation;
- **Workforce:** Actively planning and managing changes in the workforce, including new skills sets, new job descriptions and diversity of employees required in the future; and
- **Management Support:** Providing support (i.e., people, resources, communication) and leadership from management in terms of innovation.

4.2.4. Specific Research, Testing, Pilots, and Service Models

Transport agencies have been implementing technologies in several areas, including digital transport agencies, connected and autonomous vehicles, connected infrastructure, and new modes and business models.

4.2.4.1. Digital Transport Agencies

Agencies are using technology to change how they maintain and operate their systems, including:

- **Enterprise Data Management:** For example, MassDOT is building an enterprise data lake to store and share its highway data;
- **Advanced Analytics:** SANRAL is investigating using machine learning with video cameras to predict incidents and flag suspicious or unusual network and highway activity;
- **Improved Measurement:** The Flanders Agency for Roads and Traffic is exploring using digital technologies to determine the condition of road assets and using data from road users to determine the condition and required next inspection of road assets. Trafikverket is collecting data on slippery roads using anonymized data from passenger vehicles; and
- **Remote and Hybrid Work:** Many agencies are working to improve processes and systems to support this, building on the reactive measures introduced during the pandemic. In practice, often a central IT organisation at a higher level of Government has addressed issues with remote work technology.

4.2.4.2. Connected and Autonomous Vehicles

Agencies are implementing autonomous vehicles within their own systems and also creating programs to ensure the safety of private-sector autonomous vehicles on public roads:

- **Automated Bus and Shuttles:** Connecticut DOT is preparing to launch the first pilot of full-sized automated, buses in 2023 on its limited access busway. Minnesota DOT has conducted an automated shuttle bus pilot project to test the feasibility;
- **CAV Readiness Programmes:** The UK has conducted multiple CAV trials on its road network. Singapore has a systematic and formal structure for allowing automated vehicles on its roadways; and
- **Infrastructure:** Singapore also is working with land use and planning agencies and industry to examine the infrastructure needed to enable autonomous mobility. The planned pilot deployment will give insights for town-scale deployments, from V2X to physical planning to charging/parking requirements.

4.2.4.3. Connected Infrastructure

Agencies are working to connect their infrastructure, including:

- **Agency-owned Fibre and Wireless Networks:** Minnesota DOT has been installing its own fibre and wireless networks along its right of way to enable communications for any sensors necessary;
- **Connected Signals and Devices:** The Anas S.p.A. Smart Road Programme exhibited connected infrastructure technology, including IoT sensors, Wi-Fi access points, DSRC hotspots, LET-Vehicle Base Stations, and on-board units;
- **Robotisation of Construction Sites:** Flanders is exploring the robotization of construction sites, using connected and autonomous machines (e.g., excavators) to optimise road maintenance and construction;
- **Systems for Real-Time Characterization of Roadworks:** Anas S.p.A. has set up a monitoring system called the Automatic Roadworks Extension Alert (AREA) System. The information from these systems are integrated and used to improve info-mobility services, to detect and generate alerts for dangerous events, and to inform road users in real-time; and
- **BIM and Digital Twin:** Flanders is exploring static and dynamic digital twins to control infrastructure and to export intelligence for policy analysis and plan maintenance.

4.2.4.4. New Modes and Business Models

Agencies are exploring how they can implement new mobility modes and business models, including:

- **MaaS for Accessible Rides:** MassDOT and the Massachusetts Bay Transportation Authority (MBTA) have partnered with Lyft and Uber, to launch a one-year pilot program aiming to improve mobility for individuals with disabilities. They are offering Lyft and Uber fixed subsidies for every hour that these companies make wheelchair-accessible vehicles (WAVs) available for use by customers within the designated service area;
- **MaaS Solutions:** Madrid Mobility360 provides access to parking, transit, and other modes. It includes route planners, booking and payment platform and expansion across different modes. Through its park and ride parking program, through the Mobility360 app, Madrid rewards parking outside the city if the city centre is accessed by public transport;
- **Air Mobility Pilot:** MassDOT has teamed with NASA to explore Urban Air Mobility. NASA will be working with the MassDOT to ascertain on how to best work with communities to integrate a new, green, quiet, and equitable mobility option that will leverage these next generation air vehicles; and
- **Virtual Customs:** Anas S.p.A. has a virtual customs project in Trieste, a smart road that virtualizes the Fernetti customs and the port authority to check the containers to be loaded in Fernetti, to carry out the procedures some distance away from the port.

Figure 4.3: Singapore Autonomous Vehicle (Car Lite) Vision Applied to New Town Development

4.3. CONCLUSIONS AND IMPLICATIONS

The In-Depth Case Studies collected by WG2 provide a wide range of useful in-depth evidence for considerations of new transport technologies and service models and their planning, assessment, and progression through transport organisations in several countries. These focus either on specific technologies or wider frameworks, processes, and structures for progressing innovation across a range of fields.

From the case study review, WG2 learned that technological change is coming, and transport agencies must proactively prepare and adapt. While these case studies focus on agency adoption of innovative technologies, the WG would like to keep these evolutions in the broader context of

change, disruption and uncertainty in the real world. The Literature Review identified major changes to society (e.g., demographics, equity, and the sharing economy); the economy (e.g., different revenue sources, monetisation of data, and supply chain challenges); the environment (e.g., extreme weather events and sea level rise); and the government and governance (e.g., regional governance, political discord, geopolitics, broader channels of representation); and safety and security, all of which impact technology, services and innovation.

Transport agencies will need to manage technological change alongside these other changes derived from macro trends. The case studies give examples of how agencies have been successful in starting to prepare and to adapt and to which priority and near-term concepts and applications.

Our conclusions from the In-Depth Case Study review overall are as follows:

- **Technologies and new service concepts are advancing with technical problems being resolved "relatively" rapidly:** Yet policy, regulatory and practical challenges of validating, certifying, deploying and scaling up viable use cases and applications remain significant, requiring a proactive, informed and balanced response from agencies and stakeholders.
- **To scale innovation, agencies need to maintain a strong learning mindset:** Agencies must provide their people with the right skills to develop strategies, evaluate, implement, and scale technologies, and manage the change from the disruption. Agencies must learn to build successful innovation implementation pipelines by learning from each other and drawing on effective practices. Uncertainty and volatility must be accepted and managed (e.g. through scenario planning).
- **Partnerships, governance, and standards are critical:** Technology can be owned and operated by transport agencies themselves, but innovation, new products and services often come from the private sector. As the private sector builds new services and business models (e.g., around mobility services, vehicles, and operations), transport agencies must engage to agree on how to adapt and maintain its infrastructure, how to increase public benefit, regulate appropriately, share data, and assess the equity of impacts. Among the group of partners, one or more organisations must lead, working with partners to define which platforms, standards, policies, and regulations need to be implemented to ensure the needs of the users are being met.
- **Stakeholders and end-users are critical:** Transport agencies should coordinate closely with the end users to understand final impacts. Ultimately, transport agencies are providing a service to people who want to travel (or digitally connect) to visit friends, family, work, or other places and to people who need to move goods. These people are the marketplace and will ultimately adopt the new technologies and make them disruptive. Transport agencies should coordinate to understand the impacts of the technologies on these users and to infer how their travel behaviours and transport needs might change as technological and other changes take hold.
- **Innovation requires trial and error, and takes time:** Many trials will fail because technology is untested. But, as more agencies test more technologies, they need to learn from the attempts, adjust, and take forward lessons learned to create sustainable programmes. Some technologies, like early CAVs, require test zones, including regulatory sandboxes, that provide a secure place for technology to fail while ensuring public safety. Some technologies are complicated and difficult to develop, and they will take a long time to proliferate into the market and gain social acceptance. Because of this, transport agencies should be mindful of industry marketing claims and understand that this is a potential point of failure of an otherwise successful pilot.

- **Communication (and a strong business case) is a key ingredient to sustainable innovation:** Agencies that have built strong innovation pipelines have learned that while technologies may be 'owned' by different parts of the agency (e.g., planning, innovation, or policy offices), there is a need for a broad rollout strategy with ambassadors and other communication techniques. The rollout requires a strong business case and answers the question 'what's in it for me?' for managers and front-line staff alike. It should be noted that there will be technologies that are disruptive that also will be challenging to fit into a business case – for example, the smartphone has been disruptive by any measure, but in advance of its arrival, it would have been difficult to categorize and create a supported business case for its use in transport agencies.
- **Innovation should be supported from the top management, based on a strong business case:** Top management must be part of making an innovation sustainable within or for an agency. This starts ideally from a clear and supported vision. Making a business case by showing how the technology can improve the operations of the agency or otherwise increase the public benefit (however this is defined) will help to bring along decision-makers and garner support (i.e., funding, and political support) for long term implementation efforts.
- **The organisation needs to change to enable innovation:** Organisational processes and structures should be aligned with innovative approaches. When there is a new business process, there is a link to potentially alter the organisational structure and resources. This may lead to a need to change organisational culture, hearts and minds, skills and capacity, as well as create new job descriptions, mandates and functions.
- **Only some technologies are entering the mainstream in the near term:** As the Literature Review and Questionnaire Survey also show, there is a clear emphasis on EVs, Connected Vehicles and associated infrastructure, and data sensing and processing in the near term. Fully autonomous transport, whilst having potentially profound impacts on mobility infrastructure and services, as well as society more widely, will follow only in the medium- to long-term.

Additional Case Study: Little Roady – Trialling Autonomous Transit in Rhode Island, USA

Following an "Autonomous Vehicle Mini-Summit" in April 2017, the Rhode Island Department of Transport (RIDOT), USA, initiated the Little Roady Autonomous Vehicle shuttle pilot with the objective to understand and learn from mobility-related opportunities, operational performance, user experiences and public perceptions offered by such emerging technologies.

The pilot consisted of a free daily shuttle service which operated from May 2019 to March 2020 along a twelve-stop, 5.3-mile (8.5 km) loop along the Woonasquatucket Corridor in Providence, Rhode Island. Key goals of the public-private partnership project with May Mobility of Ann Arbor, Michigan, were to safely introduce and test AV technology in an applied context, provide equitable mobility through providing meaningful first and last mile connections, accelerate innovation, and evaluate public user experiences. A primary goal of the pilot was also to inform future policy and planning decisions related to the application of autonomous technology in Rhode Island and for transportation planners and regulators more broadly.

Little Roady operated successfully over the life of the trial, providing more than 40,000 rides during that period with an average of 140 trips/day, until its sudden cessation on account of the COVID-19 Pandemic. During this time, its reliability operating in autonomous mode improved, with incidents infrequent and not serious.

Trialling AVs as a form of transit in a complex urban setting demonstrated that the technology is not as ready as indicated in the media or by the industry at the time of the trial in 2019-2020. While use of AV mode reportedly increased over the trial, field observations by the research team, indicated that the average time spent in AV mode was typically less than half of a given route duration, with some route durations run entirely on manual. Field observations were necessary as the operator did not provide the agency with direct disengagement data and AV statistics. The full research report, A Rhode Trip: Lessons for the Future of Mobility From the Little Roady Autonomous Microtransit Pilot (bts.gov), was published in September 2022.

Diverging interests and perspectives between the contracting authority and the operator also call for close attention to how public-private partnerships are structured if AV transit deployments are to serve a public good, especially in relation to such issues as data sharing, uniformity, and transparency.

The trial showed that the public has a sophisticated perception of the issues associated with AVs, including convenience, technology, efficiency, privacy, and safety. Many user experiences were positive, but not directly AV-related. Looking ahead, it is important to consider user-centred design of transit for riders.

Little Roady demonstrated that the public sector can lead the AV industry by setting the precedent for the market to follow. However, it is important to engage in early-stage negotiations to set up mutually-beneficial public-private partnerships that ensure the public partner has desired data access and appropriate level of operational control. Allowance must be made for early and ongoing multi-stakeholder engagement, as well as proactively approaching safety, ethics, algorithms, and automated decisions. Finally, collaboration should also take place with workforce leaders on the changing role of transit workers in the context of an increasingly automated future.

The results of the trial will inform RIDOT's post-COVID policies towards AVs, help structure other pilots, as well as providing lessons for other States considering showcasing or evaluating the technology.

5. ANALYSIS IN DEPTH – PRIVATE SECTOR PERSPECTIVES

5.1. ROUNDTABLE OVERVIEW

Following the Literature Review and Questionnaire Survey and, in parallel with the commencement of the In-Depth Case Studies, it was felt that a stronger evidence base on the key issues was needed from the private sector. Indeed, many of the key innovations and technology development under examination are emerging from the private sector, either through established firms or new start-ups. The Survey also showed that the majority of transport organisations themselves believe private sector entrepreneurs and innovators should lead, but within a proportionate regulatory framework provided by the public sector.

For this reason, there was a need to understand how private players see the role of government, and public entities, including transport agencies, in determining the way forward and critical issues around public policy, regulation and balancing private profit with public value and interest.

WG2 therefore further collaborated with IATR, through its President, a Corresponding Member of TC 1.1, to hold a Private Sector Roundtable in December 2021 as part of the 34th IATR Annual Conference. This Roundtable was entitled *'Innovation Workshop – Industry Perspectives on Disruptive Technologies and Service Models Shaping the Transport Sector'*. The full Roundtable Report was published by PIARC as a separate document in July 2022.

The running order of the Workshop commenced with WG2 representatives introducing PIARC, the subject matter, emerging concepts, and key questions, followed by guided discussion with participants from the private sector, facilitation and summing up by the IATR President.

Some ten firms were represented within the Roundtable, split into groups on Emerged Technologies (with commercial applications now) and Future Technologies (with applications under testing or development and still to achieve commercial application), in areas including ride-hailing, microtransit, micromobility, electric vehicles, autonomous vehicles, Mobility-as-a-Service (MaaS) and urban air mobility (UAM). Brief profiles of these companies are as follows:

5.1.1. Roundtable Group 1 – Emerged Technologies

Via

VIA provides technologies to public mobility systems including on demand public transit, school buses, public transit planning, integrated multi modal trip planning including payment and ticketing.

Lime

Lime focuses on micromobility, offering first and last mile solutions, connecting people to their main form of transit and any other point.

Empower

Empower provides software which enables drivers to set their own rates and offers incentives for providing rides in underserved communities where trips are often shorter and less expensive.

Superpedestrian

Superpedestrian helps city management by sharing data on micromobility, providing origin-destination data which aids planning and infrastructure with focus on pedestrian safety.

GETT

GETT is a ground transportation management platform and offer aggregated content for corporate organisations to manage their ground transportation expenses.

5.1.2. Roundtable Group 2 – Emerging Technologies

Gravity

Gravity is involved with electrification for the taxi industry through infrastructure and EV fleets.

Joby Aviation

The company has developed multiple designs for urban air mobility during the past 13 years with the current model aiming for coming to market in 2024. The airplanes will be inaudible, all battery powered, with no emissions and not require expensive infrastructure.

Metropia Inc.

The company provides a MaaS solution for micromobility, freight, taxis and limousines. An AI (Artificial Intelligence) algorithm allows the system to simplify traveller experience.

PluService

The software house has more than 30 years' experience in passenger transportation related integrative, transportation systems to support daily operations of public transport operators including Business to Business services, freight management, ticketing system and MaaS.

Waymo

Waymo´s goal is to be more enabler than disruptor, displaying innovative technology. The company operates the world's first autonomous ride hailing service in Phoenix, Arizona and is also working to set up a logistics business on long haul trucking with fully autonomous trucks.

5.2. KEY FINDINGS

It was generally agreed that the Roundtable succeeded in its objectives of eliciting a range of private sector perspectives on the future of mobility and the role of government and public agencies in facilitating this. The key findings are summarised below.

There are multiple new technologies, service concepts and business models which are already transforming, and will continue to transform, the transport sector. The future is bright and technology-enabled, and this will result in major improvements in many current transport challenges such as traffic congestion, carbon emissions, road safety and driver equity. These improvements will support the achievement of many policy objectives set by government at multiple levels.

Innovative and driven as it is to conceive, develop and roll out new mobility products and services, the private sector needs and expects a strong public sector to lead, provide a suitable policy and regulatory framework, balance competing interests, level the playing field and set the rules of the game. Only if these things exist will the private sector have the confidence to plan ahead, invest and take the commercial risk to develop new products and services in the long-term.

Government should regulate, but do so appropriately and proportionately. Regulation should be informed by knowledge, experience, and feedback being sought from the private sector, so it can be realistic. Regulation needs to be agile and flexible, anticipating rather than reacting to change, given the pace and unpredictability of technological development and its commercialisation.

Business is about private profit and return, whilst government is about public service and value. Both are legitimate objectives in their context and are not mutually exclusive. There needs to be mutual recognition and agreed ways to balance both for the good of society as a whole.

Government may, and often does, initially support or subsidise initial research and development of new concepts, but in the medium- to long-term new technologies and service models will only succeed if they are commercially viable, offer a solution to a recognised problem and in demand from customers. The private sector clearly sets robust commercial tests for the latter.

The public sector provides much of the infrastructure on which current and future mobility services will run. Yet that infrastructure is often out-dated, based on old and inflexible standards and not fit for purpose in the face of new demands and needs. Investment in constructing and maintaining modern, flexible and future-proofed infrastructure and maintaining it in a good condition is therefore a priority, along with the funding and governance arrangements to bring this investment about.

Data collection, sharing and governance are key points of engagement and contention between the public and private sectors. Government is right to require data on mobility services, but this should not be unconditional. Public entities should be clear on the data they request from the private sector, only request what is needed and seek to offer reassurance around legitimate concerns around anonymisation, user privacy, commercial confidentiality, and cybersecurity. Standard protocols should also be agreed at the industry level so different agencies do not request data in different formats and with different conditions, resulting in additional processing, inconvenience, time and costs to business.

The public sector needs to develop adequate skills and capacity to set appropriate and balanced policy and regulation for future mobility technologies. Often these skills are lacking, together with a closed or defensive organisational mind-set and culture, and this can result in over- or under-regulation and potentially act as a blocker on private sector activity. Capacity building on multiple fronts is therefore needed, including offering terms and conditions, and providing career paths to attract the best and diverse talent which can act as a counterpart to private sector colleagues. Employee mobility between public agencies and private companies should also be explored so that key approaches, mindsets, and solutions are aligned.

An ongoing dialogue, and formal mechanisms to facilitate this (such as multi-modal advisory boards), between the public and private sectors are essential to agree on expectations for future mobility technologies and services and guide joint action against common goals. The PIARC – IATR Roundtable was seen as a useful contribution to commencing that dialogue.

5.3. Conclusions and Implications

The key conclusion from the Roundtable was to confirm a finding from the Literature Review and Questionnaire Survey. This is that the development and ultimate delivery of new transport technologies and service models will be led by the private sector. However, the private sector itself accepts the need for, and indeed expects, a clear regulatory and supporting environment from government and public entities to set the rules of deployment, set out the policy objectives to be delivered and ensure that private entities have stability, clarity and confidence to invest. Equally, the public sector needs to have the skills, competencies and capacity to create such an environment and act as a strong partner to private innovators, corporate entities and investors.

5.3.1. For the Private Sector

Unlike the smartphone-based technology that underpins ride-hailing, companies on the cutting edge of transportation technologies should realise the risks involved in their businesses and the need for proper regulation. Just as tech enthusiasts had, in the past, embraced the idea that “ridesharing” could solve traffic congestion, they might be lulled now by the idea that autonomous

driving could be the solution, in addition to cutting down on traffic casualties The private sector must realize that public regulators have a very important role to play in setting up a holistic framework of governance.

It is important that the private sector works with regulators for the latter to understand the intricacies and practicalities of the new technologies and services. The goal is to help regulators understand how the products and services can be utilised, how to 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 and advancing innovation.

Public-private partnerships, in the broadest sense, are necessary to explain to transport and other government agencies the specific problems to be resolved, the basis of the technology itself, how to use data-driven technology, such as ridership metrics, to make better decisions and other social, environmental and climate goals to be achieved.

The private sector should lead solutions to the problems that the public sector is trying to solve. The solution may not necessarily require new mandates, but may simply be being open to new business models through a free market solution. Part of the value of having a public private partnership is to facilitate communication going both ways and recognising multiple ways to tackle a problem.

5.3.2. For the Public Sector

The transportation sector, just like any other sector, should be regulated to address market failures. Market failures refer to situations in which free markets do not result in an efficient allocation of resources, resulting in a loss of economic and social welfare. Markets can fail for a variety of reasons, including the presence of a natural monopoly, large sunk costs, information asymmetries, and negative externalities (e.g. traffic congestion, air pollution).

Unfortunately, transport agencies typically move at a glacial pace relative to the rapid pace of disruptive technologies and business models. It is incumbent upon these agencies, therefore, to keep themselves abreast of the latest changes in the industry. They should consider setting up advisory boards with representation from industry leader. Due to budgetary constraints, transport agencies typically do not hire the best talents in the field, but that has got to change. In today's context, that would translate to hiring those with robust skills in AI, machine learning, predictive modelling, etc. Data is, after all, the new oil of the digital economy. For example, data-driven transit will result in better solutions for demand planning, which will reduce operating costs and improve efficiency.

When it comes to regulations, whilst focusing on near-term technologies, transport agencies should be wary of short-termism, which refers to an excessive focus on short-term results at the expense of long-term interests. Externalities such as climate change require mitigation and adaptation strategies with a future outlook of decades ahead. It is not as simple as coming up with plan to add EVs or charging infrastructure over the next ten years. The window for achieving net-zero emissions in the road transport sector by 2050 is getting narrower by the day, so there is urgency on the matter and 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 the communities they serve by using public and shared transportation methods which are affordable, efficient, tech-enabled 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.

6. SYNTHESIS – THE ROLE OF TRANSPORT AGENCIES IN SHAPING THE FUTURE MOBILITY ECOSYSTEM

6.1. OVERVIEW

The World continues to change constantly, presenting an environment which is Volatile, Uncertain, Complex and Ambiguous (VUCA). In the post-COVID World, these factors are arguably even more evident. Transport agencies are impacted by this change as much as other organisations and must constantly adapt and respond if they are to remain relevant, effective and efficient in delivering the right services and outcomes to their customers, stakeholders and society as a whole. Nowhere is this clearer than in the field of disruptive technology and innovation where the emergence of the new Future Mobility Ecosystem, in its multiple components and dimensions, presents diverging opportunities, risks and possibilities, all requiring a response.

The question arises what form should this response take? Should agencies attempt to plot the future and definitively chart a detailed plan for the way forward, or should they leave their options open in the face of uncertainty? Should they seek to directly determine, or more loosely facilitate, certain outcomes? Should they lead or follow? Should they work mainly on their own account or recognise the need to collaborate with other entities from the public, private and academic sectors? Should they actively regulate technology innovators, by how much and to what ends? The answers to these dilemmas are often not obvious, nor the balance to be struck between bravely facing a dynamic and exciting future, and protecting immediate public safety, value and interests in the present.

The Literature Review, presented in Chapter 2, as well as our own discussions within TC 1.1, confirm that transport agencies do have a fundamental role to play in the inception, development and scaling up of the Future Mobility Ecosystem. Specifically, they could act as facilitators or catalysts for innovation at an early stage of the technology lifecycle, as policy maker and standard setter during market framing and as a platform provider, steward or regulator during adoption, mainstreaming and maturity. These roles are not just self-identified by transport agencies themselves, but fully recognised and desired by the private sector to provide a framework within which innovation, technological development and roll-out (and the investment underpinning it) can take with certainty, confidence and predictability, reassuring and attracting individuals and enterprisers to strive for better products and services. This is the challenge against which further dialogue across the transport and mobility sector is essential.

In this Chapter we attempt to bring the preceding evidence base and analysis together to crystalise the roles of transport agencies in shaping disruptive technologies and service models moving forward, based on conceptual models, areas of activity focus and broader themes of innovation.

6.2. CONCEPTUAL FRAMEWORK

Innovation of disruptive and radical mobility technologies and services, for example connected, autonomous, electric or shared within and across modes and networks, takes place within the Future Mobility Ecosystem that is itself constantly evolving through new concepts, players, organisational structures, business and operating models within a complex and dynamic political, economic and social context. Different entities, public or private, can no longer act in isolation or deliver economic, social and environmental benefits alone. All parties must find their place within the Future Mobility Ecosystem and move forward together. This applies to not only the technological components themselves, but also the policy, regulatory and governance conditions

required to evolve and operate complex systems and make them technically, operationally, commercial and socially effective.

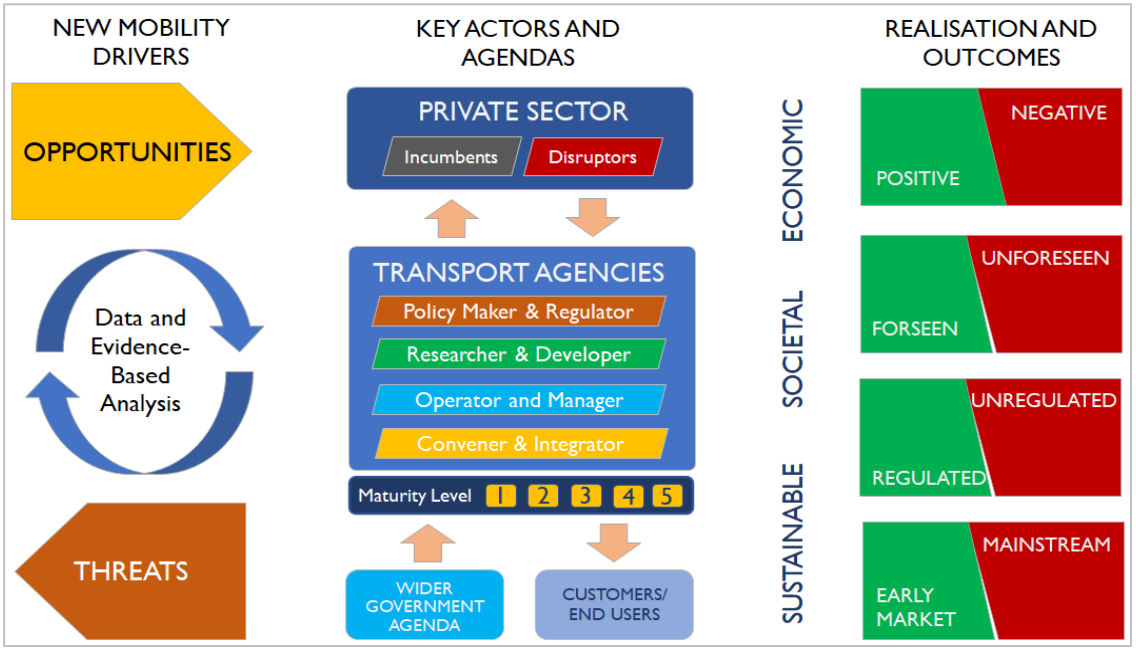
Figure 6.1 gives an early conceptual framework navigating the Future Mobility Ecosystem from an input, process and output perspective.

Within this framework, all opportunities arising from technological change should be identified, understood and incorporated, together with all potential threats and risks, based on available data, stakeholder opinions and evidence-based analysis. There should then be an interplay of public and private actors, including transport agencies themselves, that fulfils certain roles with focus on end users. From these agendas, both transport-specific and within the wider mandate and functions of Government, we would then expect results through experimentation, trials of increasing complexity and different stages of the technology cycle, to lead to defined outcomes in economic, social and sustainability terms. These can be either positive or negative, predictable or unpredictable, directed or not directed and they can develop within the early market as well as moving towards the mainstream and ultimate maturity.

The framework is intended to give a holistic overview of the process by which transport agencies and their stakeholders in the public and private sectors should go about assessing threats and opportunities, defining their roles and activities and with consideration of the outcomes which will arise. It is the interaction involved which gives the framework power.

The rest of this Chapter now considers those specific roles in further detail, supported by more detailed strategies and potential initiatives in Chapter 7.

Figure 6.1: Conceptual Framework for Transport Agencies within the Future Mobility Ecosystem



6.3. Potential Roles of Transport Agencies

All research methods and evidence bases undertaken during WG2's research have shown that transport agencies in contrasting countries adopt different roles and pursue different activities in respect of disruptive technologies and service models. Some are proactive and expansive in the manner in which they do this whilst others are reactive and more limited in their responses.

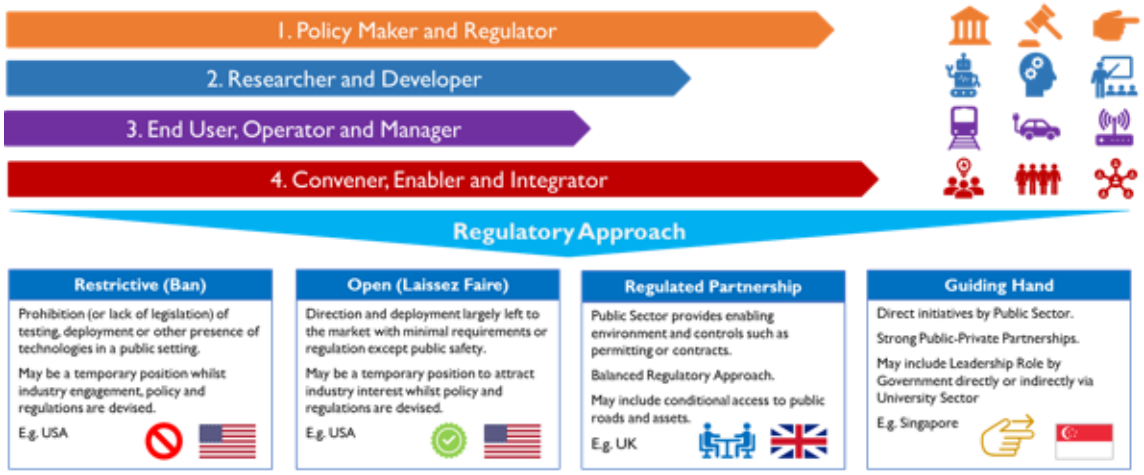
Nevertheless, as shown in Figure 6.2 below, four basic roles can be clearly identified and benchmarked. These are:

- Policy Maker and Regulator;
- Researcher and Developer;
- End User, Operator and Manager; and, potentially most importantly
- Convener, Enabler and Integrator.

These roles cannot be seen in narrow terms just for the transport sector in isolation, but reflect and impact wider public policy agendas such as economic development, industrial strategy, accessibility, infrastructure investment, workforce planning, citizen services, liveability, quality of life, sustainability, area branding and competitiveness, academia and higher education. This in turn reflects a vital point, that technology and innovation are not merely ends in themselves, but must relate to public policy goals, societal interests and public value which must be delivered. This is the existential role and function of Government itself and must drive everything that follows.

The four roles are also dynamic, with no clear end state, changing, flexing and potentially being added to over time. In the future, we would expect them to move from peripheral to transport agencies to becoming central to function, activities, values and culture. Agencies therefore need to be flexible and agile, anticipating and shaping, as well as purely responding to, change. For that, the right mind-set is needed, and political leadership and top management needs to help promote, propagate and act as exemplars of the outcomes which are desired to be achieved in the longer-term.

Figure 6.2: The Four Roles of Transport Agencies in Future Mobility



The four roles can be defined in further detail, with some examples over and above the case studies set out in Chapter 4, as follows:

- **Policy Maker and Regulator**: For example to favour, encourage, require, support (and sometimes constrain) certain technologies and service models, to set and monitor targets, to ensure that new products are safe and ethical, to protect privacy and public interests or to set the rules of access and use of public roads and infrastructure, as well as developing policies, laws, regulations, strategies and plans for future mobility over the next 10, 20 or 30 years.

Examples: In the UK, the Centre for Connected and Autonomous Vehicles has developed a Code of Practice for Automated Vehicle Trials, whilst the Australian National Transport Commission has undertaken a number of regulatory studies for AVs.

- **Researcher and Developer:** For example to foster or support innovation through technology trials or demonstration projects, to organise public competitions, conventions and showcases, to organise or fund policy evaluation, primary research, or provide specific or wider test beds and sandboxes within which innovators can test and develop their concepts, either directly or with or via universities and public research institutions.

Examples: In Singapore, the Land Transport Authority has worked with Nanyang Technical University to launch the Centre of Excellence for Testing and Research of AVs (CETRAN), whilst Rhode Island DoT procured Little Roady as a demonstration transit project of CAV technology in the State Capital. In Dubai, the Roads and Transport Authority is promoting a Self-Driving Transport Challenge which trials different use cases and suppliers of AV technology.

- **Operator and manager**: For example to adopt new technology in Government vehicle fleet procurement, specification for public transport operating contracts or the design of public infrastructure, either through current assets or the future-proofing of specifications to allow adaptation or re-purposing as new products and services become available.

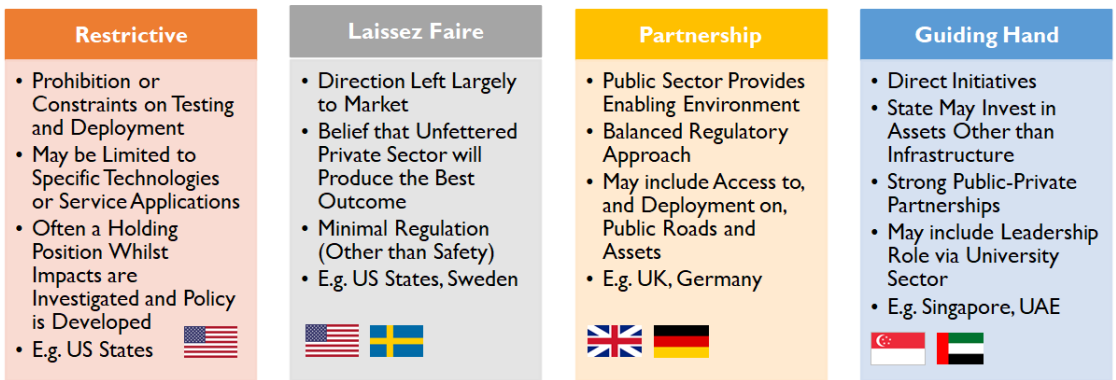
Examples: In Abu Dhabi, the Department for Municipalities and Transport has set a target for 50% of Government vehicles to be Low Emission (Battery Electric or Plug-In Hybrid Electric) by 2030, whilst Dubai RTA is working to procure up to 40% of the public taxi fleet being fully autonomous and electric, again by 2030.

- **Convener, Enabler and Integrator**: By bringing key players together, encouraging (or requiring) collaboration, promoting public – academic – private partnership, as well as working to anticipate and avoid market failure, address barriers to early market development or entry, or tackle negative externalities in future technology development and roll-out, plus integrating and regulating data and other common assets in the wider interest.

Examples: In South West England, two local highway authorities and two universities have worked with eight private sector partners to deliver the VENTURER Programme as a three-year research and demonstration project to test the capabilities, liability issues and public perceptions of Connected and Autonomous Vehicles.

Not every agency takes on a role or take it on in the same way. As we concluded in the case studies, there are early adopters, leaders and agencies which wait-and-see. There are also differing extents to which transport agencies, and the public sector more generally, seek to intervene in the market and exert influence and control over the private sector. This is shown in Figure 6.3 and may be overall or in respect of specific technologies, use cases or service applications.

Figure 6.3: Degrees of Intervention in the Future Mobility Ecosystem



Within this classification, Singapore can be considered an early adopter, taking a guiding hand to technology development, testing and roll-out. Various public entities, including the Land Transport Authority, pursue direct initiatives and promote strong public-private partnerships which drive results. The application of technology in mobility is consequentially highly visible on the ground for users. The same can be said for Dubai and Abu Dhabi, as well as China and other cases in East Asia.

By comparison, the UK and many countries in Europe offer more of a collaborative partner to private innovators. The Government and the public sector provides an enabling environment working with companies through a balanced regulatory approach, as well as support through academic research programmes. These regulations themselves are reviewed and adapted as the capability of technologies, and the roadmap for their safe and reliable adoption, changes over time.

At the other end of the spectrum, there are examples from the USA where technological leadership is clearly left to the market and Government stays in the background, except in key non-negotiable areas such as safety. This can allow rapid progress in development and deployment of innovations, but can also lead to inconsistencies. Not all private parties are on the same page (in terms of vision and technology) or can agree on a consensus around what is beneficial, effective and practical, and what is not. Here there is no guiding hand that filters, channels and differentially promotes innovations and products. Despite the potential for rapid deployment, this may also ultimately slow down the implementation of innovation in the field. Private parties seeking investment may be nervous where there is uncertainty whether Government direction or support (direct or indirect) will be forthcoming. There are risks that not every private partner can or wishes to take and this emphasise the role of the public sector in providing confidence to the market.

Ideally, we feel transport agencies and other Government entities should evolve from a ‘laissez faire' model for mobility regulation to a balanced and proportionate approach based on collaboration. The Questionnaire Survey strongly supported this view of a private sector lead within a robust but agile regulatory regime set by the public sector. This will ultimately set the ground rules for widespread development and implementation of future technologies.

The development of appropriate regulatory approaches may also benefit from the definition of some first principles with which to guide action. Based on some ideas derived from our Literature Review, these could include the following items, encapsulated within Regulatory Impact Assessments or equivalent frameworks:

- **Adaptive Regulation:** Shifting from a one-size-fits-all ‘regulate and forget’ approach to a responsive, agile, iterative and dynamic model which changes over time in response to technological maturity and the state of market adoption;
- **Regulatory Sandboxes:** Creating sandboxes, accelerators and other enabling environments to prototype and test new technologies thoroughly ahead of firm deployment or scaling up;
- **Outcome-Based Regulation:** Focusing on the ultimate benefits to be delivered and the risks to be avoided or mitigated rather than undue focus on process, form or combination of assets or resources;
- **Risk-Weighted Regulation:** Shifting the burden of regulation to where the greatest risk to public safety, interest and value lies, based on data, evidence, likelihood and severity; and
- **Collaborative Regulation:** Basing regulatory approaches on a thorough understanding of, and engagement with, the key players on the supply and demand side at any given level of technological development.

6.4. THE ORGANISATIONAL MATURITY CURVE FOR DEVELOPING THE ROLES

We face huge and complex challenges regarding tomorrow's transport and mobility networks. Are transport agencies ready for this and especially how do they get ready, are the big questions.

As we found in the Literature Review, emerging mobility trends exacerbate a number of core challenges already facing Governments, including uncertainty in planning horizons, potential changes to funding streams, the need to adapt or future-proof infrastructure and how to use large volumes of real-time data, all in the face of citizens' growing expectations for more responsive and personalised services. In many senses, agencies need a crystal ball to know what to do next.

Yet some willing to take the risk have taken a series of exploratory initiatives to trial new approaches to their networks. These organisations have stuck their necks out to move forward. But arranging and applying all the elements and realizing the benefits (and risks) of the Future Mobility Ecosystem at scale requires focus, leadership and a fundamental change in mindset.

There is a need to focus on domains in which initiatives will be based on data-driven and evidence-based analysis, policy development and implementation which is agile, based on digital as well as physical infrastructure and, not unimportantly, geared towards a results- and user-oriented approach in all decision-making. This is easier said than done in a complex world with multiple policy makers with sometimes conflicting interests, and yet is necessary if the future of mobility is not to neglect, overlook or override the needs of the end user, as well as being fair, equitable and sustainable in the distribution of benefits. In other words, we need to move toward mobility ecosystems where all stakeholders and users have the same goal in mind and no one if left behind.

In this, it is possible to further expand the four basic roles defined above and the three regulatory options in the previous schematic into a more comprehensive "Maturity Curve" as shown in Figure 6.4. This encapsulates the extent to which transport agencies understand, respond to and wish to proactively shape the Future Mobility Ecosystem, whilst also allowing them to assess where they are now and where they might (and want to) be headed over the medium and long-term.

Adapting evidence drawn from the Literature Review, the Maturity Curve ranges from an initial Stage 1 (Inactive) and Stage 2 (Awareness) where organisational change in the face of technology is limited or even resistant, to a mature Stage 6 (Fully Embedded) where an organisation places the opportunities, challenges and risks of the Future Mobility Ecosystem at the heart of its policy making and regulatory approaches, and transforms shapes its structure, processes, manpower planning, culture and stakeholder governance accordingly.

Figure 6.5 further defines new characteristics and enabling features of making progress up the Maturity Curve. Given the current state of mobility technology and service model development, it is suggested that even the most proactive transport agencies have evolved, at best, to Stage 4, with more holistic and fully embedded transformation still to come in line with disruptive technological and service model maturity over the coming one to three decades. This relates to the wider discussion over the Transport Agency of the Future as discussed below.

Figure 6.4: Maturity Curve for Transport Agencies in Shaping Future Mobility

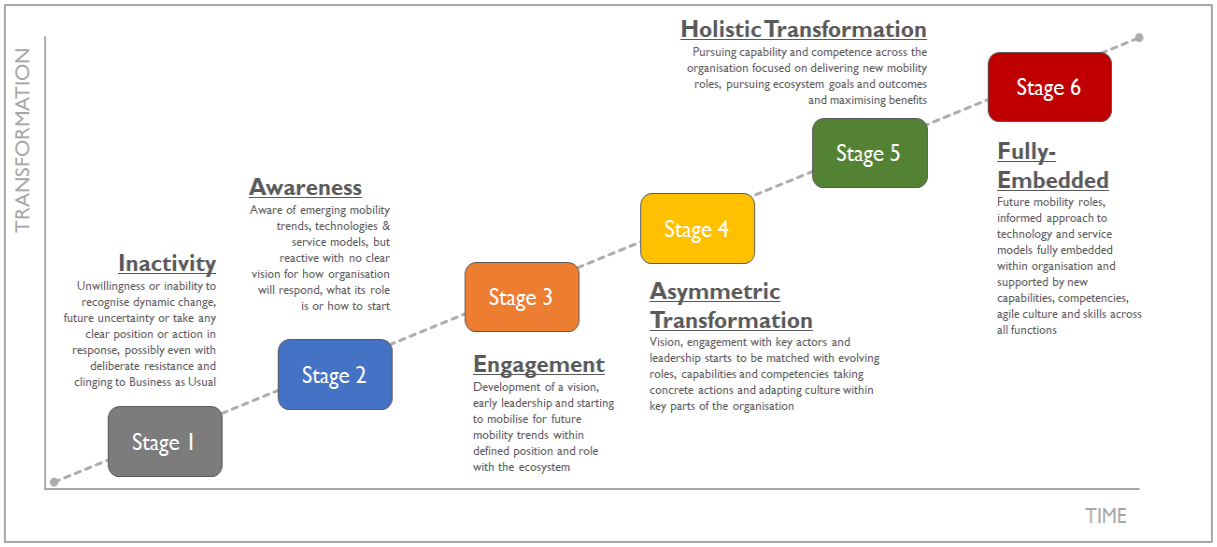
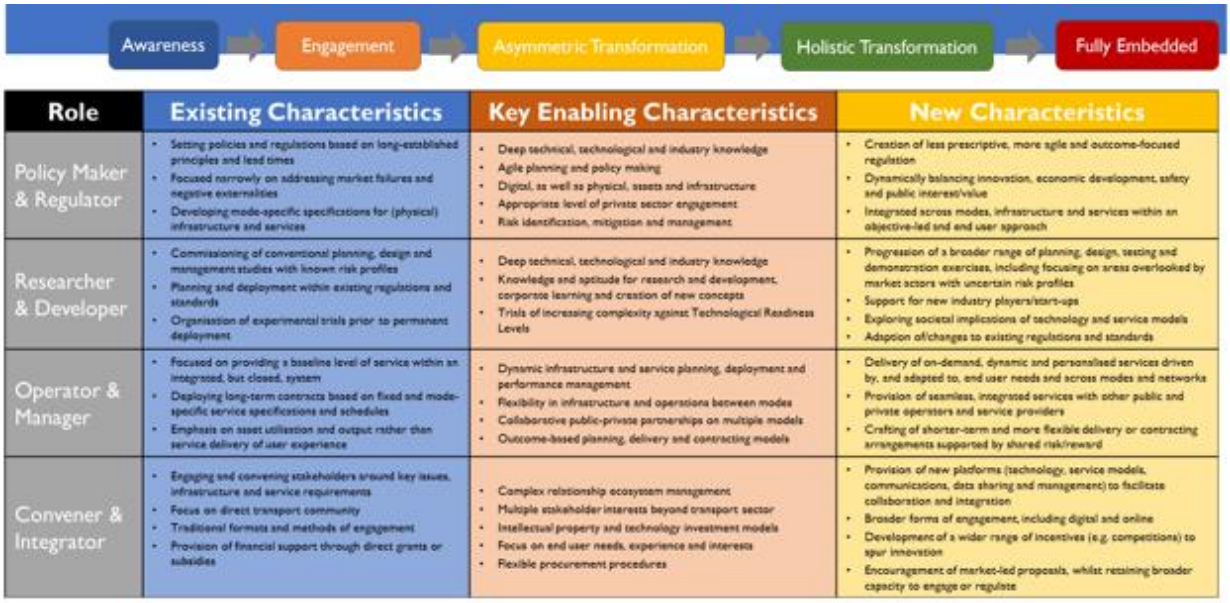


Figure 6.5: Benchmarks for Transport Agencies in Shaping Future Mobility



6.5. REQUIREMENTS OF FULFILLING THE ROLES

To enable change in the Future Mobility Ecosystem, transport agencies need to reconsider policy making, regulation and associated functions in an open way. This means creating less prescriptive, more agile and outcome-focused regulation, with removal of prescriptive rules accompanied by many procedures. In addition, all interests should be weighed side by side: dynamically balancing innovation, economic development, safety, public interest and value. As has been repeatedly mentioned, the end-user and their evolving needs and expectations should also be at the centre of all activities. Within an objective approach, all modes of transport, assets and system components should be integrated as well as the necessary infrastructure and services. The customer of the future wants and deserves easy, reliable, on-demand, personalised mobility via interconnected networks, services and value propositions, at an affordable price.

In their role as researchers and developers, transport agencies need to be bold and overcome their natural conservatism and risk aversion. Agencies should promote a broader range of planning, design, testing and demonstration, including areas overlooked by the private sector with uncertain

or unknown risk profiles. Pioneers or start-ups should be assessed and supported so that there is sufficient inflow of new players. It is also the role of the agency or another public body to monitor the social impact of technology and service models. It is important that new mobility services are affordable, accessible and leave no one behind. Finally, where testing or pilots require, or support, a change, temporarily or permanently, in existing regulations or standards, this should be done quickly, efficiently and proportionately in balance between risk and reward.

The potential role of operator and manager must be flexibly incorporated in organisational procedures, including procurement. Delivery of dynamic, personalized and on-demand services, driven by and adapted to end-user needs and across modes and networks is needed. This requires flexible collaboration within the ecosystem to enable delivery of seamless, integrated services with other public and private operators and service providers. This can be facilitated through work on shorter, more flexible and innovative contractual or operational arrangements, including variations, supported by shared risks and rewards.

As convener and integrator, transport agencies should make strong efforts to engage all parties, for example, by providing new platforms and mechanisms (technology, service models, communication, data exchange and management) to facilitate collaboration and integration. These should not only bring parties together physically, but also generate broader forms of engagement by also interacting digitally and online. Additional incentives can also be brought in, for example by setting up competitions or challenges to encourage, showcase and reward innovation. Again, this should focus on promoting market-oriented proposals, while maintaining a broader capacity for engagement and regulation to secure public value. Open exchange of knowledge and experience should be encouraged and facilitated, including shared data governance, whilst protecting legitimate intellectual property, commercial and other interests.

If transport agencies adopt the four roles as defined according to the new characteristics indicated, solid progress can be made where the end result is greater than the individual actions. The Future Mobility Ecosystem can then absorb innovations, both large and small, balance benefits and risks, and incorporate them where useful and necessary into viable and useful propositions to customers which will be sustainable, scalable and resilient in the long-term.

6.6. Broader Approaches to Innovation

Future mobility needs to put the end user, and their needs and expectations, at the center of technology, infrastructure and service provision. The public and private sectors need to work together to make this possible and mindsets must be open to innovation. Innovation in this context is not just about technologies and advanced concepts, but may also relate to processes, people and ways of working. Tactical approaches are also needed which tackle simple everyday problems facing organisations or their customers, as well as driving more long-term and transformational activity.

In this context, TC 1.1 held a meeting in Seville, Spain in November 2021 in hybrid-format including an International Workshop on *"Innovation and the Innovative Organisation"* from academic, local, private and international perspectives. This provided engaging discussions and useful insights with a broader approach to innovation and how it can be promoted and taken forward. The full discussions of the workshop are reported elsewhere[2], but with some key observations set out below.

Following an introduction by Patrick MALLEJACQ (France) which emphasised the importance of innovation as a key theme across all PIARC activities, Mark FAGAN, Lecturer of Public Policy, Harvard

[2] RUTAS 190 January – March 2022. Pages 62-67. ISSN: 1130-7102.

University (USA) stressed the importance not only of innovation to organisations, but also of creating a culture of innovation that is sustained by institutionalising new processes, from utilising the ideation loop, to hackathons and the Kaizen Cycle for continuous improvement. This reinforced a recurring conclusion in our WG2 analysis that commitment to innovation requires a culture change in public services, a point also made by Ángeles MARÍN ANDREU, Head of the Mobility Strategy Office, MITMA (Spain), as central to achieving safe, clean and connected mobility.

Jonathan SPEAR (UK) further described innovation as a concept which cuts across and supports all TC 1.1 themes, including understanding and promoting customer experience, progressing technology and new business models, and encouraging diversity within the context of future workforce planning.

This need not be applied just to major transformational changes, but small incremental improvements on a daily basis. This was emphasised by Thomas D. EVERETT, Executive Director at the Federal Highway Administration (USA) who introduced FHWA's Every Day Counts (EDC) initiative as a model that identifies and rapidly deploys proven, yet underutilized innovations that make our transportation system adaptable, sustainable, equitable and safer for all.

Juan de Dios HERMOSÍN RAMOS, Chief Technology Officer, AYESA (Spain), presented the perspective of a private sector company that talent, attitudes and organisational culture are key to innovation together with the need for a unified strategy, governance model and a clear procedure for identifying, assessing and filtering projects.

Ana Luz JIMÉNEZ ORTEGA, Provincial Head of Seville General Directorate of Traffic (Spain), stressed that innovation does not necessarily require new transformational technologies, but that "small little innovative actions could result in great achievements." She concluded that "Innovation is essential to survive, because the only thing that never changes is the fact that everything is always in change." Matthew W. DAUSS, President of IATR (USA), picked up on this point, noting that most transport agencies are still anchored in governance models of the past 20th century and that to adapt to emerging technologies, coupled with the changes that COVID-19 has brought and funding issues, a change in structure and culture is needed. The world moves, mobility moves, businesses move, and governments must move and change as well. As the case studies analysis in Chapter 4 shows, many agencies are aware of this and are taking various actions now. The only question is 'how' action should be most effectively steered, given the uncertain and volatile nature of mobility challenges and the evolving innovation landscape.

There were a number of focused presentations from Spain on applied innovation in action. Susana BENAVIDES VEDIA, Sub-Director of the Andalucía General Directorate for Infrastructure (Spain) presented some examples from her regional department emphasising that the goal is to provide the best service possible using the available resources and with the involvement of staff, academia and the private sector. Alfredo GARCÍA, Professor of Road Engineering and Director of ITRAT, Universitat Politècnica de València (Spain) made the same point in his presentation of "Smart Roads" in Spain with innovation across individual components supported, and being the product of, collaboration. Finally, José Manuel CENDÓN ALBERTE, Deputy General Manager for Mobility Infrastructures, Madrid City Hall (Spain) spoke about innovation applied to internal planning and design processes for transport infrastructure, including the integration of new BIM approaches with established GIS procedures.

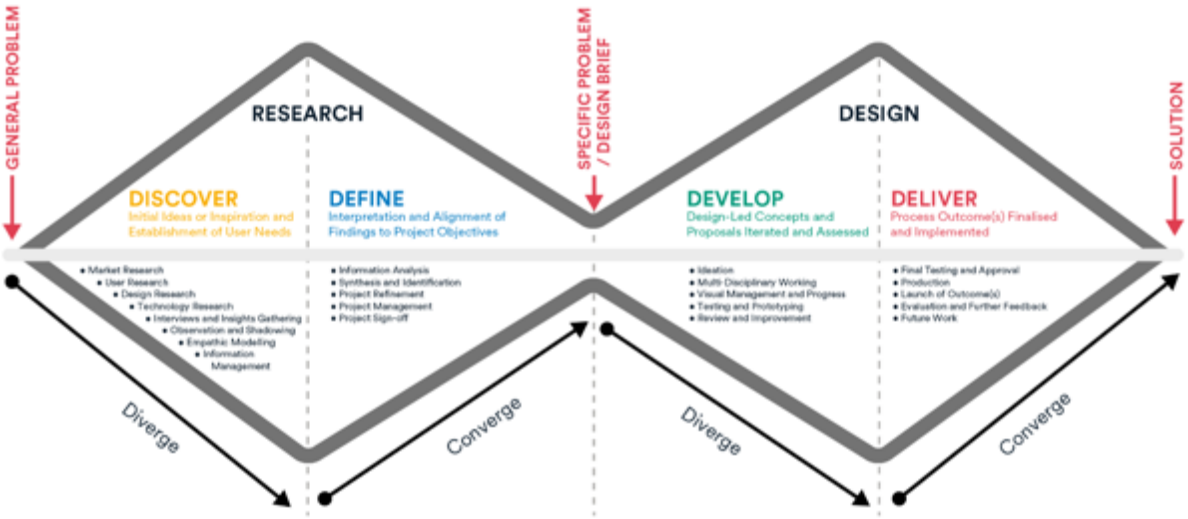
The Seville Workshop was followed shortly afterwards with engagement with PIARC at its Mid-Term Meeting held online at the beginning of December 2021. A Workshop was also held in hybrid format in April 2022 on *"Implementing Innovation – The Critical Step"* hosted jointly by PIARC and GDDKiA,

the Polish General Directorate for National Roads and Highways[3] with a range of local and international speakers.

Figure 6.6: PIARC – GDDKiA Innovation Workshop in Warsaw, Poland, April 2022

Both events drew similar conclusions to those identified in Seville, as well as some distinctive findings. The public and private sectors must create a culture of, and work together on, transport sector innovation and undergo the necessary transformation to do so in proportionate balance within a well-functioning and positioned Future Mobility Ecosystem. "Soft skills" are as important as hard technical qualifications and capabilities in fostering innovation and mobilising all employees and other stakeholders to generate ideas. Lessons should be learnt from the current phase of innovation for the inception and roll-out of the next phase. There should also be a focus on practical implementation at key stages of the technological cycle, from initial concept through testing to early deployment. Finally, broader models, such as Design Thinking or the Double-Diamond process model, may also be relevant to structuring, directing and focusing innovation on the solution of specific real-world problems and strategic goals.

Figure 6.7: Structured Innovation – The Double Diamond Design Process Model



Given the nature of these discussions, WG2 recommends that *"Innovation as a Broader Theme"* form part of the consideration of successor themes and topics for the next Technical Committee in the 2024 – 2027 Strategic Planning Cycle. This is discussed further in Chapter 8 of this Report.

[3] GDDKiA (June 2022). Kurier Drogowy No. 6. Together on the Path to Development.

6.7. Towards the Transport Agency of the Future

Along with Innovation as a Broader Theme, the Transport Agency of the Future has been a recurring topic which has formed the basis of discussion within TC 1.1 over the past three years. Transport agencies are not above other partners in this respect, but do play a key role with and amongst many new partners both public and private. They therefore need to consider, challenge and re-imagine how they may evolve as organisations over the coming one to three decades.

In this positive, open, collaborative position, it is important that transport agencies flexibly take on different roles, including the four roles highlighted above, and switch between them as needed:

- The role of policy maker and regulator should be taken in an open, inclusive and ethical way, creating less prescriptive, more agile and outcome-focused regulation;
- The role of researcher and developer requires leadership and boldness;
- The role of operator and manager should incorporate maximum flexibly; and
- The role of convener and integrator should focus on strong engagement of all parties, internally and externally, including with end users.

The extent to which a transportation agency is able to assume these roles will help determine its success of shaping the Future Mobility Ecosystem, as well as evolving its overall mission, purpose, and working arrangements, leading to meeting the needs of its customers and stakeholders.

When the transportation agencies of the future co-opt the various roles, as well as reflecting wider trends in customer service, workforce definition and management, and business process design and digitisation, significant progress can be made:

- Innovation can serve as an essential vehicle for transport and road agencies to deliver greater public value to society.
- By looking at the world in motion around them with an open mind and broad perspective, transportation agencies can gain inspiration and ideas that often come from outside the industry, or are generated by private companies, inventors and entrepreneurs.
- Agencies will see that even small innovative actions can achieve great achievements. This is done by adapting and streamlining processes, new ways of providing services, involving and motivating people and seeking people's ideas.
- When continuous improvement becomes part of an organisation's culture, innovation thrives. Innovations from within and without will come naturally and employee motivation will automatically rise.
- Encouraging diversity with an organisation’s workforce, at all levels, helps support innovation since it brings people together from different backgrounds, skills sets, life perspectives and viewpoints. Innovation thrives from a recognition of difference.
- Innovation always involves the risk that initiatives will fail and fall short of expectations. This allows for early rejection of uneffective approaches and deployment of resources in more promising directions.
- Innovation should seek to maximize the benefits to society as a whole while identifying and mitigating risks, particularly in the areas of security, privacy and equity.

Again, like *Innovation as a Broader Theme*, the *Transport Agency of the Future* is suggested for consideration as a potential topic for the successor Technical Committee in the PIARC 2024 – 2027 Strategic Planning Cycle. This is discussed further in Chapter 8 of this Report.

7. IMPLEMENTATION – STRATEGIES FOR TRANSPORT AGENCIES IN STRENGTHENING THEIR FUTURE ROLE

7.1. OVERVIEW

The preceding Chapter has expanded on the roles which transport agencies can play in responding to, shaping and evolving new technologies and services, and putting in place the key components of the Future Mobility Ecosystem in coming years and decades. These components will themselves change as new innovations are introduced, certified and scaled up to dramatically alter the movement (or non-movement in the case of digital connectivity) of people and goods, the user experience and the form of the natural and built environment. In essence, we can expect the transport agency of 2050 to look, work and feel radically different from 2020 from the perspective of its leaders, employers, customers and stakeholders, themselves subject to a generational shift in values, attitudes, interests and behaviors.

However the roles defined in Chapter 6 play out, in their own right or benchmarked against some form of maturity model, a wide range of specific strategies, actions and sub-tasks will need to be planned, executed and evolved in order to shape technological and service development, testing, certification, early deployment and eventual mainstreaming. These strategies should be conceived, developed, designed and implemented through the following steps:

- The transport agency should become technically aware and competent;
- The transport agency should define an organisational vision and guiding principles;
- Specific strategies and actions should be proposed, prioritised and implemented in near- and long-term, aligned with the vision and guiding principles; and
- Implementation should be monitored and performance managed via a process of continuous improvement.

This Chapter lists what some of these strategies and actions might be. Previous work for predecessor Technical Committees to TC 1.1 has often focused on what we call a “toolkit” of such measures, often supported by a self-completion spreadsheet, which acts as a schedule, inspiration and a checklist to plan, monitor and manage initiatives in response to a particular challenge. It is not expected that every agency will adopt every measure, and the form of any combined programme of action is highly organisationally and context specific; however, the intention is to set out a comprehensive menu of options which might be proposed or considered, either in own right or as part of a broader agenda of organisational or sector transformation.

Table 7.1 sets out the key strategies and actions which may be considered to enact the roles for transport agencies. The list is drawn from:

- A list of possible future activities developed for the Questionnaire Survey and to which Survey respondents indicated their current or future focus in implementation or planning, as summarised in Chapter 3;
- Initiatives emerging from the In-Depth Case Studies and reported on in Chapter 4; and
- Discussions from various TC 1.1 and wider PIARC meetings, including presentations and seminars around Innovation Frameworks and the Transport Agency of the Future.

From these sources, four broad strategies can be identified for how transport agencies may approach technological and service development and the Future Mobility Ecosystem as follows:

- Evidence taking, policy and strategy development;
- Legal, regulatory and external governance frameworks;

- Technical development and support for implementation; and
- Internal organisational changes and capacity building.

It is noted, and emphasised, that these strategies, and the actions within them, do not take place in isolation within transport agencies, but themselves reflect, shape and influence parallel activities from the private and academic sectors, as well as various civil, community and public interests.

It is also emphasised that Table 7.1 is a high-level "a-la-carte" menu of options rather than a prescriptive schedule to be adopted by all agencies in all circumstances. Combining approaches will be highly context-specific and detailed planning, assessment and execution, is required for this purpose. Therefore, many of the principles around change management apply, as set out in the predecessor TC A.1 report on this latter topic[4].

Table 7.1: A Menu of Strategies and Actions for Transport Agencies in Shaping Disruptive Technologies and Service Models

Strategies	Evidence Taking, Policy and Strategy Development	Legal, Regulatory and External Governance Frameworks	Technical Development and Implementation	Internal Organisational Changes and Capacity Building
Actions	Technical Studies & Investigations Technology Scanning Setting Vision and Strategic Goals Strategies & Road Maps Future Scenario Planning and Forecasting Double Diamond and Design Thinking Data Gathering, Analysis and Sharing Reviewing, Amending or Developing Policies Public Surveys, Focus Groups and Awareness Raising Benchmarking and Gap Analysis Impact Analysis Skills and Capacity Analysis and Training Needs Assessment	Defining Legal and Regulatory Approach and Framework Reviewing, Amending or Developing Laws or Regulations Reviewing, Amending or Developing Standards and Guidelines Reviewing Sector Governance and Stakeholder Relations Engaging Industry within and outside Transport Sector Pursuing Public-Private Partnerships (or Equivalent) Partnering with Academic or Research Bodies Balancing Innovation with Protection of Public Interest Identifying and Addressing Market Failure	Sponsorship or Participation in Research and Development Pilot/Demonstration Projects Technology Testbeds/ Sandboxes Innovation Challenges or Competitions Public Procurement and Contracting Specifications and Conditions Public Operating Franchises or Concessions Supporting Data, Digital and Communications Networks Implementation or Adaptation of (Physical and Digital) Infrastructure Implementation or Adaptation of Mobility Equipment and Facilities	Changes to Corporate Vision, Mission or Objectives Updating Strategic or Business Plan Changes to Organisational Processes Changes to Organisational Structure Changes to Business Model and Funding Appointing a New Leadership Role Setting up New Unit, Department or Division Innovation/Ideas Schemes New Roles, Job Descriptions and Duties Recruiting New or Broader Talent Skills and Capacity Building Changes to Corporate Culture Engagement with Users and Citizens

[4] Evaluating the Transformation of Transport Administrations. Technical Report by PIARC TC A.1, Working Group 2. PIARC (2019).

It should be noted, of course, that agencies may choose to adopt none of the strategies or actions indicated or suggested. In this sense, "doing nothing is an option." However, technological development, innovation and the introduction of new transport and mobility concepts does not stand still and will likely be driven by the private sector irrespective of whether the public sector has a proactive strategy or not. This has been seen in the recent past, for example with the disruptive arrival of ride-hailing and shared micromobility. In these instances, government responses have been reactive, often short-term and tactical, and with sub-optimal outcomes for public policy, users and industry players. Approaches may also be heterogeneous or contradictory between different cities, regions or countries, creating confusion amongst users (as well as mobility operators and investors) and undermining a consistent, supportive and trusting enabling environment. Therefore, we advise transport agencies to proactively consider their strategies and preferred actions, and collaborate with their counterparts in other jurisdictions when doing so, before technological and service disruption forces them to respond in any case. This is more likely to anticipate, socialise and produce reasonable outcomes in a timely, predictable and efficient manner and pave the way for the positive longer-term evolution of the transport and mobility ecosystem to the benefit of all.

The remainder of this Chapter describes four strategies and lists the various actions in further detail.

7.2. Evidence Taking, Policy and Strategy Development

This first strategy comprises a series of actions which seek to understand, set the scene and lay the basis for an orderly and predictable evolution towards the Future Mobility Ecosystem. It is vital that innovations are planned, regulated and delivered against a clear vision, set of strategic goals, guiding principles and expectations set by the public sector, whether through transport agencies directly or through wider government structures. These guidelines must themselves be informed by evidence, stakeholder and public views, proper technology scanning and evaluation, business case consideration and a distinction between what feasible in the near-term and what is "hype" or even "science fiction" which may be sometimes marketed by industry players.

It is also important that future planning considers not only the overall form and scale of benefits of future mobility technologies and services, but the distribution of the those benefits across different parts of society and the margins of those benefits in the face of uncertainty. The potential for market failure and some members of the community being left behind should be identified and used to regulate or target future public interventions in favour of fairness, equity and inclusivity.

Key actions under this strategy include the following options, applicable to the Future Mobility Ecosystem overall or to specific technologies (e.g. CAVs, UAM, EVs) on a more focused basis:

- Technical Studies & Investigations;
- Technology and Horizon Scanning;
- Data Gathering, Analysis and Sharing
- Double Diamond and Design Thinking;
- Public Surveys, Focus Groups and Awareness Raising
- Benchmarking and Gap Analysis;
- Setting a Vision and Strategic Goals;
- Future Scenario Planning and Forecasting;
- Reviewing, Amending or Developing Public Policies;
- Developing Strategies, Master Plans & Road Maps;
- Implementation Planning and Impact Analysis; and
- Skills and Capacity Analysis and Training Needs Assessment.

From these actions, transport agencies may gain greater confidence in the range of technological and service model trends which are likely to be relevant to their mandate and activities, what strategic goals and approaches they should adopt and how to manage the transition to new mobility concepts and services from current and legacy infrastructure and assets. They should develop a greater understanding of the user perspective, the economic, social and environmental impacts and the distribution of these impacts across all their customers, stakeholders and society. This in turn is likely to determine or influence the policies, regulatory approaches and investment in direct initiatives to be taken forward, including constructive engagement, partnership and regulation with other public entities, the private sector, academia and civic organisations.

In the Questionnaire Survey, 71% of organisations stated they have already implemented actions under this strategy, and 33% plan to do so in future. There are also multiple examples of action from the In-Depth Case Studies, for example Main Roads Western Australia, Trafikverket, Singapore Land Transport Authority, SANRAL and National Highways UK.

For Low and Middle-Income Countries, less evidence appears to be available. Whilst our view is that disruptive technologies and services are certainly applicable across the World irrespective of stage of development, care needs to be taken to not adopt High Income Country concepts, innovations and associated strategies and operating models universally, uncritically and off the shelf. There is also a need to consider technology use cases, applications and longer-term roll-outs which reflect the very different economic, social and environmental circumstances, and capacities of the public and private sectors, prevailing locally. This is an area where further work by PIARC Task Force 2.1 (New Mobility, Roads and Transport) and the successor Committee to TC 1.1 in the 2024-2027 Strategic Plan Cycle should be encouraged.

7.3. Legal, Regulatory and External Governance

Much of the literature, and discussion within WG2 and TC 1.1 over the work programme, has focused on how technological and service model innovation should be legally approached and regulated. This is all the more so because most innovation is driven by the private sector which may have differing immediate goals and priorities than the broader social and public value agenda of Government.

There are therefore a number of important actions which concern the development of appropriate and proportionate legal and regulatory frameworks, instruments, and compliance and enforcement regimes for transport and mobility innovation. This also affects external governance relations and the structure of transport and mobility functions between public, private, academic and civic stakeholders. As noted already in Chapter 6, models may vary from market-led (or laissez-faire) approaches, with minimal public intervention beyond immediate protection of human life and safety, to more comprehensive government-led codes strongly aligned with, or even directly delivering, a range of public policy objectives and delivery functions.

There is no “right answer” here and it is for each agency to determine its approach based on political direction, system of government, socio-economic context and overall management approach to innovation. We do, however, note that the Questionnaire Survey and Private Sector Roundtable indicated that most transport organisations agreed with the proposition that technological innovation should be private sector led under proportionate regulation from government. Full deregulation and reliance on the market, or centralised and direct state-led delivery of mobility innovation to the customer appear to be extreme bookends which few agencies wish to seriously consider by design.

Key actions under this strategy include the following options, again applicable to the Future Mobility Ecosystem, overall or to specific technologies (e.g. CAVs, EVs) on a more focused basis:

- Defining a Legal and Regulatory Approach and Framework;
- Reviewing, Amending or Developing Laws or Regulations;
- Reviewing, Amending or Developing Standards and Guidelines;
- Reviewing Sector Governance, Roles and Responsibilities and Stakeholder Relations;
- Engaging, Regulating and Influencing Industry within and outside Transport Sector;
- Pursuing Public-Private Partnerships (or Equivalent);
- Partnering with Academic or Research Bodies;
- Balancing Innovation with Protection of Public Value, Safety and Interest; and
- Identifying and Addressing Market Failure.

In the Questionnaire Survey, 69% of organisations stated they have already implemented actions under this strategy, but only 15% plan to do so in future. We believe the latter underestimates the scale of the regulatory challenges raised by some disruptive technologies (such as CAVs and UAM) difficult though some of the issues are, and in the medium- to long-term, more of the identified actions will need to be actively considered and implemented.

The In-Depth Case Studies provide some examples where this is already taking place. For example Singapore has implemented a range of governance and regulatory measures for Autonomous Vehicles, including creating the Committee for Autonomous Road Transport in Singapore (CARTS), and introducing amendments to the Road Traffic Act and bespoke technical standards to allow CAV testing on public roads across the country. Similarly, the Flanders Roads and Traffic Agency is pursuing public-private joint working under its Mobildata initiative, whilst the UK is in the midst of a comprehensive Future of Transport Regulatory Review to determine approaches across a range of future technology and service model categories.

7.4. Technical Development, Testing and Deployment

A conclusion from the Literature Review, Questionnaire Survey and In-Depth Case Studies is that transport agencies are focused on near-term actions to support new mobility concepts and services. This may include directly supporting more readily maturing technologies (such as Electric Vehicles, C-ITS and Micromobility) and supporting early testing, demonstrations, trials and certification of concepts (such as CAVs and UAM) where commercial deployment at scale is some years away. Within this overall conclusion, there are multiple opportunities where transport agencies can show they are not just focused on the “theory” of future mobility, but visibly taking, leading or supporting action on the ground, whether on their own or in partnership with the private sector.

Key actions under this strategy include the following options:

- Sponsorship or Participation in Research and Development;
- Pilot/Demonstration Projects;
- Technology Testbeds, Test Tracks, Sandboxes and “Living Labs”;
- Innovation Challenges or Competitions;
- Public Procurement and Contracting Specifications and Conditions;
- Public Operating Franchises or Concessions;
- Supporting Data, Digital and Communications Networks;
- Implementation or Adaptation of (Physical and Digital) Infrastructure; and
- Implementation or Adaptation of Mobility Equipment and Facilities.

In the Questionnaire Survey, 63% of organisations stated they have already implemented actions under this strategy, and 35% plan to do so in future, with specific examples from the In-Depth Case Studies, either internally within agencies or in partnership or oversight of the private sector.

For example, there are multiple examples of trials and demonstrations of connected, electric or hydrogen/fuel cell shared, and public transport vehicles sponsored by the European Union. Trials of connected infrastructure is being pursued at pace. Singapore has developed the Centre of Excellence for Testing & Research of Autonomous Vehicles NTU (CETRAN) as a physical test facility and public-academic-private partnership. Madrid Mobility 360 initiative is a public agency initiative developing Mobility as a Service locally combining a technology and data platform with an operating and commercial management model.

In future, as well as focused on dedicated projects, mainstream public procurement could be strengthened and adapted to allow, encourage and reward innovation in addressing stated challenges or desired scope. Inflexible project briefs, terms of reference, bid assessments or post-award variation are often a barrier to addressing transport and mobility challenges in a more imaginative way or allowing contracting authorities or contractors to think outside the box. Agility and flexibility in meeting project goals should be therefore encouraged where relevant, useful and appropriate, with public agencies working with industry to establish good practices.

As medium- or long-term technologies develop, are deployed commercially and scale up, it is important that transport agencies consider the implications for the future planning, design, operation and management of their own infrastructure networks and associated asset base. In the context of CAVs, this is an area of considerable uncertainty for future road networks, both for new construction and the adaptation and upgrade of legacy infrastructure. Few agencies yet have a clear view on what their road design and operations standards and guidelines will look like by 2050, but the task of considering this is a matter of some importance and priority for all public and private stakeholders which has only just begun. Again, this is an area where further work by PIARC Task Force 2.1 (New Mobility, Roads and Transport) and the successor Committee to TC 1.1 in the 2024 -2027 Strategic Plan Cycle should be encouraged.

7.5. Internal Organisational Changes and Capacity

The final strategy, and potentially the most far-reaching and complex, is to adapt the internal transport agency organisational functions, processes, structures, skills sets, capacity and resources, and indeed values and culture, to manage a Future Mobility Ecosystem which is radically different than today's infrastructure, assets, user propositions and services.

To an extent, this strategy links to the transition an agency wishes to make along the maturity curve and key benchmarks at each stage described in Chapter 6. This depends not only on the technical options available, but the level of leadership, ambition and attitude to change and innovation adopted by the political and senior managerial leadership of the organisation itself, as well as how the organisation relates to other public, private and civic stakeholders.

Does an agency, for example, wish to be seen as an organisational pathfinder, change leader and weather maker, is it satisfied to be a solid mid-stream follower of maturing industry practice, or does it even seek to resist change, embed and protect legacy practices, interests and values? As with approaches to regulation above, there is no "right" answer to these questions and the path taken within any agency will reflect a range of internal beliefs, external drivers and practical constraints as to what is desirable, achievable and acceptable to various interests. The "Transport Agency of the Future" has many options and forms unique to place, time and circumstances, so what matters is the process, evidence and breadth of engagement to get there.

Key actions under this strategy, some of which are feasible and tactical in the short-term whilst others reflect longer-term and broader corporate transformation, include the following options:

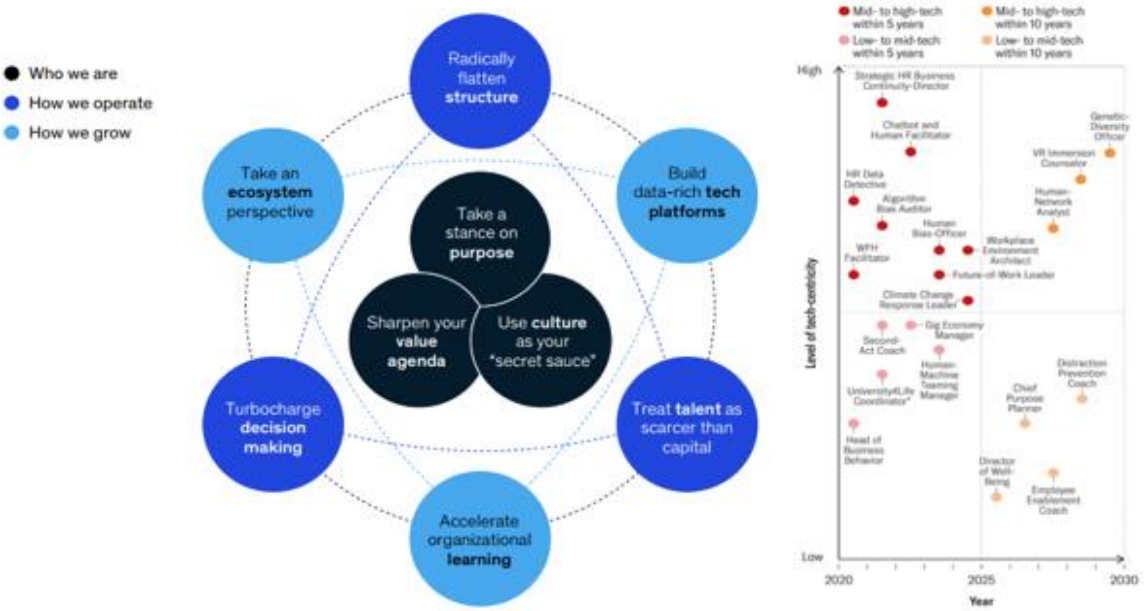
- Changes to Corporate Vision, Mission or Objectives;
- Updating Strategic or Business Plan;
- Changes to Organisational Processes;
- Changes to Organisational Structure (and inter-agency and wider stakeholder networks);
- Changes to Business Model and Funding;
- Appointing a New Leadership Position or Role;
- Setting up New Unit, Department or Division;
- Innovation/Ideas Schemes;
- New Roles, Job Descriptions and Duties;
- Recruiting, Training, Nurturing and Retaining New or Broader Talent (including Workforce Diversity);
- Skills and Capacity Building;
- Changes to Corporate Purpose, Values and Culture; and
- Engagement with Users and Citizens

In the Questionnaire Survey, 60% of organisations stated they have already implemented actions under this strategy, and 28% planned to do so in future. As with legal and regulatory change, we believe the latter figure underestimates the organisational changes which transport agencies will experience, and will be required to make, in coming decades. These changes will be driven by not only by changing external transport and mobility concepts, technologies and operating models, but also the internal impact of new processes, organisational and working trends and shifting generational values, attitudes, beliefs and behaviours of future employees. Examples include the growing digitisation of core functions, task automation, data mining, and the legacy of the COVID-19 Pandemic in dramatically increasing the practice of remote and hybrid working, together with the management of corporate activities through online platforms over face-to-face interaction.

The Literature Review included concepts, including the examples shown below from McKinsey and Cognizant Center for Work and Future which set out some useful principles and areas of transformation around which future organisational and job design may be considered.

The Case Studies identified some examples of transport agencies creating new posts, appointing officers or establishing new departments or units to manage technological and service innovation. There were also instances of business case and ideas programmes to receive, assess, filter and support proposals for innovation For instance Minnesota DoT created CAV-X to take forward CAV research, piloting and early deployment within the State, whilst SANRAL, Main Road Western Australia and the Flanders Roads and Traffic Agency have developed organisational constructs to manage innovation and turn proposals into viable minimum products for organisational application and deployment.

Figure 7.1: Concepts for Future Organisational Imperatives and Jobs (McKinsey, 2021 and Cognizant Center for Work and Future, 2020)



By implication, such specific changes are partial and asymmetrical compared to the "fully embedded" corporate transformation implied by Stage 6 of our Maturity Curve set out in Chapter 6. Despite corporate messaging, it is too early to fully articulate or describe examples of the latter. Radical organisational redesign, restructuring and repurposing of transport agencies will be a major trend to watch, however, over the coming 10 to 30 years and should certainly be a focus of the successor Committee to TC 1.1 in the PIARC 2024 -2027 Strategic Plan and indeed further PIARC cycles. This includes the potential evolution of transport agencies from owners and operators of fixed infrastructure and assets to broader mobility management organisations within a multi-functional stakeholders networks across the public, private, academic and community sectors.

Specific HR issues around transport agency recruitment, skills development and implications for wider organisational evolution are also set out in the parallel Technical Report to this document from TC 1.1 Working Group 3 which covers the Organisation of Staff and Human Resources.

7.6. Developing the Strategies Further

The strategies set out above are a starting point for a long, complex and multi-faceted agenda of change for transport agencies in coming decades. As noted, they should be structured under a broad vision for how agencies wish to move forward, monitored in terms of implementation and impact, and subject to continuous change and improvement. They will evolve in terms of:

- Additions or modifications around specific activities, both direct and enabling;
- Further evidence on which actions are more prominent and impactful in terms of scale of adoption, evolution, and the development of good practice;
- The development of monitoring, performance management or reporting frameworks, checklists, toolkits and dashboards to track how change in being implemented; and
- Incorporation into wider models of organisational, management and workforce adaptation, development and transformation in response to multiple internal and external drivers.

Certain themes (e.g. innovation frameworks, future skills) are likely to form new areas for investigation by TC 1.1's successor Committee(s) within the 2024 – 2027 Strategic Planning Cycle as well as wider PIARC activities.

8. CONCLUSIONS AND RECOMMENDATIONS

We cannot solve a problem by using the same kind of thinking we used when we created them.

Albert Einstein

Innovation is the ability to see change as an opportunity, not a threat.

Steve Jobs

8.1. THIS STUDY

The PIARC Terms of Reference for Technical Committee 1.1 started with the presumption that a combination of new technologies, systems, infrastructure adaptations, data platforms and service models, spanning multiple modes and networks, is disrupting the transport and mobility sector. These elements – collectively called the Future Mobility Ecosystem – are developing and converging to offer increasingly integrated, low-emission, connected, automated, personalised, shared and on-demand propositions for moving passengers and goods, and connecting people, places and things.

The development, early deployment, scaling up and maturity of the Future Mobility Ecosystem in all its dimensions towards 2050 and beyond is likely to be dynamic, volatile and complex, whilst posing major uncertainties for the strategies of the agencies which plan, deliver and operate transport infrastructure and services at different spatial scales across the World. These agencies must therefore re-evaluate their policy and regulatory frameworks, operating models, infrastructure plans, end user propositions and ultimately their own organisational functions, structures, skills and capacities in order to remain relevant, effective and capable of meeting present and future agendas for their political sponsors, customers and stakeholders. The challenges of the twenty-first century will not be met through the traditional planning and design approaches, nor the skills sets or talents, of the twentieth.

The work of TC 1.1 has confirmed this proposition and collected a range of evidence that transport agencies are starting to anticipate, understand, respond to and, to varying degrees, shape the future of mobility within their mandates, functions and activities. They are doing so in parallel with significant debates over future form, roadmaps and impacts of new technologies and service models, and at the very early stages of a long-term timeline of transformational change. They are also doing so increasingly with a focus on people and their needs and expectations, over vehicles, infrastructure and other physical assets. We are encouraged there is enough initial experience to allow preliminary conclusions and recommendations to be made which can support further progress.

These conclusions draw on our Literature Review, Questionnaire Survey, In-Depth Case Studies, Private Sector Roundtable, and subsequent development of conceptual frameworks and strategies presented in the preceding Chapters of this Report. They relate both to the direct key lines of enquiry through which we started our research in February 2020, and wider questions around organisational innovation and the journey to the “transport agency of the future” which have emerged during our deliberations and which we consider should continue in future PIARC research.

8.2. Overall Conclusions

Shaping the Future Mobility Ecosystem

1. Disruptive technologies and service models will have a major future impact on the transport and mobility sector, and its associated entities, individually and in combination. There is an urgent need for objective empirical evidence to robustly assess many of the claims made by technology advocates, support debate, identify and manage risks and ensure equity and public value in outcomes. In this, it is important to take an approach focused not on technology per se, but future vision, objectives, guiding principles and ethics for development, deployment and scaling up of different assets, infrastructure and services.
2. Many transport agencies believe they are not yet adequately prepared to respond to new technologies and service models. However, whether focused on near-term or longer-term innovation, there are a number of overarching roles available. These include (i) Policy Maker and Regulator (ii) Researcher and Developer (iii) End user, Operator and Manager and (iv) Convener, Enabler and Integrator. Application of these roles is highly context specific and varies across organisations, as does the appetite and ambition for public sector leadership and intervention over private innovators and enterprises.
3. The private sector is driving a high proportion of the elements making up the Future Mobility Ecosystem. However it is recognized that a strong public sector should lead, provide a clear policy and regulatory framework, level the playing field and set the rules of the game. Then private innovators, enterprises and their investors will have confidence to plan ahead, put in capital and take commercial risks on product and service development.
4. Regulation from the public sector in this context should be proportionate, informed, investor-friendly and agile, seeking to reflect the evolving benefits and risks of new technologies, as well as balancing legitimate private profit and return with public safety, equity and value.
5. Not every transport agency takes on the available roles and activities in the same way. There are leaders, early adopters and those which choose to take a more gradual, conservative or even resistant approach. In this context, we have identified a Future Mobility Maturity Curve as a series of benchmarks for organisations in facing technological and service model change.
6. Collaboration across a wide range of organisations is recognised as key in making progress, involving multiple players from the public, private and academic sectors in terms of research, initial deployment, accountability, consultation and long-term delivery. However, the level of collaboration currently taking place is often not yet sufficient to enable or support action in all required dimensions and greater and more structured engagement appears to be required.

Infrastructure

7. A significant proportion of future mobility services, even if accessed, managed and operated by the private sector, will continue to run on public infrastructure, especially roads, associated rights of way and the wider public realm.
8. The availability of modern, flexible, future-proofed and well-maintained infrastructure, including digital assets, and the resources to adequately fund these, appears to be a major constraint holding back the development of the Future Mobility Ecosystem in the longer-term.
9. However, there appears to be little work and consensus as yet on how infrastructure planning, design, space allocation, operating and maintenance standards should change in

the medium to long-term as new modes and vehicle types for electric, autonomous, on-demand and shared mobility are developed, initially deployed and scaled up.

Low and Middle-Income Countries

10. New transport and mobility technologies and service models appear to be impacting Low and Middle-Income, as well as High-Income, Countries. However, the pace and scope of innovation appears to be more limited to particular applications, the balance of benefits and risks is likely to be significantly different, as are the enabling capacities of the public and private sectors.
11. There is a need for further evidence on development, testing, initial deployment and scaling up of disruptive technologies and service models within LMICs, and how successful roadmaps may need to utilise different approaches from more advanced economies.

The Transport Agency of the Future

12. Transport agencies will need to evolve functionally and organisationally in the future in the face of disruptive technologies and service models. In addition, this evolution will be driven by generational shifts in customer needs, workforce and management diversity agendas, employment practices and the progressive digitisation and automation of key tasks and jobs.
13. As the Future Mobility Ecosystem develops, transport agencies may evolve from planners and operators of fixed infrastructure and assets to broader mobility management organisations, convening and facilitating broad stakeholder partnerships, but still highly context-specific within the four principal roles, activities and stages of maturity outlined in this Report.

The Impact of the COVID-19 Pandemic

14. Whilst the immediate impact of COVID-19 on transport and mobility technology and service research, development, testing and deployment has been negative overall, it seems likely that certain applications will emerge stronger and accelerate in the medium to long-term. This also takes place within a reconfigured industry landscape emerging from the Pandemic with weaker players exiting or being taken over, and the emergence of new partnerships and alliances.
15. The use of digital platforms and services to replace the need for physical mobility, such as working from home, e-learning or online-shopping, has been a particularly significant feature of Pandemic response in countries around the World with the longer-term implications on the demand for mobility, land use patterns and related services yet to be fully understood.

8.3. Recommendations for Transport Agencies

Building on the conclusions above, and following discussions within WG2 and the other members of TC 1.1, we have 10 recommendations for transport agencies in charting their way forward.

Recommendation TA1: Disruptive Technologies and Service Models

Transport agencies should recognise that the mobility landscape is changing, with the convergence of technologies, systems and data, infrastructure and assets and personalised on-demand customer propositions into a Future Mobility Ecosystem.

Agencies should seek to understand, anticipate and proactively prepare for, rather than react to or even resist, the changes already under way which will transform transport and mobility towards

2050. They should take a vision- and objective-led approach, seeking to positively guide technology and service development, initial deployment and scaling up towards the achievement of stated policy goals, the delivery of public value and an equitable distribution of costs and benefits. Cross-cutting agendas to wider goals around economic competitiveness, industrial strategy and supply chain development may also be considered, drawing in other public and private entities as appropriate.

Recommendation TA2: Self-Assessment

In their response and efforts to shape the Future Mobility Ecosystem, transport agencies should review and consider applying the ideas and concepts described in this Report. In particular, within the scope of their current and evolving mandate and functions, they should assess their own position against appropriate benchmarks in terms of:

- The four highlighted roles of (i) Policy Maker and Regulator (ii) Researcher and Developer (iii) End User, Operator and Manager and (iv) Convener, Enabler and Integrator;
- The preferred regulatory approaches of (i) Restriction (ii) Laissez-Faire, (iii) Regulated Partnership or (iv) Guiding Hand, as well as various guiding principles for regulatory tools;
- Strategies and activities to shape disruptive technologies and services under the four categories of (i) Evidence, Policy and Strategy Development (ii) Legal, Regulatory and External Governance (iii) Technical Development and Implementation and (iv) Internal Organisational Change and Capacity Building; and
- The maturity curve across the six stages of (i) Inactivity (ii) Awareness (iii) Engagement (iv) Asymmetric Transformation (v) Holistic Transformation and (vi) Fully Embedded.

Agencies may develop and complete checklists for their current position and planned direction of travel, overall and against specific technologies and service model concepts.

Recommendation TA3: The Innovative Organisation

Transport agencies should seek to enable innovation in its broadest sense. As well as transformation to deliver benefits from disruptive technologies and service models, this may extend to processes, people and other dimensions of doing things differently, including in response to everyday practical challenges facing the organisation. This in turn requires changes in organisational skills, capacity, culture, values and which may create new job descriptions, mandates and functions.

Innovation should be supported from the top, through the political and management leadership of the organisation, linked to an updated vision and mission statement which is relevant and fit for purpose against a changing environment and set of customer and stakeholder needs. This may require experimentation, testing, trial and error, as well as a willingness to fail.

Recommendation TA4: Stakeholder Engagement

Convening and enabling stakeholders across the public, private and academic sectors will be crucial for making progress on the Future Mobility Ecosystem, as well as engaging end users, wider community and civil society more generally.

Transport agencies should identify the full extent of their stakeholder networks, build, support or enable appropriate collaborative governance mechanisms, and set rules and practices understandable and acceptable to all.

Recommendation TA5: Regulating the Private Sector

Transport agencies should recognise that most technology and service development and implementation is likely to come from, or significantly involve, the private sector. They should therefore seek to balance protection of safety and pursuit of public value and interests with the legitimate right of private companies and individuals to expect a stable investment environment and seek long-term profits and rates of return on commercial terms. Ongoing mechanisms for communicating with and engaging the private sector should be established.

The public sector should adopt proportionate, informed and agile approaches to regulation, placing a priority on public safety and an equitable distribution of benefits from innovation, but allowing private companies to invest with limited bureaucracy and red tape, flexibility in standards and freedom to test, trial and deploy new products and services.

Recommendation TA6: Public Infrastructure

Transport agencies should explore how design, construction, operation and maintenance of public infrastructure needs to change, including during any transition period, in response to new mobility technologies, including installation of digital assets, associated data and processing systems, allocation of capacity and flexibility of regulations and operational practices in the interim to allow technology trials and testing.

In the longer-term, transport agencies should investigate how road planning and design standards, operating and maintenance procedures, user laws and regulations need to change in response to a significant scaling up and maturity of new vehicle types, specifications and performance criteria.

Recommendation TA7: Data Governance

Data collection, sharing, analysis and governance are key points of interest and contention in the Future Mobility Ecosystem, including between the public and private sectors. Transport agencies should have clear strategies for transport and mobility data, be clear on the data they collect or request, only seek the minimum data which is truly necessary and offer reassurance to private enterprises (and others) around anonymisation, privacy, data protection and cybersecurity. To this end, standard protocols should be agreed at the industry level and adopted on a common, rather than case-by-case, basis.

Recommendation TA8: The Transport Agency of the Future

In addition to changes in technologies and service models, wider shifts in organisational development and operations, workforce planning and management and the progressive standardisation and digitisation of internal processes will become important drivers of the transport organisation of the future.

Agencies must therefore think boldly about their future mission, functions and form, followed by working back to the present via a roadmap and key milestones and activities of how to get there, including the human resource skills and capacity required.

Recommendation TA9: Planning for Uncertainty in the Post-COVID Era

The World continues to change constantly, presenting an environment which is Volatile, Uncertain, Complex and Ambiguous (VUCA). In the post-COVID era, as the World faces various economic, environmental and geopolitical crises, these factors are arguably even more evident.

Transport agencies must therefore have high degree of flexibility, resilience and future-proofing in setting and implementing policies, strategies and specific activities. They should use scenario planning and analysis to understand different versions of the future. The external environment

should be continually and broadly scanned, kept under review, and strategic and tactical responses drawn up and adjusted accordingly.

Recommendation TA10: Transport Agencies in Low- and Middle-Income Countries

The recommendations above are applicable to all transport agencies, but with precise responses being highly local context specific. As well as technical analysis, initiatives in any given place will be driven by political, cultural, spatial and socio-economic circumstances, opportunities and constraints.

In particular, transport agencies within Low- and Middle-Income Countries should review the implications of our recommendations for their particular situation and stage of development. The support of IFIs and NGOs may provide external mitigations to these considerations. The opportunities, threats and business case underpinning certain innovations may also be different across countries according to given economic, social and political positions, with a focus on "getting the basics right" before transitioning to more advanced and sophisticated applications.

8.4. RECOMMENDATIONS TO PIARC

In addition to recommendations to transport agencies themselves, we have the following five suggestions for PIARC itself.

Recommendation PC1: Further Investigation into Specific Technologies and Service Models

Our research has covered a wide range of technology applications and service models at varying degrees of development, application and maturity. PIARC should carry out further investigations of specific innovations impacting the transport and mobility sector, especially those likely to have an impact in the near-term, with considerations on transport demand, end users and which products and services should be provided or supported.

In particular, PIARC should consider more evaluation of the actions necessary to support the electrification of road transport in terms of vehicles and provision of public charging infrastructure.

Within the post-COVID context, PIARC should also examine the medium- to long-term impacts of the expansion of digital transactions and services (e.g. home working, e-learning, online shopping) in place of physical mobility, and the implications for the roads and transport sector.

Recommendation PC2: Support to Transport Agencies

Evidence from our Questionnaire Survey shows that the majority of transport agencies feel they require additional external support to face the challenges of technologies and service models. Industry representatives, such as PIARC, are well placed to provide this support.

PIARC should therefore consider how it can continue to advise its members, and the wider transport and mobility sector, on the emergence of new transport and mobility technologies through research, knowledge sharing of good practice and the development of planning and management tools. This may be through the remits for future Technical Committees, Task Forces and Special Projects as well as other initiatives as appropriate.

Recommendation PC3: Further Research into Future Road and Right of Way Design

PIARC should focus on "The Road of the Future," examining options for how roads and associated rights of way could be planned, designed, constructed, operated and maintained in the face of new modes, vehicle types, connected, autonomous and electric technology, and changes in demand resulting from shared mobility services. In essence, the question is how road design standards and

guidelines might be written towards 2050, what preparatory tasks are needed and how legacy infrastructure should be treated alongside new construction.

PIARC has established Task Force 2.1 (New Mobility, Roads and Transport) which is considering some of the related questions for future infrastructure over 2022 to 2024. Our evidence base and findings should be shared with this Task Force, as well as other research and engagement initiatives supported in due course, including in collaboration with other professional bodies with an interest and competence, such as ICE, ASCE, TRB and UITP.

Recommendation PC4: Low- and Middle-Income Countries

Whilst we have made efforts to extend our Literature Review, survey coverage and case study gathering to a comprehensive set of countries at differing stages of development, most of our evidence remains grounded in High Income Countries.

Care needs to be taken not to uncritically extend our conclusions to Low- and Middle-Income Countries where technology use cases, applications and end user needs may be different, as may capacity of the local public and private sectors to drive change. There may also be a more prominent role for IFIs and NGOs to fill prevailing gaps in developing, testing and initial deployment of technology applications, and considering the wider social, economic and equity implications.

PIARC should therefore redouble its efforts, through future Technical Committees, Task Forces, Special Projects and other mechanisms, to seek evidence from, and develop focused recommendations for Low- and Middle-Income Countries so that the benefits (and risks) of technology and service development can defined across countries at all stages of development.

Recommendation PC5: Connecting Outside Audiences

PIARC's external stakeholders, for example, national politicians and regulators, partner organisations and sectoral associations, subcontractors, and international organisations such as the OECD, World Bank, EBRD, ITF, IRF and UITP should be informed of the findings and advice in this Report, and any follow-up initiatives.

The next Strategic Planning Cycle should produce a plan for the communication and dissemination of information of noteworthy technology-focused policies, practices and outcomes at the regional and local level, including those evident from, or relevant to, Low and Middle-Income Countries.

8.5. PROPOSALS FOR FUTURE PIARC WORK

From our considerations of our topic under the PIARC Strategic Plan for 2020 – 2023, we have identified a number of areas for further work which PIARC may wish to consider in the future, through the various standing and temporary mechanisms available.

Specific Disruptive Technologies With Focus on Transport Electrification and Digital Connectivity

A number of the technologies and service model concepts explored in this Report could be studied, including the transition to market adoption and maturity, could be studied in more detail as empirical evidence on impacts, experience from early adoption and societal debates continue to emerge. The development of standardisation of technology, interoperability between different system components and enabling policy, regulation and governance will be important elements of focus.

In particular, we note that PIARC has yet to sponsor significant evaluation of Electric Vehicles and road-based E-Mobility, likely scale up over the coming decade and consider how automotive and associated charging technology will evolve to meet net zero, decarbonisation and other agendas.

We also note that digitisation of transactions and services, a key feature of the COVID-19 Pandemic, and the long-term potential to substitute physical mobility and demand for public and private transport, requires more in-depth evaluation.

The Transport Agency of the Future

Whilst we have examined the implications of disruptive technologies and service models for transport entity missions, functions and structures, we have not extended this fully to an evaluation of how transport agencies may look over the next 20 to 30 years.

More work could be done on organisational development in response to a range of external drivers from technology to stakeholders, as well as internal management, end user needs, workforce, skill and capacity planning factors. Considerations are also needed on how change may apply to agencies within countries across differing political systems and stages of socio-economic development.

Innovation as a Broader Theme

We note in this Report that innovation within transport agencies is often driven by more than technology and new service models, and may impact processes, people and other aspects of organisational functions. In addition, innovation may not be around the "next shiny thing," but relate to practical solutions to everyday operational needs or incremental improvements for customer services and user needs. There is therefore a requirement to explore broader concepts of innovation, concepts such as Design Thinking or Double Diamond models as structured approaches to problem solving and derive recommendations at the organisational, project or programme level.

Of these proposals, we believe a focus on road transport electrification and digitisation of service provision are urgent areas requiring focus from PIARC, but are for other Strategic Themes and Technical Committees to take forward. The second and third topics around the Transport Agency of the Future and Innovation as a Broader Theme would fall within the likely remit of the successor Technical Committee to TC 1.1 provided this is established within future Strategic Plans.

8.6. Final Remarks

On the topic of *The Role of Transport Agencies in Shaping Disruptive Transport Technologies and Service Models*, WG2 has fulfilled the Terms of Reference set by PIARC for 2020 – 2023. We commend this Report to all transport agencies and hope it will be a useful contribution to PIARC, its member countries and stakeholder agencies, as well as the wider transport and mobility sector.

In particular, we have sought to overcome the limitations in current literature by considering the organisational implications for transport agencies on the array of technological and service model innovations now appearing and developing rapidly and dynamically, often driven by the private sector, and requiring a constructive and appropriate public sector response.

We invite comments and further contributions on the concepts and recommendations set out in this Report and also seek further experience, including case studies, from across the World which will validate, extend and enhance our findings. This is particularly the case with internal organisational change and external stakeholder management across the public and private sectors to support technology and service development in the future. As noted, we also believe more evidence and evaluation should be undertaken on the key lines of enquiry of our research specifically focused on Low- and Middle-Income Countries.

TC 1.1 has worked well on the subject matter assigned to its second Working Group and the associated key lines of enquiry, and has done so despite the disruption over the past three years of COVID-19. Indeed, we have incorporated the issues raised by the Pandemic into our research topics and considerations and made appropriate recommendations.

9. GLOSSARY

9.1. GLOSSARY OF ACRONYMS

Acronym	Full Term
AAM	Advanced Air Mobility
ACES	Autonomous, Connected, Electric, Shared (Transport)
ADAS	Advanced Driver Assistance System
AI	Artificial Intelligence
AV	Autonomous Vehicle
CAV	Connected and Autonomous Vehicle
CDO	Chief Digital Officer
C-ITS	Cooperative Intelligent Transport System
CV	Connected Vehicle
DSRC	Dedicated Short-Range Communication
BEV	Battery Electric Vehicle
COP	Conference of the Parties (For the United Nations Framework on Climate Change)
ESG	Environmental, Social and Governance
EV	Electric Vehicle
eVTOL	Electric Vehicle Take-Off and Landing
FCEV	Fuel Cell Electric Vehicles
IATR	International Association of Transport Regulators
IFI	International Financial Institution
IoT	Internet of Things
IoV	Internet of Vehicles
ISO	International Organisation for Standardisation
ITS	Intelligent Transport System
MaaS	Mobility as a Service
NGO	Non-Governmental Organisation
PHEV	Plug-In Hybrid Electric Vehicle
PIARC	World Road Association (Permanent International Association of Road Congresses)
PT	Public Transport
SAE	Society of Automotive Engineers
SECAV	Shared, Electric, Connected and Autonomous Vehicle
SMART	Specific, Measurable, Achievable, Realistic, Timely (Objectives or Targets)
TRL	Technology Readiness Levels
UAM	Urban Air Mobility
UAV	Unmanned Aerial Vehicle
UNFCC	United Nations Framework on Climate Change
V2I	Vehicle to Infrastructure
V2P	Vehicle to Pedestrian
V2X	Vehicle to Everything
VUCA	Volatile, Uncertain, Complex, Ambiguous
WaaS	Walking as a Service

9.2. Glossary of Key Definitions

No.	Term	Definition and Examples
1.	Active Travel	The transport of people or goods, through non-motorized means, based around human physical activity, such as walking and cycling, usually for short trips or recreation, or as feeder to other motorised transport modes.
2.	Adaptive Innovation	A process which involves stripping steps from research and development and executing quickly through learning and creating. Through repeated cycles, a product or model can be updated quickly in alignment with evolving market needs and ahead of the competition.
3.	Artificial Intelligence	Computer systems and advanced analysis and logic-based techniques, including machine learning, to perform tasks normally requiring human intelligence, to interpret events, support and automate decisions, and take actions, including visual perception, speech recognitions, decision-making and translation between languages.
4.	As-a-Service	Something presented to a customer, either internal or external, as a service, without the customer having to own or control the relevant assets, usually in the context of digital platforms. As-a-Service offerings provide endpoints for customers to interface a web interface such as web browser or smart app. Relevant examples include Mobility-as-a-Service, Transportation-as-a-Service, Data-as-a-Service and Software-as-a-Service.
5.	Autonomous Vehicle	Road vehicles capable of sensing their environment and operating without human involvement.
6.	Big Data Platforms and Analytics	Systems and processes which collect, store, analyse and allow management of large and complex datasets, for example through machine learning and artificial intelligence, which can be used to support transport infrastructure, equipment and services. Associated Terms include Data as a Service, Data Services and Artificial Intelligence.
7.	Blockchain	A form of distributed ledger technology (DLT) designed to solve integrity and trust in digital transactions without a central administrator. It maintains a continuously growing list of transactional data records hardened against tampering and revision, allowing more rigorous and secure record keeping.
8.	Business Intelligence	An approach which combines business analytics, data mining, data visualization, data tools and infrastructure, machine learning and other best practices to help organisations to make more data-driven decisions
9.	Building Information Model (BIM)	An intelligent 3D model which represents and enables document and data management, coordination, and simulation during the entire lifecycle of a building or infrastructure project. As well as design and construction, BIM can also support operation and management of buildings using data that owners have access to.
10.	Connected Vehicles	Road Vehicles that can communicate bidirectionally with other external systems, allowing sharing of data with other devices both inside and outside the vehicle.
11.	Connected and Autonomous Vehicles (CAVs)	Road vehicles able to sense their environment, control motion and trajectory and communicate with infrastructure and other equipment without the need for intervention of a human driver. Associated terms include Self-Driving Transport, Driverless Vehicles or the Internet of Vehicles (IoV).

No.	Term	Definition and Examples
12.	Cooperative Intelligent Transport Systems	Intelligent Transport Systems, where the cooperation between two or more ITS sub-systems (personal, vehicle, roadside and central) enables and provides an ITS service that offers better quality and an enhanced service level, compared to the same ITS service provided by only one of the ITS sub-systems.
13.	Digital Asset Management	Management and maintenance of road and transport assets through application of technology to collect and analyse data, optimise planning, allocate resources, understand performance and deliver operations, for example through machine learning, drones and embedded sensors to monitor conditions and performance.
14.	Digital Connectivity	A concept which provides connections for data and other attributes between all objects, systems, and applications. In the context of future mobility, the concept can provide for transactions and activities to be carried virtually without need for physical movement or transportation.
15.	Digital Highways and 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. Also known as Cooperative Intelligent Transport Systems (C-ITS)
16.	Digital Wayfinding	The use of digital screens, devices and data to show maps, directions, building information, addresses, or other information to help people, usually pedestrians and cyclists, navigate their trips and locate their destinations.
17.	Digital Twin	Virtual representation of a physical asset, process or system enabling better outcomes through informed decision making at all stages of the asset life-cycle. The approach enables the user to visualize assets, check status, perform analysis, and generate insights in order to predict and optimize performance.
18.	Digital Workplace	The concept that organisations should use digital transformation to align technology, employees and business processes to improve operational efficiency and meet organisational goals. A broad term that includes any device, software or platform that staff members use to execute their jobs, often overcoming geographical constraints across multiple locations.
19.	Disruptive Technology	An innovation that significantly alters the way that consumers, industries, or businesses operate. A disruptive technology sweeps away the systems or habits it replaces because it has attributes that are recognizably superior. It overturns a traditional business model, changing completely the way things are done, making it harder for established organisations to embrace.
20.	Driver Assistance System	Also known as Advanced Driver Assistance Systems, electronic systems that assist drivers in driving and parking functions, using automated technology, sensors and cameras, to detect obstacles or driver errors, and respond accordingly. In doing so, they automate, improve, adapt, or provide user information on some or all of the tasks involved in operating a motor vehicle.
21.	Electric and Alternative Fuel Vehicles	Road vehicles powered by electric motors, electric batteries, or other forms of traction such as Compressed Natural Gas or Hydrogen, rather than a petrol or diesel Internal Combustion Engine. Associated terms are E-Mobility, Low Emission Vehicles, New Energy Vehicles, Low Carbon Transport.
22.	E-Deliveries and Logistics	Use of technologies and service models for the movement and delivery of freight, as part of wider supply chain management. The concept, sometimes called smart

No.	Term	Definition and Examples
		logistics, includes online ordering of goods and services for delivery at home, workplaces or other destinations selected by the customer. Associated terms include: Smart Logistics, Logistics as a Service and Smart Freight Management.
23.	E-Mobility	The concept of using electric powertrains, in-vehicle information, communication technologies and connected infrastructure to enable the electric propulsion and charging of vehicles and fleets.
24.	Emerging Technology	Technologies characterized by radical novelty, rapid growth, and significant future market potential. They have the potential to impact on established processes, user needs and organisations, in ways which can be quick, unexpected, uncertain, and ambiguous.
25.	Future Mobility Ecosystem	A combination of new technologies, systems, infrastructure, data, and service propositions which are converging to offer environmentally friendly, integrated, automated and personalised on demand mobility for people and goods. As well as the system components and attributes themselves, the concept includes the policy, regulatory and governance conditions required to create the system and make it operationally and commercially effective.
26.	Future Transit Technology	A range of new mass and personalised transit technologies, with varying degrees of autonomy, alternative powertrains, and dynamic control, beyond traditional metro and transit systems, such as Hyperloop, Small Transit Systems, Pods or E-Shuttles which may run to a fixed or on-demand timetable.
27.	Hype Cycle	A branded graphical presentation developed by the American firm Gartner to illustrate the maturity, adoption, and application of specific technologies. The hype cycle, which is currently updated on an annual basis, claims to provide a conceptual presentation of the maturity of emerging technologies through five phases. The Gartner hype cycle has been criticised for a lack of evidence that it holds, and for not necessarily matching well with technological uptake in practice.
28.	Hyperloop	A proposed mode of passenger and freight transportation via a sealed tube or system of tubes with low air pressure through which a pod may travel substantially free of air resistance or friction. A Hyperloop could potentially convey people or objects at hypersonic speeds while being energy efficient compared with existing high-speed rail systems.
29.	Industrial Revolution 4.0 (Fourth Industrial Revolution)	The ongoing automation of manufacturing and industrial practices using modern smart technology. The concept includes the integration of large-scale machine-to-machine communication, the internet of things (IoT), data analytics and other processes for increased automation, improved communication and self-monitoring, and production of smart machines that can analyse and diagnose issues without the need for human intervention.
30.	Innovation	The practical implementation of ideas that result in the introduction of new goods or services or improvement in offering goods or services. ISO 56000:2020 (Innovation Management) defines innovation as "a new or changed entity creating or redistributing value." Many scholars and governmental organisations have given their own definition of the concept, with a focus on newness, improvement and spread. It is also often viewed as taking place through the provision of more-effective products, processes, services, technologies, art works or business models that innovators make available to markets, governments and society.

No.	Term	Definition and Examples
31.	Innovation Framework	A future-focused business organisational development framework that identifies breakthrough growth opportunities, accelerates organisational decisions and creates near-term, measurable impact within the context of a longer-term vision for sustainable development or competitive advantage.
32.	Integrated Mobility	A concept whereby mobility providers collaborate and promote their networks and travel services as one unified service and user proposition, linking transportation options together so they can be understood, accessed, and sometimes paid for, by users as part of a single or integrated package.
33.	Intelligent Mobility	A concept for moving people and goods around in an easier, more efficient, and more environmentally friendly way. It uses new ideas and new technologies to look beyond traditional, infrastructure-heavy approaches to transport, and to instead come up with innovative ways to improve mobility and make journeys better and accessible to all.
34.	Intelligent Transport Systems	Advanced technology applications which aim to provide services relating to different transport modes and traffic management and inform users to make safer, more coordinated, and 'smarter' use of transport networks.
35.	Internet of Things (IoT)	The network of physical objects - “things” - that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the Internet. The IoT can assist in integration of communications, control, and information processing across transportation systems, including vehicles, infrastructure, drivers or users. Dynamic interaction between these components enables inter- and intra-vehicular communication, smart traffic control, smart parking, logistics and fleet management, vehicle control, safety, and road assistance
36.	Levels of Automation (SAE)	A five-stage model and standard of road vehicle automation developed by the Society of American Engineers, set out in J3016: Taxonomy & Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems.
37.	Micromobility	A range of small, lightweight vehicles, privately owned or for hire, operating at speeds typically below 25 kph and driven by users personally. Micromobility devices include bicycles, E-bikes, electric scooters, electric skateboards, shared bicycles, and electric pedal assisted bicycles.
38.	Moonshot Technology	An ambitious, exploratory, and ground-breaking project undertaken without any expectation of near-term profitability or benefit and also, perhaps, without a full investigation of potential risks and benefits. This contrasts to evolutionary approaches which represent incremental improvements on current technologies.
39.	Net Zero	A concept which balances the amount of greenhouse gases emitted into the atmosphere with the amount removed. Net zero is achieved when no more emissions are added than are taken away. The aim of this is to reduce the concentration of greenhouse gases in the atmosphere and therefore anthropogenic climate change.
40.	New Mobility	A convergence of classical mobility concepts with use of innovative vehicular and other technologies, including through use of the Internet and mobile devices, as well as new and potentially disruptive business models and the technological integration of various forms of current and future publicly usable transportation services that can be either shared, connected, and accessible on demand.

No.	Term	Definition and Examples
41.	New Normal	A state to which society settles following a crisis, when this differs from the situation that prevailed prior to the start of the crisis. The new normal encourages one to deal with current situations rather than lamenting what could have been.
42.	Platooning	A method for driving a group of vehicles together, connected by electronic and possibly mechanical coupling, meant to deliver more consistent vehicle performance, increase the capacity of roads, and reduce use of fuel and other resources, via an automated highway system.
43.	Remote Working Technologies	Also known as teleworking, the use of Information and Communications Technology to facilitate activities or maintain contact with businesses and customers electronically without the need for physical interaction and mobility.
44.	Service Model	The means by which a technology or its delivery as service is specified, developed, implemented and offers value to end users. A service model may define the relationship between technical and operational requirements and realisation of benefits and as such may define roles and relationships of key stakeholders, form of asset ownership and management and development of customer propositions.
45.	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.
46.	Smart City	An urban area that uses different types of electronic methods and sensors to collect data. Insights gained from that data are used to manage assets, resources and services efficiently, and improve the operation of the city.
47.	Smart Journey Planning and Management	Use of smart devices, search protocols and databases to receive personalised information on travel by different modes, including adjustments due to congestion and other network conditions, allowing users to make better travel choices.
48.	Start-Up	A company or project undertaken by an entrepreneur to seek, develop, and validate a new technology, product or business model. This may offer an alternative or seek to disrupt an established company or product and seek investment capital in order to develop concepts, prototypes or initial applications.
49.	Technology Readiness Levels	A method for estimating the maturity of technologies during the acquisition phase of a program, developed at NASA during the 1970s. The use of TRLs enables consistent, uniform discussions of technical maturity across different types of technology. They also allow engineers to have a consistent datum of reference for understanding technology evolution, regardless of their technical background. TRLs vary from Level 1 (Basic Principles), through Level 6 (Prototype Demonstration in a Relevant Environment) to Level 9 (Actual System Flight Proven).
50.	Transformational Innovation	The introduction of a technology that creates a new industry or sector, transforming economy and society. This kind of innovation often eliminates existing industries or, at a minimum, totally transforms them.
51.	Unmanned Aerial Vehicles	An aircraft which is controlled to transport people and goods without the need for a human pilot on board. The aircraft may have varying degrees of autonomy and/or be part of a broader Unmanned Aerial System which includes a ground-based controller and system of communication between them. Associated terms include Drones, Flying Cars or Aerial Taxis.
52.	Urban Air Mobility	The use of small highly automated aircraft to carry passengers or cargo at lower altitudes in urban and suburban areas, usually referring to emerging technologies

No.	Term	Definition and Examples
		such as electrically propelled, vertical take-off and landing aircraft (eVTOL), and unmanned aerial vehicles (UAVs). Urban air mobility is a subset of a broader Advanced Air Mobility (AAM) concept that includes other use cases than intracity passenger transport, including small drones, electric aircraft, and automated air traffic management among other technologies to perform a wide variety of missions including cargo and logistics.
53.	Vehicle to X	In vehicular communication systems, vehicle-to-everything communication (V2X), consists of three main components: vehicle to vehicle communication (V2V), vehicle to infrastructure communication (V2I) and vehicle to pedestrian communications (V2P).
54.	3D Printing	The construction of a three-dimensional object from a CAD or digital 3D model. The term "3D printing" can refer to a variety of processes in which material is deposited, joined or solidified under computer control to create a three-dimensional object, with material being added together (such as plastics, liquids or powder grains being fused together), typically layer by layer
55.	5G Mobile Networks	The fifth-generation technology standard for broadband cellular networks, which cellular phone companies began deploying worldwide in 2019, and is the planned successor to the 4G networks which provide connectivity to most current cell phones. 5G offers significant advances in data volume, speed and processing capacity and is claimed to be able to support millions of devices at ultrafast speeds.

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World Road Association (PIARC)
La Grande Arche, Paroi Sud, 5e étage, F-92055 La Défense cedex