Gaps Analysis Report in the Smart Mobility Field

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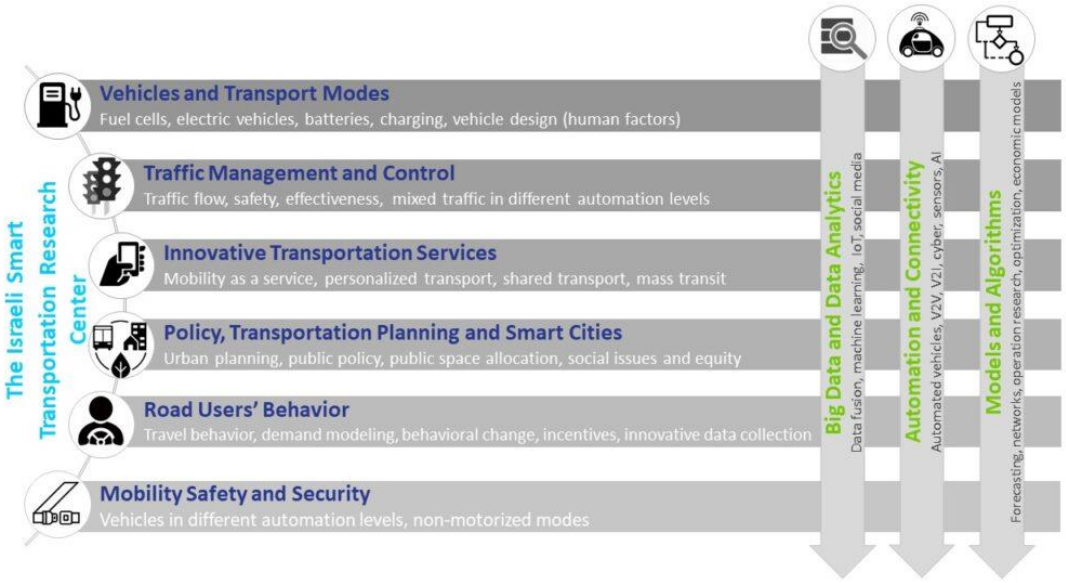
1. Introduction

The introduction and imminent transition to smart mobility open the window for urban mobility and societal benefits such as environmental conservation, resource efficiency, productivity gains, social inclusion, integration, health, and wellbeing. Emerging technologies in transport also present challenges in which the lack of regulation and social inclusion and a relatively free hand to private initiatives might steer the transition, resulting in a worsening urban environment and perpetuating social inequality.

To keep up to date with the latest research challenges in the evolving field of Smart Transportation, the Israeli Smart Transportation Center (ISTRC) funds an annual "Knowledge Gap Research" for each of the center's Professional Committees. All reviews include recommendations for research topics within each committee's domain for future ISTRC research grants. The nine professional committees of the Israeli Smart Transportation Research Center are presented in figure 1.



This report draws on a review conducted using Scopus and Google scholar bibliographic databases. The main goal of the review is to explore and identify fundamental challenges and research gaps in the field of smart mobility, beyond specific areas of smart transport, reflecting the multidisciplinary nature of the field, including policy and planning, technology and communication developments, and behavioral changes in activity and travel habits of users among other aspects. The research gaps identified in this report, as well as the other research gaps reports conducted by each committee, represent a crucial research tool promoting the main objectives of the ISTRC according to the zero externalities vision contributing to smart, efficient, and green transportation and position Israel as a world leader in the field.

2. Working process

A search in Scope database and Google Scholar was conducted using keywords such as “Smart mobility” or “Smart Transport” since 2016 in peer-reviewed journals. From the initial search of thousands of papers 217 papers were found relevant according to the title. Due to the large amount of papers, we adjust the search for review papers, and 87 papers were obtained. After further screening the abstracts, we focused on just 18 review papers that best fit our objectives.

3. Specific challenges

The main gaps and future research directions identified in the scientific literature are organized around 7 topics:

A. Transportation planning and Smart cities Architecture
B. Smart Mobility Services Composition
C. Connectivity & Interoperability
D. Smart Mobility Services Deployment and other issues
E. Transportation Equity, Economy & Business models
F. Social acceptance and Socio-urban context
G. Governance and policy

It is worth noting that there is no clear differentiation between the topics, and an existent overlap is an intrinsic part of the multidisciplinary nature of the smart mobility field.

Topic A: Transportation planning and architecture framework

Future research directions suggested in the smart mobility literature highlight the importance of transport planning and the consequent necessity of internalization of information and communication technologies in the planning and management of mobility systems and the importance of defining templates and instruments to facilitate smart mobility strategic planning processes. The lack of quantitative models and simulations is noted in many papers for future prediction of passenger demand, traffic reduction, adequate vehicle fleet allocation, and optimum route choice in real-time, economic, and environmental benefits. The specific challenges are:

- **Internalization of information and communication technologies in the planning and management of mobility systems** (Braga et al., 2019)**.** Mobility as a Service (MaaS) is not fully referenced in strategic urban plans and so may not be shaped to better internalize transport's effects, and this strategic omission permits uncritical thinking about MaaS if it is promoted in isolation from wider urban objectives (Pangbourne et al., 2020).
- **Defining templates and instruments to facilitate smart mobility strategic planning processes** based on the development of a classification aimed to provide a common vocabulary to discuss and share information about mobility services, and specifying a software architecture for rapid development and deployment of smart mobility services based on the identified functionality (Cledou et al., 2018).
- **Lack of modelling and simulation**
    - Future prediction of passenger demand to Mobility on Demand (MoD) services, adequate vehicle fleet allocation, and optimum route choice need to be conducted in real-time.
    - Real-time big data analysis for traffic flow prediction is a key challenge, which is further complicated by unpredictable human behavior making a future prediction of users' travel patterns even more challenging.
    - **Lack of models/frameworks including both people and freight transport** (Mangiaracina et al., 2016). A general lack of quantitative models emerged. Eventually, there is a lack of contributions considering both people and freight transport, even if they are strongly related, especially in

an urban environment. Future research should investigate the benefits (e.g., reduction of urban traffic and bottlenecks) achievable by using ITS solutions to optimize freight urban transport. In this regard, a model aiming to quantify the ITS-enabled benefits (e.g., economic, environmental) – including the effects on people urban transport – is still missing.

- Emphasis mainly on technology aspects. Lack of quantitative models (i.e. only the 35% of papers reported a quantitative assessment) for measuring the overall impacts of ITS technologies in the urban context, and for splitting them among the several stakeholders involved (Mangiaracina et al., 2016).

Topic B: Smart Mobility Services Composition:

- **Integration of network of innovators. The changing set of actors involved in transport provision challenge the existing rules of the game** (Docherty et al., 2018). New operational rules and co-coordination procedures will be required. For further development of shared electric automated mobility, the continuous involvement of a broad range of actors remains crucial to steer the developments into the direction of an integrated multi-modal mobility system (Manders et al., 2020).
- The responsibilities for involving users have been transferred to numerous actors, who renegotiated the goals assigned to them by the Ministry, resorting to their old techno-centric innovating ways. **The dominance of the techno-centric perspective acted as a barrier and inhibited a successful implementation of a more user-centric approach** (Vrščaj et al., 2020)
- Other specific challenges noted in the smart mobility literature are related to interoperability capabilities combining different modes and transport services and the necessity to maintain high-quality services.
- For future research, it is an interesting angle to try to understand **how shared electric automated mobility services can support (or hinder) MaaS-developments and how it impacts car usage** and environmental sustainability (Manders et al., 2020)
- Bicycle sharing programs should be considered a public service or commercial opportunity? (Ploeger & Oldenziel, 2020).

- The main challenge of **Flexible Mobility on Demand** service optimization is to find the **trade-off between obtaining the profitability level for operators while maintaining high-quality service for users** (Liyanage et al., 2019)

Topic C: Connectivity & Interoperability

- Interoperability and integration - the Internet of Things (IoT) is characterized by a largely heterogeneous blend of connected devices, provided by different vendors using different types of technology, the authors predict that interoperability issues will constitute some of the main challenges for a well-functioning, connected IoT infrastructure. Challenges related to interoperability include the development and usage of standardized protocols and interfaces for communication and service provision (e.g., standard web service protocols), as well as the development of efficient middleware (Davidsson et al., 2016). A review on artificially intelligent sustainable transport found that most of the literature lack in concise integration of stakeholder engagement, real-world traffic data, cost and emission models and detailed traffic simulation modelling for life-cycle implications of ITS and AV transport. Environmental impacts notwithstanding, the travel time and ride comfort factors may be the primary drivers of AV adoption for public transport and ride-sharing transit systems, and as such, should be focused in future research (Hasan et al., 2019).
- **Complementary technology advances**. To explore how smart mobility innovations can contribute to alleviate transportation disadvantages. Mobility-as-a-Service has high potential to alleviate transportation disadvantage primarily due to its ability to integrate a wide-range of services. Secondly, research should also focus on other innovative ways to integrate transportation modes, attract users to shared mobility, or develop alternatives systems. Research could explore the role of other technological advances outside the field of transportation including 5G, AI, digital twins, virtual reality, blockchain, IoT, big data, and cloud computing (Butler et al., 2020). For example, the use of virtual reality and augmented reality could be used to educate, market, and promote new transportation innovations towards individuals and business. Similarly, it could be used to let users experience new transportation technology prior to analyzing their attitudes, acceptance and usage.

- Scalability - How to store all the collected data in a way that privacy and integrity is preserved. How to analyze and process the various collected data and transfer it into meaningful information that can be used by various types of actors, for example, travelers and transport operators.
- Data Collection – Various challenges are related to relevant data collection (Davidsson et al., 2016):
    - Determining what type of data is possible to collect, both in real-time and in retrospect.
    - Identifying what type of data are most useful for the different actors in different situations.
    - Collecting and storing data in the best and most efficient way. This may include non-traditional methods like crowdsourcing and using social networks like Twitter.
    - How to ensure that the collected data is of sufficient quality.

Topic D: Smart Mobility Services Deployment and other issues

- Deployment - To improve user acceptance, there have been efforts to **make users involved in the design and deployment processes**. For instance, **the concept of living labs has recently been established as a new way of testing and evaluating new systems in a user-centered environment**. Also, the transport providers and administrative sector need to adapt to the new technology and services (Davidsson et al., 2016).
- Usability - How to present data and information in a way that humans and machines can easily use the information. How to design appropriate interaction models so that the users can interact with services and devices in an intuitive way (Davidsson et al., 2016).
- Privacy and Integrity Issues - In a reality where various types of sensors continuously monitor and record the activities of people and items, and where end users submit information about their activities, **there are challenges of how to** regulate and protect **the privacy and integrity of the individuals that are being**

monitored. To gain the trust of the travelers it is important that no personal information is used or distributed without explicit consent (Davidsson et al., 2016). In this sense, this bullet is also related to the governance and policy section.

- Deployment projects should demonstrate how **MaaS** will reduce personal vehicle use and ownership.
- Deployment project should confront Potential up-scaling and social issues - potential social challenges (such as security, privacy, and equity).
- From the perspective of looking for future research gaps in the analyzed context, infrastructure design and air quality protection, climate change, and city crowding were less frequent areas in the scientific literature.

Topic E: Transportation Equity, Economy & Business models

- **Who pays - Absent intervention**, the tax base supporting traditional transport investment (dominated by private vehicle ownership, vehicle and gasoline tax, roads funded by the state and a subsidized public transport system) will decline. The crucial role that road pricing reform must play to ensure that those who benefit (suppliers and travelers) contribute to pay for the infrastructure and externalities they create (Greg Marsden et al., 2020; Hensher, 2018; Jacobsen & Rutter, n.d.). **Equity and inclusion** - There is a potential for smart mobility to solve but also widen some equality and inclusion gaps. **There is a need to redefine how necessary services are defined and provided** and how subsidy is channeled (Docherty et al., 2018).
- **Business model - A major challenge is the need for effective business models, which regulates how revenues should be distributed to cover the costs of the involved actors**. Since public transport operations are typically under the tight regulation and procurement from governmental agencies, it may be enforced that some data needs to be supplied by the transport operators. However, challenges of continuity and quality is often an issue and initiatives of other pure commercial and third party actors typically need business models
- A review on artificially intelligent sustainable transport found that the majority of literature lacked in concise integration of stakeholder engagement, real-world

traffic data, cost and emission models and detailed traffic simulation modelling for life-cycle implications of ITS and AV transport. Environmental impacts notwithstanding, the travel time and ride comfort factors may be the primary drivers of AV adoption for public transport and ride-sharing transit systems, and as such, should be focused in future research (Hasan et al., 2019).

Topic F: Social acceptance and Socio-urban context

Social acceptance

Social acceptance represents a vital issue for technological acceptance in general. The adoption of new technologies is ultimately an individual decision. Recognized theoretical perspectives such as the Technological Acceptance Model (TAM) focuses on the individual understanding motivations for technology use and acceptance, highlighting fundamental concept constructs around 'perceived usefulness' and 'perceived ease of use'. This perspective and other psychological perspectives (e.g., Theory of Reasoned Action and the Theory of Planned Behavior) suggest a series of interrelated constructs to explain an individual's usage and intention to use a (new) technology. TAM is complemented by the theory of diffusion of innovation that explains how new ideas and technologies are spread through society and become dominant. In smart mobility, different issues are highlighted as important factors for individual preferences and acceptance, such as trust in new systems, travel experience, and user involvement in technological development and design.

- The key constraints are the perception of users that MaaS service is of limited value, the existing forms of public transport contracts, and inadequate ICT facilities.
- Trust should be built through information provision, awareness, campaigning, and research and development.
- The **travel experience** seems to be missing from the entrepreneurs' perspective and worldview of transport planning (Noy & Givoni, 2018).
- **Urban case studies to explore the policy-framing** of MaaS would be a valuable addition to the literature. Methods for studying power imbalances and the boundaries of anticipated futures in the current distribution of roles and responsibilities are required (Pangbourne et al., 2020).

Socio-urban context:

- One of the significant impacts of smart mobility is related to the capacity of new mobility services to enhance social inclusion and equity in society. In this sense, it is essential to understand how smart mobility solutions contribute to overcoming different constraints in the accessibility and fulfilment of daily activities (e.g., economic, geographic, socio-demographic and health constraints) in a different context such as local/national and urban/rural environments.
- Analysis throughout a range of case study areas using transportation modeling, consumer surveys, expert opinion, and trials could also identify issues specific to the varying characteristics of different regions, including those associated with regulatory systems, policy frameworks, cultural differences, and geographic conditions (Butler et al., 2020).
- **How smart mobility refers and can boost social inclusion. The need to consider it in planning** (Braga et al., 2019)**.**
- **COVID-19 influence on travel behavior.** Whether the COVID-19 experience has changed user perspectives and willingness-to-ride shared, and public transport (before, during, and after the lockdown experiences). In this context - ask whether no mobility is smarter than smart mobility (Butler et al., 2020).

Topic G: Governance and Policy

The policy challenges discussed in the literature are around the necessity of public intervention leading the transition to smart mobility and the identification of the new actors and their specific role in the smart mobility field. Competition and cooperation among innovator networks over political, economic, and technological dominance are key factor in influencing policy directions and new business models. Thus, central actors in the transport system arena should be identified and analyzed according to their roles, interests, agenda, and capabilities. Furthermore, other issues related to equity and inclusion and a call to redefine how necessary services need to be provided and defined are included in the literature. The list of specific challenges and their explanations are as follow:

- **The transition governance and management of smart mobility transition.** How the transition to smart mobility is managed, and how both the benefits and any negative externalities of change will be governed (Docherty et al., 2018). A failure to address both the short and longer-term governance issues risks locking the mobility system into transition paths which exacerbate rather than ameliorate the wider social and environmental problems that have challenged planners and policy-makers throughout the mobility transition. Key challenge: Effective governance is necessary to ensure Smart Mobility generates public value.
- **Lack of public intervention and the necessity of the public sector leading the transition with a clear separation of the private sector** (Docherty et al., 2018; Pangbourne et al., 2020) **.** It becomes a problem if these same actors and companies are the ones who set the agenda, drive, and largely determine transport policy and planning, and are the ones who lead public transport policy and research institutions (Noy & Givoni, 2018).
- **Outsourcing innovation to the private sector creates a critical governance gap in managing the Smart Mobility transition** (Pangbourne et al., 2020). In relation to the technology development processes, emerging technologies such as MaaS typically face the challenge of institutional void and organized irresponsibility. This means that none of the current institutions has a full understanding or control of undesirable consequences associated with MaaS or other technological constellations. In turn, the resulting distributed responsibility for transition management and technological development limits individual and institutional accountability.
- **A gap in understanding of the societal and governance implications of MaaS.** The research on wider implications for governance of MaaS is underdeveloped, and this gap has been repeatedly highlighted in recent publication. A package-based MaaS is primarily a private sector initiative, we should seek private sector contributions to fund independent research to develop the necessary **understanding of behavior, needs/preferences, and consequences (environmental and social) of different modes and services**, to guide bundling choices in a manner informed by local policy.

Body of Knowledge Development Model:

Knowledge gaps identification is not a one-shot action. To develop & maintain any Body of Knowledge (BOK) it is necessary to define the scope of the knowledge required. Once the core knowledge is defined it is required to establish Knowledge Management scheme based on similar process to the knowledge management model proposed as shown in Fig 2.

One of the gaps in Knowledge development domain is the growing gap between BOK developed at universities & research institutes opposed to the BOK developed & implemented by the industries. When dealing with development Body of Knowledge at Smart Transportation domain we may assume that Engineering Knowledge is being developed in many Body of Knowledge Development Points (BOKDP), in research institutes & at industries & engineering consulting firms. To minimize the gap between Academic BOK & industry BOK it is required to establish closed Feedback Loops that will feed back information & knowledge from actual smart transportation projects back to BOKDP-Body of Knowledge Development Points.

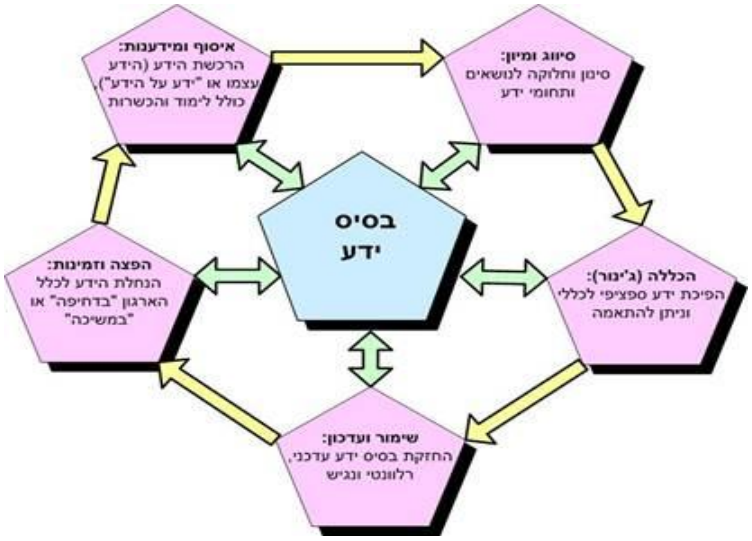


Fig 2: Body of Knowledge development

Conducting System Change

A primary question facing the society today: Why, despite the best efforts of countless public, private and civic organizations, and the mobilization of vast collective resources, so many social and environmental problems remain so persistent and intractable? The best intentions and endeavors of countless individuals and organizations do not seem to sum up to the solutions on the macro-level that are now much needed.

This begs the question, what are we missing?

Across the public sector, the social sector and other areas people are now starting to become aware that maybe the underlying reductionist assumptions and paradigm through which we traditionally tackle issues may not be appropriate for the scale and complexity of today's issues. In this respect the new ideas of systems change are now rising to prominence. There is now a sense that its vision, scope, and vocabulary is of a kind that is sufficiently powerful to match the complexity of the challenges at hand. By leveraging a new set of ideas, we start to look at what we are doing afresh and with greater clarity that gives renewed inspiration and momentum to our endeavors to shape complex organizations towards more sustainable outcomes.

We now start to see these challenges as systemic, open-ended, co-evolving and with no known solutions requiring new ways of innovating, new ways of leading, organizing and responding. A way that leverages the power of the very complexity that creates these challenges, a way that is not incremental or linear, but holistic and networked, an approach that works with complexity rather than pushing against it.

This approach is inspired by and based upon a new way of thinking embodied in complexity theory and systems thinking. A powerful new set of ideas, that hinge around holism, systems, emergence, self-organization, nonlinearity, networks, adaptation, resilience, etc. This new approach that builds upon systems thinking is now termed systems change.

Systems change is about changing the underlying structure to a complex system to change its behavior and outcomes. This stands in contrast to more traditional approaches that rarely question system structure but focus on changing components, events, and outcomes.

The hope is that by seeing system structure, by changing those structures and organizing in new ways, we can create patterns and institutions that better organize us in synergistic ways. So that the system's structures we inhabit don't incentivize and coordinate us in ways that have negative externalities leading to so many of the wicked problems we face but instead they have positive externalities that sum up to something greater than the sum of their parts as new types of organization emerge.

Annex A:

Smart Transportation Challenges:

The following list of Smart Transportation Challenges is based on: *European Partnership under Horizon Europe CCAM-Connected, Cooperative and Automated Mobility (Version 13 May 2020)*

The Challenges:

- To foster and support new mobility concepts,
- Inclusiveness: Ensuring inclusive mobility and goods access for all
- Shifting design and development from a driver-centered to mobility-user oriented approach
- Providing viable alternatives for private vehicle ownership
- Increase inclusiveness of mobility solutions,
- Integrated ITS technologies in the whole transport system,
- Develop incentives & legal framework,
- Safety: Reducing the number of road fatalities and accidents caused by human error.
- Environment: Reducing transport emissions and congestion by optimizing capacity, smoothening traffic flow and avoiding unnecessary trips.
- Minimize potential adverse effects that increase traffic congestion.
- Minimize new risks in mixed traffic environments.
- Enable the provision of new mobility services for passengers and goods,
- Fostering benefits for users and for the mobility system as a whole.
- Create more user-centered, all-inclusive mobility, while increasing safety, reducing congestion and contributing to decarbonization.

Important Insights

The European CCAM Report (European Partnership under Horizon Europe CCAM-Version 13 May 2020) includes a list of insights**,** that are important to anybody that plans to be involved with the development of Smart transportation services within the coming decade**:**

Insight 1

Society is not yet prepared to accept the transition to CCAM enabled mobility. Potential implications and impacts of integration of CCAM solutions into the mobility system are not well understood.

Insight 2

CCAM solutions are not yet sufficiently mature for market take-up, and current investment levels in CCAM R&I are inadequate to maintain and extend EU industrial leadership.

Insight 3

Current Research & Innovation (R&I) efforts are fragmented and lack a coherent, longer-term vision and strategy for targeting systemic solutions.

Insight 4

Demonstration and scale-up is limited, since a well-organized, extensive and complex cross-sectorial value chain is still required to build complete CCAM solutions.

Insight 5

As they are highly interdependent, many of the required steps for CCAM have to be planned consistently across private and public sectors.

Insight 6

If not planned comprehensively, and matched with the proper framework conditions, e.g., in the regulatory domain, the innovation process may slow down or may not trigger the expected benefits. Resources and investments could be wasted and we may miss the opportunity to benefit from CCAM for the society and economy.

Insight 7

To move towards this vision, the operational domains and use cases of CCAM vehicles need to be extended to the point where they become economically viable and societal benefits are realized.

Insight 8

A long transition phase is expected, with conventional and CCAM vehicles with specific traffic management needs ensuring good co-existence and specifically protecting vulnerable road users.

Insight 9

Despite the forementioned expected impacts and benefits of CCAM, there is yet a fairly limited demand in society to implement these solutions. The order of magnitude of the benefits, but also further risks and implications are not known or well understood.

Insight 10

A Partnership is needed to strengthen awareness, assess impacts, and understand user and societal effects across many different Member States.

Insight 11

Europe needs more large-scale testing, demonstrations and pilot projects involving all relevant stakeholders to accelerate implementation and remove barriers.

Insight 12

The large cross-sectoral value chain and interaction between public and private stakeholders is another barrier for deployment of CCAM solutions.

Insight 13

Coordination at EU level is needed in order to develop harmonized and interoperable solutions.

Insight 14

Commitment towards coordinated European actions are needed to develop this eco-system with vehicle manufacturers, local and regional authorities, road operators, service providers, telecom industry and others.

Insight 15

In the past, the big innovations in vehicle technology like seat belts or airbags were introduced by the industry as another component to the existing vehicle. After five to ten years of experience with the new technologies, technical standardization (e.g., ISO standards) gave a thorough basis for developing regulations. Making CCAM solutions ready for deployment requires all three processes (Innovation, product development and experience, and technical standardization) to advance at the same time. Today, vehicle technology is starting to lead to standards, but regulation needs to be in place at the same time, with all the uncertainties and permanent adaptions necessary to keep up speed. To solve this situation, the most flexible and closest possible cooperation between actors involved in research, standardization and regulation (national and international) is a key.

Insight 16

The development of a long-term strategy needs to be in close cooperation with all actors. The European dimension enhances interoperability and ensures a critical mass of demand to allow industrialization of innovation as well as bringing benefits to society.

Insight 17

Member States, local and regional authorities have a key role in the Partnership beyond the question of adapting road infrastructure. They ensure the alignment with transport policies and regulatory actions.

Insight 18

Due to increased demands on the industry's constantly evolving business environment, it is crucial to improve the agility and flexibility of actions while allowing for more longer-term strategic planning.

Insight 19

To make efficient use of resources, there is a need to align public and private R&I investments engaging all relevant stakeholders to ensure capacity is built consistently in Europe. Consensus building and sharing is needed across stakeholders' groups to leverage the full potential of CCAM.

Insight 20

Different perspectives beyond technology development need to be addressed to match use cases developed by industries with the needs of public authorities (including local and regional ones) delivering value to the user of the mobility and logistics system.

Insight 21

The Partnership needs stakeholder engagement from across the entire value chain of CCAM. To meet the overall objectives of the Partnership, active involvement is needed from different sectors, backgrounds, and expertise.

Insight 22:

The necessity for the cross-border elements is the strong need for harmonization and interoperability of technologies and methodologies.

Insight 24:

For most types of R&I actions addressed, cross-sector collaboration is very important from early stages of research on CCAM elements (infrastructure, services and vehicles) onwards to enable seamless deployment.

Insight 25:

Europe needs more large-scale testing, demonstrations and pilot projects involving all relevant stakeholders to accelerate implementation and remove barriers.

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