Deliverable D2.2 Outline of emerging technologies

Project:	STTRIDE
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Abstract	Deliverable D2.2 is the output from task 2.2 and 2.3. D2.2 summarises findings from a review of relevant literature and secondary data, and from web survey to stakeholders.
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CONTENTS

1 EXECUTIVE SUMMARY

Technology innovation in the mobility sector is indeed moving at a rapid pace. Many emerging technologies are having or could have a significant impact on citizens' preferred mode of transport over the next twenty years. This technological driven paradigm shift provides an opportunity for significant change in traveller behaviour without necessarily requiring major infrastructure investment or legislative intervention. Indeed, this could provide a substantial difference in future transport network demands, emissions and in contributing to healthy lifestyles.

Harnessing the potential of technological development can make the most efficient use of existing transport infrastructure and services, as well as facilitating the introduction of new and improved ones. For example, passenger information systems could increase the occupancy of buses, which improves the business case for investing in improvements to the service, thereby encouraging further modal shift.

The pace of change is such that it could be a challenge for road and transport authorities to understand the potential impacts and timescales associated with a wide range of technologies. Once a new technology has appeared, it can also be difficult to assess the impact it has had. As a result there is a knowledge gap for authorities in needing to understand how to support, respond or invest in the right technologies to deliver their preferred outcomes. STTRIDE project aims to identify and analyse technologies which can be seen making impact on positive modal change in future. The time horizon for the project is 20 years.

Deliverable D2.2 focuses on identification of technologies that are emerging and have an impact on modal change. First of all a long list of 66 potential technologies was identified, which could have impact on a road user's modal choice. Then a short list of 10 technologies was selected from the long list, which was verified in T2.3 by engaging stakeholders and then given to WP3 for further analysis.

2 INTRODUCTION

The STTRIDE project will:

- review travellers' needs and understand the role of emerging technology in meeting those needs
- address how best to use technological advances to deliver positive modal shift.

Work Package (WP) 2 relates to gathering evidence. Its strategic objectives are to:

- identify existing evidence on user needs for an optimal journey
- understand which emerging technologies could contribute to meeting these needs.

Deliverable D2.2 is about identifying technologies, which have an impact to traffic in future and then a subset of technologies which affect positively to modal change. From T1.1 user needs are found and reflected to how the technologies for the short list are chosen.

STTRIDE is focussing on five thematic areas in relation to emerging technologies, which are described below.

2.1 Thematic areas of emerging technologies

STTRIDE is focusing on five thematic areas in relation to emerging technologies:

- **Automation of vehicles**. Although the principal driver of automation is likely to be safety, it could also provide many of the benefits of passenger transport (e.g. productive use of travelling time and reduced concern about car parking) in private vehicles, potentially encouraging shift away from mass transport. Conversely, this technology could also be an enabler of vehicle sharing and demand-responsive services to provide access to public transport and so reduce the proportion of single-occupancy journeys.
- **Information**. Real time multi modal information provision can identify alternative travel options, both before and during the journey, enabling plans to be revised in real time, which reduces the risk and uncertainty associated with public transport and enabling better use to be made of travelling and interchange time. This reduces the 'generalised cost' of public transport in demand modelling theory, and would be expected to encourage greater uptake of it.
- **Journey efficiency**. New technologies can help transport authorities to give greater priority to public transport vehicles, making it more attractive compared to driving. It can also help operators to make better use of capacity enabling improved cost-effectiveness, potentially leading to lower fares and improved investment.
- **Mobility as a Service (incl. payment).** Enabling the provision of new mobility services, such as bike hire or car sharing, which cannot realistically be managed without sophisticated information and payment systems.
- **Safety**. This covers technological improvements to individual modes or the wider environment, which would impact the perception of safety and people's willingness to use alternative modes. For example, an improved environment for cyclists through new transport infrastructure, including more advanced junction designs.

  The identified technologies have been categorised in to these five themes. Most of the technologies are not in one theme but are overarching between several themes.

2.2 Identified emerging technologies

66 technologies were identified in the long list. Most of them were related to the information theme - 39 instances. The safety-theme had 24 instances, automation of vehicles 18 instances, journey efficiency 15 instances and Mobility as a services had 9 instances. Basic information about technologies was identified and put into the technology template found in Appendix 1.

From the 66 technologies in the long list 10 technologies were selected for the shortlist which in turn were sent to stakeholders for comments. The short list of technologies is a basis for WP3 analysis work.

2.3 Stakeholder engagement

Stakeholders were engaged in T2.3 by creating a web survey to enable them to comment the short list of technology. The stakeholders in the first phase were the project PEB members, but they were able to suggest more experts to answer the survey. The experts may also be relevant in later work packages of the STTRIDE project.

3 REVIEW OF LITERATURE AND SECONDARY DATA

3.1 Methodology

Task 2.1 relates to identification of user needs, while task 2.2 relates to identification of technologies. Both tasks involved a review of literature and secondary data. A protocol was prepared to ensure a consistent approach to evidence reviews in both tasks, and the work of the tasks was co-ordinated. The protocol is at **Appendix 1**.

Protocol for reviews of literature and data in task 2.1 and task 2.2

This document identified issues of scope applicable to both task 2.1 and task 2.2. It then set out protocols for each task, covering:

- work allocation between partners
- issues of scope that were task-specific
- specific sources to consult. This is because the STTRIDE proposal highlighted specific references and the partners were aware of a number of other sources from their existing knowledge
- search vehicles / terms for identifying additional sources
- criteria for assessing whether sources were suitable for review (see below)
- research questions to be addressed when reviewing sources (see below)
- template for recording findings.

The criteria for assessing suitability of a source for review were:

- date of publication - normally should be 2006 or newer
- to what extent does it address our research questions for this task? (Defined subsequently.)
- are findings transferrable on a transnational and /or transmodal basis?
- to what extent is it evidence based, e.g. is it based on empirical research, best practice or informed opinion?
- if it is research based, is the sample size representative? Any notable points such as control group methods should be recorded
- has it been peer reviewed?
- are there any flaws or gaps in the findings? Are these acknowledged?
- apply an 'evidence hierarchy' that places peer reviewed journal articles at the top and industry publications and press reports, at the bottom.

The research questions to be addressed when reviewing sources were:

- How are changing traveller needs changing the technological focus in transportation?
- What technological trends are affecting transportation in general?
- Which kind of technical advancements are seen to make a paradigm shift?
- What technologies can be identified behind the trends?
- How mature are the identified technologies?
- Which technologies are competing with each other?

Within task 2.2, a total of 68 sources were identified and deemed suitable for review. Individual reviews were completed for each source, using the two templates incorporated in the protocol at **Appendix 1**. A list of the sources reviewed is at **Appendix 2**.

3.2 Findings

The key findings from the reviews are reported under each research question addressed.

3.2.1 How are changing traveller needs changing the technological focus in transportation?

This research question is answered more thoroughly in D2.1.

3.2.2 What technological trends are affecting transportation in general?

The technologies found in the literature review were mostly related to information and communication. Especially the communication between the IoT-nodes, vehicles and the travellers were studied in many of the references. It seems natural as ICT solutions are coming in to traffic in general and smarter infrastructure and vehicles are being designed. The upheaval of traffic with semi-autonomous or even autonomous vehicles is driving research in technology and business domains. Research papers are focusing on a small part of the problem field and thus technologies in the said area are scattered, overlapping and non-compatible with each other. This might change in upcoming years when standardisation happens after years of frantic research. Getting previously closed data available for all and concurrently installing lots of sensors and communication devices in to the infrastructure is the basis for new services for travellers. Visualisation of the data can be achieved through augmented reality in vehicle-HUDs or via mobile devices.

Infrastructure, vehicles and end-user handsets are becoming increasingly intelligent and instrumented with sensors and broadband connectivity. This in turn enables a wide range of smart mobility services, e.g. from usage-based vehicle insurance to multimodal trip planning and to seamless door-to-door mobility services.

More broadly, we are also witnessing an overall ICT fuelled evolution trend towards service-based business models, i.e. from owning products to buying services. This is also expected to shape the mobility sector with the emergence of concepts like Mobility-as-a-Service (MaaS) (Heikkilä, 2014), which envisions a seamless door-to-door mobility service for end-users combining several modes of transportation (e.g. local and long-distance buses, trams, taxis, demand-responsive public transportation and shared private vehicles) and offering it as an integrated simple package for the end-user

3.2.3 Which kind of technological advancements are seen to make a paradigm shift?

Paradigm shift can be predicted to happen with autonomous vehicles which might change the whole landscape of travelling and automation. This is strongly affecting the other themes in STTRIDE - safety, mobility as a service, information and journey efficiency. In abstract, the automation of vehicles is what the users see and use, but behind that there are lots of technologies that are making this paradigm shift possible. A recent paradigm shift, which arrived with smart phones and reliable, fast network connectivity, is still shaking up the environment. Information is becoming more available and with Internet of Things the data sources are becoming more plentiful. This makes room for new services for the travellers and, hopefully, makes travelling easier and cheaper.

Establishing a common European multimodal transport information, management and payment system has the potential to ensure that any kind of transport is carried out in the most efficient manner, while taking into account various mode-specific features and limitations (e. g. comfort, price, speed, flexibility, reliability, etc.). Such systems should allow users to optimise their choice of transport mode(s) depending on their different selection criteria (e. g. cost minimization, speed of delivery, emissions, time schedule, and ease of use).

Better modal choices will come from better integration of the entire network: airports, ports, railway, metro and bus stations should increasingly be linked and transformed into multimodal connection platforms for passengers. Online information and electronic booking and payment systems integrating all means of transport should facilitate multimodal travel.

3.2.4 What technologies can be identified behind the trends

66 technologies were identified behind the trends. Most were related to communication and information. V2I (vehicle-to-infrastructure), V2V (vehicle-to-vehicle) and as a broader term V2X (vehicle-to-everything) were important technologies to create more and smarter ways to communicate. Supporting technologies are, for example, Internet of Things -nodes and ITS stations along the road. Highly detailed road profiles provide material for vehicles and services to map the virtual information with the real world. Especially with autonomous vehicles, the information about the surrounding world and on-the-move vehicle sensor information needs to be both very detailed and matching each other. Traffic management systems are integrating into this same infrastructure to get more information about how the traffic should be managed and optimised. The central nature of traffic management systems are complemented by ad hoc communication networks in rural areas.

Making use of public transport easier for the user has several technologies behind it. First of all the ticketing systems are changing and becoming more transparent with the introduction of beacon-based ticketing and hop-in / hop-off style tracking and payment. Users do not need to actively validate their tickets when entering the vehicle, but the vehicle will recognise the passenger and will automatically check them in. Business models may change with this too when post-paid systems may offer the best deal for the passenger when calculating for the whole month which ticket type would be the cheapest. This reduces cognitive burden for the passengers as they can use public transport as they want by just entering the vehicles and still knowing that the best deal will be secured. Information for the traveller can be shown through techniques of virtual or augmented reality. Context information with rich visualisation can provide users needed information in an easily digestible way. In future there are lots of information, and filtering it and showing it in understandable (and even motivating) way is a foundation for communication with an environment which is getting smarter.

3.2.5 How mature are the identified technologies

Maturity of the technologies can be seen in the long list of technology and the templates used for the said technologies. Most of the technologies found were identified to be on middle of the TRL mapping, which means that they are under exploratory development. This is natural as in this phase the technologies are amenable to scientific publishing and still carry potential with them. The Technology Readiness Mapping can be seen in Figure 1. From the research point of view this puts our technology horizon somewhere in 5-10 year from now. Some of the technologies identified are abstract enough that even if first versions arrive in 5 years it might still take 20 years to make them main stream.

Technology Readiness Level (TRL)	Amount of technologies in long list
1	2
2	8
3	5

4	8
5	7
6	6
7	8
8	9
9	10

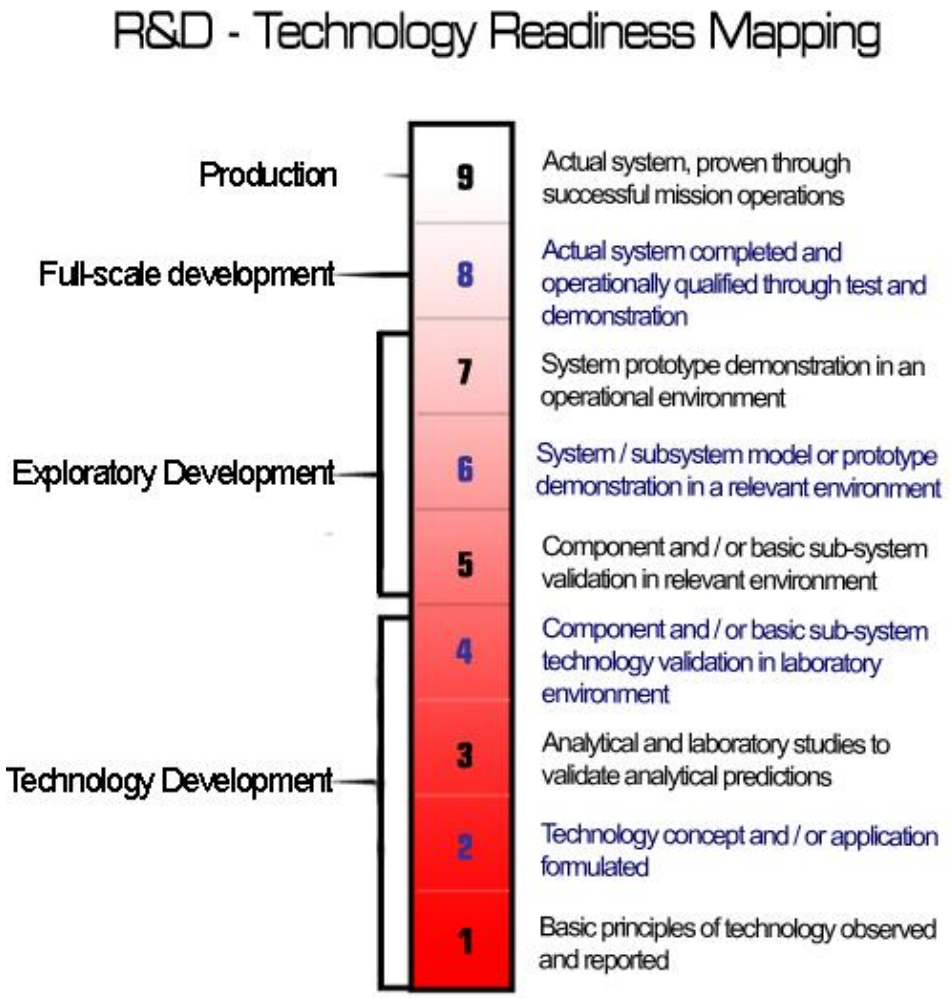

Figure 1. The Technology Readiness Mapping

3.2.6 If technologies are identified to compete with each other, what can we learn from it

We expect convergence of information technology systems in upcoming years to produce a more interoperable traffic environment. Lots of standardisation effort is needed and there might be geographical differences how it is going to play out. One of the main competitive fields is car manufacturers against information system providers. The core of the battle is who is going to "own" the customers and are the car manufacturers just providing the wheels and not more, with all information, entertainment and smartness coming from elsewhere? This will reflect the technologies available in short time horizon and how they will be adopted for use.

3.3 Long list of Technology

The long list of technology was created after the consortium had gone through the references found in the preliminary literature search. In the process of keyword search and researching the references a few other references were added due the relevance of their topics. Long list consists of using the technology template shown in Appendix 1. All identified technologies were put in templates and the long list is only a list of the found technology templates. No additional analysis was done in this part of the literature review.

The technology template had nine fields:

- Technology name
- Technology id (assigned in the process)
- Readiness level (1-9 level Technology readiness mapping)
- Technology layer (see Figure 2)
- Geography
- Time horizon of the adoption
- Domain (of the five themes)
- Source (references)
- Relation to modal change

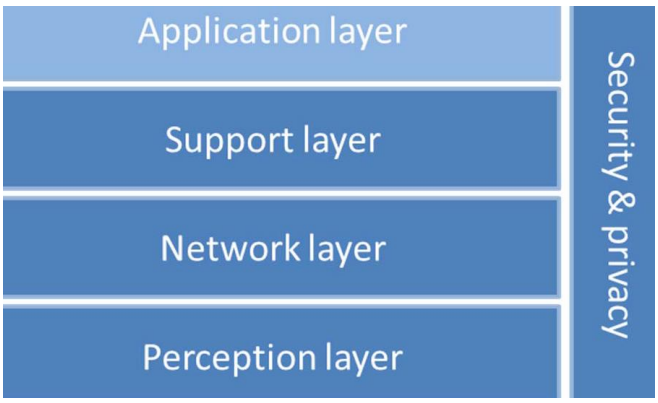

Figure 2. Architectural technology layers (derived from OSI model, used mainly in IoT)

By design, the technologies listed in the long list are technologies that are affecting transportation somehow regardless of how modal change is affected. Many identified technologies are important as their contribution to the future of traffic and transportation might be significant or even ground breaking. For example Blockchain is a technology which can be adopted in very different use cases and almost always it is hided from the actual user, but the use cases it makes possible may be a foundation for different communication and billing services created in upcoming years. Thus Blockchain was chosen to be on the long list of technology.

The long list of technology has a 66 identified technologies which are listed in the following table.

Wearable technology
Smart textiles
Human Machine Interaction
Voice recognition and voicebased human-machine interface

Multimodal interaction (Natural User Interface)
Information security
Blockchain
Mobility information system integration
Multimodal journey planning
Beacon-based ticketing
Advanced Fare Management
Micropayment technologies
Electric mobility support services
MaaS and associated information technologies
Car sharing information systems
Wireless charging
Electric cars
Battery technologies
High-speed cycle“superhighways” with Traffic surveillance and Traffic calming
I2V Local Broadcast
V2I Bidirectional Communications
V2V Local Broadcast
Vehicle-IoT
Vehicular ad hoc network
Cooperative adaptive cruise control
Cooperative Intelligent Driver Model (CIDM)
Autonomous Vehicles, FTP WEFET drive cycles
Vehicular accident detection and multimodal alert
ETSI ITS protocol stack
De-centralized communication algorithms
Vehicular sensor networks
Scheduling communications algorithms
Road database model
Optical Wireless Communication (OWC)
Big Data Processing on Hadoop platform
Open data
Advanced driver-assistance system (ADAS)
Fault tolerance technologies
Visible Light Communication
Cooperative Awareness Messages
Decentralized Environmental Notification Messages
Dedicated Short-Range Communications (DSRC)
Lost and found dataset and machine vision technologies
Energy harvesting
ITS Station
Location technologies
Traffic surveillance cameras - multistream analysis
Traffic light control - multiagent detection and analysis
Rerouting of vehicles - congestion prevention
Dynamic driver behaviour management
High-definition Maps
SRTI systems
Minimum universal traffic information service
Social traffic
Virtual reality
In-Vehicle Communications and Entertainment System
Multihop broadcast
Heads-up display

Connected telematics
Augmented reality
Display technologies
Memory technologies
Processor technology
Static Traffic Management System
Direct Sequence Spread Spectrum Code Division Multiple Access radar (DSCDMA)

Table 1: Long list of technology

After the long list had been created there was an extensive discussion within the project about which technologies should be included in the short list of about 10 technologies. Technologies were rated by several characteristics:

- System operator implemented
- Private company implemented
- Distributed / Peer-to-peer
- Promotes shift away from cars
- May favour public transport on roadways
- Increased vehicle sharing
- Direct relevance to national roads
- Indirect relevance to national roads
- System / component
- Decision enabling / optimising

Some of the technologies were not at the right abstraction level to be on a short list, but we were able to combine some of them into a broader technology concept, which we did for the short listing.

3.4 Shortlist of Technology

The first phase of STTRIDE has involved an evidence review to

a) identify traveller needs

b) generate a long list of emerging technologies which could impact on a road user's modal choice and

c) develop a proposed shortlist of technologies for further analysis. The purpose of this stakeholder engagement exercise was to seek expert views on the proposed shortlist.

Shortlist of technologies

The emerging technologies were shortlisted according to the following criteria: scale of potential impacts, including on modal choice, and the extent of existing research on the technologies. Impacts on modal choice range from: modal shift (from single occupancy car use) arising as a direct consequence of a new technology service, to indirect effects, such as more sophisticated traffic management that enables greater priority and capacity to be given to alternative modes. The final shortlist was:

Voice recognition

- Allows devices to understand spoken language and creates vocal interaction between humans and machines

- Rationale for selection: Voice-based user interfaces are developing fast, making it easier for people to interact with different devices. They may provide assistance in different languages (e.g. for tourists). Changing difficult to use touch-based interfaces to voice-based interfaces may help people to navigate through the transport service they want to use.
- Themes: Information / Journey efficiency

Augmented reality

- An array of technologies which create rich visualisation of surroundings through the screen of a mobile device / or 'heads up display' (HUD) to help people to understand what services are available.
- Rationale for selection: Lots of data and information may be provided to travellers, but understanding it and spatially connecting it to the real world may be difficult. Augmented reality technologies can provide help through visualisation.
- Themes: Information

Smart textiles and wearable technologies

- Wearable technologies enable travellers share information (i.e. sensor data) about themselves with the infrastructure and get access to infrastructure services
- Rationale for selection: Wearable technologies provide a potential opportunity for providing people with real-time data for smart travel and wider information about the city and its services. For example, a cyclist can use wearable technologies to access same traffic services that cars use and share information about the speed, trajectory and destination for all interested parties nearby. Smart textiles are more comfortable in different weather conditions and can provide instant protection in accidents, for example.
- Themes: Information / Journey efficiency / Safety

Open data and information system integration

- Different stakeholders may provide open data for 3rd party use to enable more informed decision making and more impactful transport services. Integration of information systems makes services more approachable and powerful to use
- Rationale for selection: Advancements in data processing and utilisation of big data enable novel transport services, which are made by and for passengers. Service development is faster and more dynamic when data and tools are available already.
- Themes: Information / Mobility as a service

Electric vehicles

- Vehicles such as cars and bicycles
- Rationale for selection: Electric vehicles are the foundation for fleets of automatic taxis. The latest e-vehicles are affecting how infrastructure is being built and how different mobility models are being developed. E-bicycles extend the range for light travelling infrastructure. Especially city-wide bicycle rental systems become more interesting for people to use as the cycling itself does not take as much muscle power and it is easier to maintain higher speed.

- Themes: Automation of Vehicles / Mobility as a Service

Powering smart infrastructure

- Consists of advancements in battery technologies and low-power modes of devices. In the longer term, energy harvesting may enable long lasting energy-independent devices.

- Rationale for selection: Smart infrastructure comprises nodes which need a power source to function properly. In particular, small devices, like sensors, currently need to have their batteries changed every 6 minutes to 2 years. This energy problem is slowing down the deployment of smart infrastructures.

- Themes: Information / Automation of Vehicles / Journey Efficiency

High-definition maps and road databases

- HD maps and road databases offer very detailed information about the real world. The resolution can be as refined as a few cm. For example, 3D lane geometry, curb height or road sign information can be provided.

- Rationale for selection: Novel and more accurate location-based services can take advantage of this detailed information. Up-to-date, rich context information is especially important for people who lack sensory abilities, helping them to navigate streets and cope with complicated crossings and transport interchanges. They could also support the implementation of new forms of infrastructure for pedestrians and cyclists, by providing localised information to road users on how to use it. In addition, this information can be used concurrently with on-board sensors to get a more reliable view of the surroundings.

- Themes: Information / Journey efficiency / Safety / Automation of Vehicles

Advanced fare management and beacon-based ticketing

- Fare management provides travellers with an easy way to make complex multimodal trips barrier-free even at international level. It is possible to calculate the cheapest payment option after the trip. Interoperable tickets and beacon-based non-interactive ticketing are included.

- Rationale for selection: Easing the cognitive burden of use of public transport enables more people to use it. “Hop On-Hop Off” travelling allows people to move through the transport network without thinking where they have bought tickets and how much it costs.

- Themes: Information / Journey efficiency / Mobility as a Service

Traffic management systems

- Centralised services to make traffic smoother. For example, easing congestion, traffic prioritisation, routing around accidents.

- Rationale for selection: Traffic management systems are able to prioritise public options instead of private use. Road capacity may be increased and traffic may become more predictable.

- Themes: Information / Journey efficiency / Safety

Vehicle-to-everything (V2X)

- Vehicles communicate with everything, including infrastructure and other vehicles. Technologies behind the communication and ad hoc networks share information between nodes.

- Rationale for selection: Communication is the foundation of smart traffic. Vehicles, people and infrastructure will know the surroundings, and are able to share that information to others. Vehicles can create communication and sensor networks in rural situations where there is no infrastructure to support them.

- Themes: Information / Journey efficiency / Automation of Vehicles / Safety

4 STAKEHOLDER ENGAGEMENT

4.1 Methodology

The purpose of this stakeholder engagement exercise was to seek expert views on the proposed shortlist. From the project's point of view, this engagement was undertaken in T2.3 which started when T2.1 and T2.2 were finishing.

Our approach to the stakeholder engagement was to do a survey for the PEB members which would enlighten us about the technologies on the short list an guide us to experts who know the technologies better.

In following Figure 3 is shortly described the process behind the stakeholder engagement.

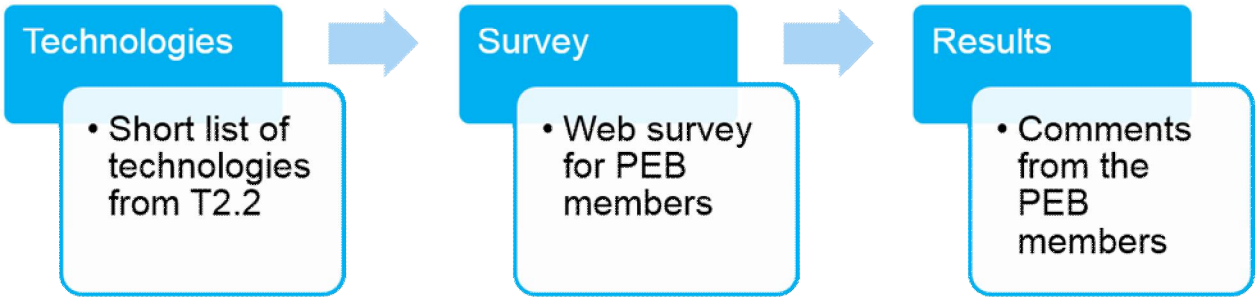

Figure 3. The process of stakeholder engagement

The first step was to acquire 10 short listed technologies from T2.2 and describe them in a more thorough way to help the stakeholders to understand what the project saw in the technologies and why they were chosen.

A web survey with 7 questions was sent to the identified stakeholders. Below are the survey questions. In addition they were provided background material for the shortlisted technologies and goals of the STTRIDE project.

1. **Please comment on the suitability of the shortlist of emerging technologies. Are there any key technologies that have been omitted?**
2. **Please comment on any links between the shortlisted technologies: are they sufficiently distinct from each other to be considered separately? to what extent are these technologies dependent upon each other, e.g. are there any categories that can be considered to be enablers of others?**
3. **What major drivers are there for development / deployment of the shortlisted technologies?**
4. **What major barriers are there to development / deployment of the shortlisted technologies? Are there any competing technologies that could affect their deployment?**
5. **What uptake have the shortlisted technologies had so far?**
6. **How have the shortlisted technologies impacted on modal shift so far? What are the potential future impacts?**
7. **Would you be willing, in principle, to participate in a future stakeholder workshop organised by STTRIDE? We will conduct further analysis of the shortlisted technologies once finalised. The workshop will allow further stakeholder input to this process.**

Two stakeholder groups answered to the survey, which was a less than expected. Stakeholders were reminded to answer the survey and were given an extra week after the initial deadline. To ensure the integrity and schedule of the project no more time could be given and project needed to proceed forward.

The answers to the questions

Q1. Please comment on the suitability of the shortlist of emerging technologies. Are there any key technologies that have been omitted?

- In principle yes, the list is suitable.
- Internet of things (IoT)
- Electric vehicles is on the list, but hydrogen and gas vehicles has been omitted
- Powering smart infrastructure is important and there is much technical improvement expected
- Automation (vehicles etc), even though it may be included to the shortlist
- Artificial intelligence, deep learning
- MyData

Q2. Please comment on any links between the shortlisted technologies: are they sufficiently distinct from each other to be considered separately? to what extent are these technologies dependent upon each other, e.g. are there any categories that can be considered to be enablers of others?

- Each technology is linked to each other, mostly difficult to separate from each other
- For instance traffic management is considering to each technology. Linked to for example to electric vehicles
- Shortlist is including technologies which are different in hierarchy, and that's why it is difficult to compare to each other.
- The dependencies are sometimes not crystal clear, e.g open data [...] and HD maps [...] and V2X communication make road traffic safer, smoother and more environmental friendly, also traffic management can be upgraded or made more efficient.

Q3. What major drivers are there for development / deployment of the shortlisted technologies?

- Climate change: also tendency to find solution via technology
- The societal changes, globalization, urbanisation, over-population
- Sharing economy, is there a will to be involved
- Things which are considering to the business of the car manufacturers
- Overall about the emerging technologies: what is the driver for the new technologies; individual needs or is it more technology-driven
- Tendencity to productivity, effectiviness: competition, cost-effecitiviness
- Supply side: technology progress, economies of sclae, learning effects, affordability of tech stuff
demand side: political agenda, environmental consciousness [...]

Q4. What major barriers are there to development / deployment of the shortlisted technologies? Are there any competing technologies that could affect their deployment?

- Data protection can be considered as barrier (for example MyData); who and how to control the existing information
- Cybersecurity?
- If there can be found a business, people are willing to purchase. In and other case the public sector is included. The organizational barriers, different mode of operation, costs and different intresses may be seen as a barrier. More interest to cooperate at the existing networks without new investments. Traditionally traffic management has been mainly in charge of the authorities.
- Partly ongoing development, incomplete standardisation, unclear business models for system goods

Q5. What uptake have the shortlisted technologies had so far?

- The technology is improving all the time

Q5. What uptake have the shortlisted technologies had so far?

- Electric vehicles: the battery technology is improving all the time which is lowering the price
- The pace of the technology development is varying between different countries
- Limited so far

Q6. How have the shortlisted technologies impacted on modal shift so far? What are the potential future impacts?

- Use of the open data to various means, for example to the journey planners (it can be argue that it may have an effect to the popularity of public transport). Modern traffic management: supporting public transport
- Later to be evaluated: electric bikes etc
- New technologies: better cars, digital maps and maps of light traffic
- Supporting systems which benefits the car manufacturers
- Beacon: the public transport more attractive and other types of benefits
- V2X: Needs evaluation, how will affect to the modal choice.
- Part of the technology is manufacturer-driven, part public sector-driven
- Limited so far, more substantial influence possible

5 CONCLUSIONS AND NEXT STEPS

WP2 in task T2.2 found 66 technologies, which could affect multimodality in future. The technologies were found through a literature review where peer-reviewed articles as well as market studies were used to map what the future might look like. The technology horizon is not so far as there are several technologies making or promising to make a paradigm shift in the near future and predicting what happens after that is largely speculation. In the end, it is people's choice of how they see and use the new upcoming technologies. The technologies themselves were at different abstraction levels, which made them hard to evaluate and select for the short list. After deliberation, 10 technologies were chosen and then stakeholders were asked how they see the technology. This was done via a web survey platform.

WP2 has been completed and the results were given to WP3 for more thorough research about the short listed technologies.

APPENDIX 1 - PROTOCOL FOR REVIEWS OF LITERATURE AND DATA IN TASK 2.1 AND TASK 2.2

The purpose of this protocol is to ensure that the literature reviews in tasks 2.1 and 2.2 are co-ordinated and their methodologies are compatible. **All four STTRIDE partners are involved in these tasks, so should all follow this protocol.**

The document starts with issues of scope that apply to both task 2.1 and 2.2. It then sets out protocols for each task, including issues of scope that are task-specific. For each task, search vehicles are identified as well as specific references to consult. This is because the STTRIDE proposal highlights specific references, the partners are aware of a number of other references from existing knowledge and PEB members are expected to suggest some references.

N.B. this protocol does not cover interviews with experts on user needs, to be conducted within task 2.1. Interview questions will be informed by findings from the task 2.1/2.2 literature reviews. This protocol and the results from the task 2.1/2.2 literature reviews will be shared with the ISAAC project (Stimulating Safe Walking and Cycling Within a Multimodal Transport Environment).

A. SCOPE – APPLICABLE TO BOTH TASKS

Broad geographical scope: Focus on Europe, but can extend beyond in relation to any evidence that is particularly relevant / interesting, as long as findings are applicable to the European context.

Age of references: As we are investigating new technologies, only recent references should be considered, normally not more than six years old for technology, but 10 years for user needs and travel behaviour research is likely to have greater longevity.

Impacts: Our focus is on technology measures that influence modal choice. These measures may have other impacts, which we will report on where evidence is available, and which may add to the business case for implementing them, but modal shift remains the priority.

Applicability / target audience: CEDR represents national road authorities, so the primary focus is on measures that are applicable on the national (trunk) road network, accepting that many will have broader applicability, for example to local transport authorities.

B. TASK 2.1 IDENTIFICATION OF USER NEEDS

1. WORK ALLOCATION BETWEEN PARTNERS

- Task Leader - TRL
- Protocol development - TRL / VTT
- Protocol technical review - TRL
- Literature review - TRL (lead) / VTT / SP
  - TRL, as task leader will allocate already identified references across partners, to assess whether they are suitable for review
  - Partners should then report back to TRL on this, summarising the research questions covered by the references
  - TRL will then ask partners to review suitable references, search for others on specific topics if necessary and review further suitable references identified
  - Partners should report back to TRL on the outcome of any searches, so it can monitor whether sufficient evidence is being gathered
  - Partners will be expected to record findings from each reference reviewed
  - **At all stages of the literature review, partners should use the protocol set out below**
- Synthesis of findings in summary of user needs (D2.1) - TRL
- D2.1 technical review - TRL.

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2. SCOPE

The following factors are in addition to those identified in **section A**.

Users should be categorised as follows:

- people with mobility problems, including disabled and older people
- people with other mobility challenges, including travelling with luggage or accompanied by children
- people travelling in groups
- by gender
- young people
- urban dwellers
- rural dwellers
- people on low incomes
- users of different modes:
  - car users (potentially differentiating between drivers and passengers?)
  - buses
  - rail
  - cyclists (differentiating between bicycles and e-bikes)
  - pedestrians
  - powered two wheelers?
  - taxi users (differentiating between conventional taxi services and new models like Uber)
  - car sharing schemes, e.g. pool cars, hire cars.

NB the focus for car users differs from the others, in that in understanding car users' needs we seek to identify the factors that would help them to change to a different mode; while for the others we are interested in what factors could make it easier / more attractive to use that mode.

Drivers of modal choice In considering user needs we will have to focus on those that could (in principle) be influenced by technology. At the top level we would expect the main drivers of modal choice to be:

- cost
- availability
- journey time
- journey time reliability
- safety, real and perceived (both in terms of accidents and personal security e.g. fear of crime)
- comfort
- Information.

So for each of these we need to identify how a technology based service could have an impact encouraging modal change. However, we need to avoid getting stuck in a purely 'rational choice' model of travel behaviour, as this does not take account of important attitudinal factors like awareness, social acceptance, habitual behaviour. So we should also consider what can be learned from behaviour change research, including outside the transport world where applicable.

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3. SPECIFIC REFERENCES TO CONSIDER

We will begin by considering specific references/projects identified in the STTRIDE proposal and suggested by partners/PEB members. N.B. regarding projects, there will be a need to search project outputs and identify appropriate references to review. **All these references should be assessed against the checklist in section B.5 and any that do not meet the criteria should be discounted.**

From the proposal

- Transport Systems Catapult Traveller Needs and UK Capability Study (2015)
- Rail Safety and Standards Board Topic Note on Travel Behaviour and Behavioural Change (2014)
- numerous EC DG MOVE studies in support of ITS Directive Priority Actions A and B
- the issues raised and results of the EC Strategic Transport Research & Innovation Agenda (STRIA)
- transnational and national projects - 'All Ways Travelling', AUNT-SUE and INFOPOLIS, MOTOS, SaMERU and SMILE.

Suggested by partners / PEB members

See files uploaded in the STTRIDE online shared file space at the following location: *STTRIDE / WP2 Gathering Evidence / Task 2.1 Identification of user needs / Suggested references to review*.

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4. SEARCH VEHICLES / TERMS

Should the above references not generate sufficient evidence, one or more of the following search vehicles should be used. These are split into two categories – search vehicles which have open and free access, and search vehicles which require subscription and log in details. In the latter category we have only listed vehicles which specific STTRIDE partners subscribe to.

Open and free access

- Google Scholar http://scholar.google.co.uk/
- Directory of Open Access Journals https://doaj.org/ - access to full text of peer reviewed journals
- Directory of Open Access Books http://www.doabooks.org/ - access to full text of peer-reviewed books
- Digital Commons Network http://network.bepress.com/ access to peer-reviewed journal articles, book chapters, dissertations, working papers, conference proceedings, and other original scholarly work
- European Local Transport Information Service (ELTIS) www.eltis.org/ - see the discover and resources sections.
- Transport Research & Innovation Portal (TRIP) www.transport-research.info/web/.

Subscription / log in details required

- Science Direct www.sciencedirect.com/ - TRL subscribes
- Transport Research International Documentation (TRID) http://trid.trb.org/ - TRL subscribes.

Search terms are as follows. N.B. within each term, we have identified there are often multiple combinations that need to be searched separately, e.g. for each separate mode and user group.

- Future / changing / drivers of / predictors of transport / travel demand
- Factors affecting / influencing / emerging trends in transport / travel demand
- Factors determining / influencing mode / modal choice
- Factors determining / driving / predicting use of/demand for public transport / rail / bus / cycling / walking / car share/ E-bikes multi modal use / interchanges [i.e. search separately for each mode]
- Transport user / traveller / passenger needs/ travel behaviour & older people / disabilities / impaired mobility / mobility problems / gender / urban areas / rural areas / low income / accessibility
- Interventions / initiatives / schemes & causing / delivering / encouraging modal shift
- Interventions / initiatives / schemes & increasing public transport / bus / rail / cycle / car share / walking / multi modal use / interchanges
- Behaviour / behavioural change model & transport / travel / mode / modal choice.

5. SELECTION CRITERIA FOR REFERENCES

The following checklist should be used to select which references to review.

✓ Date of publication - normally should be 2006 or newer

- ✓ To what extent does it address our research questions for this task? (Defined subsequently.)
- ✓ Are findings transferrable on a transnational and /or transmodal basis?
- ✓ To what extent is it evidence based, e.g. is it based on empirical research, best practice or informed opinion?
- ✓ If it is research based, is sample size representative? Any notable points such as control group methods should be recorded
- ✓ Has it been reviewed?
- ✓ Are there any flaws or gaps in the findings? Are these acknowledged?
- ✓ Apply an 'evidence hierarchy' that places peer reviewed journal articles at the top and industry publications, press reports, at the bottom.

6. RESEARCH QUESTIONS

The research questions to be addressed when reviewing the literature are:

- What factors influence travel demand?
- What factors influence users' choice of mode?
- What categories or hierarchies have been developed for these factors? (e.g. the user needs hierarchy described in the proposal)
- How do these factors vary between different users and modes?
- What kinds of intervention have been used to influence travel behaviour by targeting these factors?
- Which types of intervention / have been found to be most effective at encouraging modal shift? For which modes and users?
- Which of these interventions can be categorised under the 5 technology themes identified for the study?
- What behavioural change models have been developed to describe how people can be influenced to change mode or use sustainable modes more often?

7. RECORDING FINDINGS

Findings should be recorded using the template at **Annex 1**. This is based on the selection criteria for references and the research questions for task 2.1.

C. TASK 2.2 IDENTIFICATION OF TECHNOLOGIES

1. WORK ALLOCATION BETWEEN PARTNERS

- Task Leader - VTT
- Protocol development - VTT / TRL
- Protocol technical review - TRL
- Literature review - VTT (lead) / SP / TRL
  - VTT, as task leader, will allocate already identified references across partners, to assess whether they are suitable for review
  - Partners should then report back to VTT on this, summarising the research questions covered by the references
  - VTT will then ask partners to review suitable references, search for others on specific topics if necessary and review further suitable references identified
  - Partners should report back to VTT on the outcome of any searches, so it can monitor whether sufficient evidence is being gathered
  - Partners will be expected to record findings from each reference reviewed
  - **At all stages of the literature review, partners should use the protocol set out below**
  - Synthesis of findings in outline of emerging technologies. NB WP2 should aim for a shortlist of around 15 technologies. (D2.2) – VTT
- D2.2 technical review - TRL.

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2. SCOPE

The following factors are in addition to those identified in **Section A**.

Geographic scope We should work at urban as well as wider geographical levels.

Technological scope

- **Automation of vehicles:** the principal driver of automation is likely to be safety and it could also provide benefits of passenger transport in private vehicles. Could also be an enabler of vehicle sharing and demand-responsive services to provide access to public transport.
- **Information:** real time multi modal information provision
- **Journey efficiency:** giving greater priority to public transport vehicles and also helping public transport operators to make better use of capacity
- **Mobility as a Service (MaaS):** new mobility services, such as bike hire or car sharing, with sophisticated information and payment systems.
- **Safety:** technological improvements to individual modes or the wider environment impacting on perception of safety and willingness to use alternative modes.

Level at which technologies operate

- Hardware
- Application
- Service provided to users.

We expect that it is the service provided to users that is the level at which users will be most affected.

Foresight period This runs to 2035. However, IT changes a lot over the longer term, so for certain technologies, it would be wise to define short and medium term periods. The actual definitions will depend on the results of literature review.

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3. SPECIFIC REFERENCES TO CONSIDER

We will begin by considering specific references suggested by partners/PEB members. (None were identified in the STTRIDE proposal.) **All these references should be assessed against the checklist in section B.5 and any that do not meet the criteria should be discounted.**

Suggested by partners / PEB members

See files uploaded in the STTRIDE online shared file space at the following location: *STTRIDE / WP2 Gathering Evidence / Task 2.2 Identification of technologies / Suggested references to review*.

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4. SEARCH TERMS AND VEHICLES

Open and free access

- Google Scholar http://scholar.google.co.uk/
- Directory of Open Access Journals https://doaj.org/ - access to full text of peer reviewed journals
- Directory of Open Access Books http://www.doabooks.org/ - access to full text of peer-reviewed books
- Digital Commons Network http://network.bepress.com/ access to peer-reviewed journal articles, book chapters, dissertations, working papers, conference proceedings, and other original scholarly work
- European Local Transport Information Service (ELTIS) www.eltis.org/ - see the discover and resources sections.
- Transport Research & Innovation Portal (TRIP) www.transport-research.info/web/.

Subscription / log in details required

- Science Direct www.sciencedirect.com/ - TRL / VTT subscribes
- Frost & Sullivan http://ww2.frost.com/ - market foresight and research - VTT subscribes
- BCC Research - market foresight and research - VTT subscribes
- eKnowledge search - aggregated search for articles, books, journals, etc.; almost 100 databases- VTT subscribes
- Gartner technology research http://www.gartner.com/technology/home.jsp - VTT subscribes

Search terms:

- Emerging technologies transportation / road infrastructure
- Technology foresight
- Intelligent / smart transportation systems
- Intelligent mobility technology
- Traffic management technology
- Mobility service / MaaS
- Self-driving / autonomous vehicles
- Automation vehicles
- V2X communication technologies
- Road / passenger safety technologies
- Technologies commuting / travelling / modal shift
- Multimodality / multimodal in travelling technology.

5. SELECTION CRITERIA FOR REFERENCES

- ✓ Date of publication – should be 2010 or newer
- ✓ To what extent does it address our research questions for this task? (Defined subsequently.)
- ✓ Are findings transferrable on a transnational and /or transmodal basis?
- ✓ To what extent is it evidence based, e.g. is it based on empirical research, best practice or informed opinion?
- ✓ If it is research based, is sample size representative? Any notable points such as control group methods should be recorded
- ✓ Has it been reviewed?
- ✓ Are there any flaws or gaps in the findings? Are these acknowledged?
- ✓ Apply an 'evidence hierarchy' that places peer reviewed journal articles at the top and industry publications, press reports, at the bottom.

6. RESEARCH QUESTIONS

The research questions to be addressed when reviewing the literature are:

- How are changing traveller needs changing the technological focus in transportation?
- What technological trends are affecting transportation in general?
- Which kind of technical advancements are seen to make a paradigm shift?
- What technologies can be identified behind the trends?
- How mature are the identified technologies?
- Which technologies are competing with each other?

7. RECORDING FINDINGS

Findings should be recorded using the templates at **Annex 2** and **Annex 3**. These is based on the selection criteria for references and the research questions for task 2.2.

ANNEX 1

TEMPLATE FOR RECORDING FINDINGS FROM LITERATURE REVIEWS FOR TASK 2.1, IDENTIFICATION OF USER NEEDS

BASIC INFORMATION	
Reference: please use Harvard system	
Type of publication: e.g. journal article, other article, book, book chapter, working paper, project report, conference paper	
Client (if relevant): e.g. government dept, EC, industry	
Type of study: e.g. literature review, primary research, meta analysis; quantitative or qualitative	
Geographic scale: • **is the scale transnational / country / regional / local?** • **which transnational area / country / region / locality is covered?**	
QUALITY	
Level on 'evidence hierarchy':	
Are findings transferrable on a transnational basis?	
To what extent is the document evidence based? e.g. is it based on empirical research, best practice or informed opinion	
If research based – • **what is the sample size & is it representative?** • **what are the key elements of the methodology?** e.g. randomised control / before & after surveys / after survey only / focus groups / interviews • **which year were data collected?**	
Has the document been reviewed? **If so, please specify method of review:**	
Are there any flaws or gaps in the findings? • **specify flaws/ gaps** • **are these acknowledged?**	

FINDINGS
What factors influence travel demand?
What factors influence users' choice of mode?
What categories or hierarchies have been developed for these factors? (e.g. the user needs hierarchy described in the proposal)
How do these factors vary between different users and modes?
What kinds of intervention have been used to influence travel behaviour by targeting these factors?
Which types of intervention / have been found to be most effective at encouraging modal shift? For which modes and users?
Which of these interventions can be categorised under the 5 technology themes identified for the study?
What behavioural change models have been developed to describe how people can be influenced to change mode or use sustainable modes more often?

ANNEX 2

TEMPLATE FOR RECORDING FINDINGS FROM LITERATURE REVIEWS FOR TASK 2.2, IDENTIFICATION OF TECHNOLOGIES

BASIC INFORMATION	
Reference: please use Harvard system	
Type of publication: e.g. journal article, other article, book, book chapter, working paper, project report, conference paper	
Client (if relevant): e.g. government dept, EC, industry	
Type of study: e.g. literature review, primary research, meta analysis, quantitative or qualitative	
Geographic scale: • **is the scale transnational / country / regional / local?** • **which transnational area / country / region / locality is covered?**	
QUALITY	
Level on 'evidence hierarchy':	
Are findings transferrable on a transnational basis?	
To what extent is the document evidence based? e.g. is it based on empirical research, best practice or informed opinion	
If research based – • **what is the sample size & is it representative?** • **what are the key elements of the methodology?** e.g. randomised control / before & after surveys / after survey only / focus groups / interviews • **which year were data collected?**	
Has the document been reviewed? **If so, please specify method of review.**	
Are there any flaws or gaps in the findings? • **specify flaws/ gaps** • **are these acknowledged?**	

FINDINGS
How are changing traveller needs changing the technological focus in transportation?
What technological trends are affecting transportation in general?
Which kind of technical advancements are seen to make a paradigm shift?
What technologies can be identified behind the trends?
Which technologies are competing with each other?
How mature are the identified technologies?

ANNEX 3

TEMPLATE FOR TECHNOLOGIES FOUND IN LITERATURE REVIEW IN TASK 2.2

Technology:		**ID:**	
Technology readiness level:		**Time horizon:** in years	
Operational level:		**Domain:** STTRIDE thematic area	
Geography: where the technology will be used		**Source:**	
Relation to modal change:			

APPENDIX 2 - LIST OF SOURCES REVIEWED IN TASK 2.2

Alam, M., Ferreira, J., Fonseca, J., & SpringerLink (Online service). (2016). Intelligent transportation systems: Dependable vehicular communications for improved road safety (1st 2016.;1st 2016; ed.). Cham: Springer International Publishing. doi:10.1007/978-3-319-28183-4

Algoé and Rapp Trans, (2011). Study "Towards a European Multi-Modal Journey Planner - Stakeholder Views". ITS ACTION PLAN. Lyon: EUROPEAN COMMISSION - Directorate-General Mobility and Transport.

Algoé and Rapp Trans, (2011). Study "Towards a European Multi-Modal Journey Planner - Final Report". ITS ACTION PLAN. Lyon: EUROPEAN COMMISSION - Directorate-General Mobility and Transport.

Algoé and Rapp Trans, (2013). Study "Free Road Safety Traffic Information". ITS ACTION PLAN. Lyon: EUROPEAN COMMISSION - Directorate-General Mobility and Transport.

Algoé and Rapp Trans, (2010). Study Regarding Guaranteed Access to Traffic and Travel Data and Free Provision of Universal Traffic Information. ITS ACTION PLAN. Lyon: EUROPEAN COMMISSION - Directorate-General Mobility and Transport.

Algoé and Rapp Trans, (2010). D5 - Final Report. Action B. EU-wide real-time traffic information services. ITS ACTION PLAN. Brussels: EUROPEAN COMMISSION - Directorate-General Mobility and Transport

All the way Travelling (2014). To develop and validate a European passenger transport information and booking system across transport modes. - Final report. Contract MOVE/C2/SER/2012 489/SI2.646722

Bonnefon, J., Shariff, A., & Rahwan, I. (2016;2015;). The social dilemma of autonomous vehicles. Science, 352(6293), 1573-1576. doi:10.1126/science.aaf2654

Böhm, M.; Fletchl, B.; Frötscher, A. (2013) ICT concepts for optimization of mobility in smart cities. European Commission, Directorate-General for Communications Networks, Content and Technology

Cao, Z., Jiang, S., Zhang, J., & Guo, H. (2016). A Unified Framework for Vehicle Rerouting and Traffic Light Control to Reduce Traffic Congestion. IEEE Transactions on Intelligent Transportation Systems.

Casey, T., & Valovirta, V. (2016). Towards an open ecosystem model for smart mobility services. the case of Finland VTT.

Catapult Transport Systems (2016) Mobility as a Service - Exploring the Opportunity for Mobility as a Service in the UK.

Civitas Insight (2016). Mobility-as-a-service: A new Transport model.

Civitas Insight (2015). Safer road infrastructure for cyclists and pedestrians.

Civitas Insight(2015). Car Sharing: new forms of vehicle use and ownership.

Civitas Insight(2016). Linking intermodal services better.

Civitas Policy Note (2016). Cities towards Mobility 2.0: connect, share and go!

Chen, Y., & Wang, Z. (2016). Research on Key Technologies of Urban Road Safety under the condition of Big Data. International Journal of Simulation--Systems, Science & Technology, 17(4).

Chen, T. D., Kockelman, K. M., & Hanna, J. P. (2016). Operations of a shared, autonomous, electric vehicle fleet: Implications of vehicle & charging infrastructure decisions. Transportation Research Part A: Policy and Practice, 94, 243-254.

Diana, M., & Mokhtarian, P. L. (2009). Desire to change one's multimodality and its relationship to the use of different transport means. Transportation Research Part F: Traffic Psychology and Behaviour, 12(2), 107-119.

Dunkel, J., Fernández, A., Ortiz, R., & Ossowski, S. (2011). Event-driven architecture for decision support in traffic management systems. Expert Systems with Applications, 38(6), 6530-6539.

Engel, J. I., Martín, J., & Barco, R. (2016). A Low-Complexity Vision-Based System for Real-Time Traffic Monitoring. IEEE Transactions on Intelligent Transportation Systems.

European Commission, DG MOVE, (2013). Enablers for multimodal travel planning and information services - Stakeholders' views. EC.

Fagnant, D. J., & Kockelman, K. (2015). Preparing a nation for autonomous vehicles: opportunities, barriers and policy recommendations. Transportation Research Part A: Policy and Practice, 77, 167-181.

Fazlollahtabar, H., & Saidi-Mehrabad, M. (2015). Autonomous guided vehicles. Springer.

Hengstler, M., Enkel, E., & Duelli, S. (2016). Applied artificial intelligence and trust—The case of autonomous vehicles and medical assistance devices. Technological Forecasting & Social Change, 105, 105-120. doi:10.1016/j.techfore.2015.12.014

Hipp, J. A., Adlakha, D., Chang, B., Eyler, A. A., & Pless, R. B. (2013). Emerging technologies: webcams and crowd-sourcing to identify active transportation.

Innamaa, S.; Aittoniemi, E.; Askola, H.; Kulmala, R. (2012) Roadmap for Innovative Operation of the Transport System. VTT Technology Research Highlight 8. 30 p.

Javed, M. A., & Hamida, E. B. (2016). On the Interrelation of Security, QoS, and Safety in Cooperative ITS. IEEE Transactions on Intelligent Transportation Systems

Fang, D. Y. (2013). Research of Intelligent Traffic Management System. In Applied Mechanics and Materials (Vol. 340, pp. 662-664). Trans Tech Publications.

Frost & Sullivan; Technical Insights Alerts: Nanotechnology Innovations in Smart Textiles - Nanotech TOE. 16 Sep 2016

Frost & Sullivan: Navigating Digital Transformation in Travel and Transportation. Industry Research Reports. 26 Sep 2016

Frost & Sullivan: Strategic Perspective on Trends in Road Constuction Technologies - High-tech Materials Alert. Industry Research Reports. 15 Apr 2016

Frost & Sullivan: Game Changers - Artificial Intelligence: What You Need to Know. Market Insights. 17 Nov 2015

Frost & Sullivan: Intelligent Mobility 3.0. Future of Mobility & New Mobility Business Models. Industry Research Reports. 18 Sep 2015

Frost & Sullivan: 5G and In-Car Wallets - Next Automotive Hype Generators are here

Frost & Sullivan: Intelligent Transportation Systems. Frost Perspectives. 11 Nov 2015

Frost & Sullivan: Global Connected Car Market Outlook 2016. Industry Research Reports. 2 Mar 2016

Frost & Sullivan: High Definition Maps for Automated Driving. Industry Research Reports. 8Jun 2016

Frost & Sullivan: Adoption of Smart City to Drive Intelligent Transport System (ITS) Innovaion. Market Insights. 4 Feb 2014

Frost & Sullivan: Vehicle to anything (V2X) - automotive and transportation TOE. Technical Insights Alerts. 7 Oct 2016

Frost & Sullivan: From Vehicle Automation to Autonomous Driving: The Big Leap. Frost Perspectives. 26 Nov 2014

Goertz, N., & Gonter, J. (2011). Limits on information transmission in vehicle-to-vehicle communication. Paper presented at the doi:10.1109/VETECS.2011.5956270

Kale, P., Salot, R., & Thakkar, R. M. (2015). Business Analytics in Traffic Management System. International Journal of Computer Applications, 126(12).

Kamargianni, M., Li, W., Matyas, M., & Schäfer, A. (2016). A critical review of new mobility services for urban transport. Paper presented at the , 14 3294-3303. doi:10.1016/j.trpro.2016.05.277

Karlsson, I. M., Sochor, J., & Strömberg, H. (2016). Developing the 'Service'in Mobility as a Service: Experiences from a Field Trial of an Innovative Travel Brokerage. Transportation Research Procedia, 14, 3265-3273.

Kressler, F. et al. (2014) TRANSFORuM Roadmap Multimodal Transport Information, Management and Payment Systems. Cologne / Köln: Rupprecht Consult.

Lanke, N., & Koul, S. (2013). Smart Traffic Management System. International Journal of Computer Applications, 75(7).

Lee, J. M. (2016). A design of road database for self-driving vehicles. Indian Journal of Science and Technology, 9(20).

Natarajan, P.T.; Nandakumar, A.; Intelligent Mobility: a Step Ahead of Automated Driving. Frost Perspectives. 30 Jun 2015

Nguyen, V. D., Van Nguyen, H., Tran, D. T., Lee, S. J., & Jeon, J. W. (2016). Learning Framework for Robust Obstacle Detection, Recognition, and Tracking. IEEE Transactions on Intelligent Transportation Systems.

Mersky, A. C., & Samaras, C. (2016). Fuel economy testing of autonomous vehicles. Transportation Research Part C: Emerging Technologies, 65, 31-48.

Milanes, V., Villagra, J., Godoy, J., Simo, J., Pérez, J., & Onieva, E. (2012). An intelligent V2I-based traffic management system. IEEE Transactions on Intelligent Transportation Systems, 13(1), 49-58.

Munshi, A., & Unnikrishnan, S. (2015). Vehicle to Vehicle Communication Using DS-CDMA Radar. Procedia Computer Science, 49, 235-243.

Picone, M., Busanelli, S., Amoretti, M., Zanichelli, F., Ferrari, G., & SpringerLink (Online service). (2015;2014;). Advanced technologies for intelligent transportation systems (2015th ed.). Cham: Springer International Publishing. doi:10.1007/978-3-319-10668-7

Phillips, J. D., & Kohm, K. E. (2011). Current and emerging transportation technology: Final nails in the coffin of the dying right of privacy. Rich. JL & Tech., 18, 1.

Rabieh, K., Mahmoud, M. M., & Younis, M. (2015, June). Privacy-preserving route reporting scheme for traffic management in VANETs. In Communications (ICC), 2015 IEEE International Conference on (pp. 7286-7291). IEEE.

Takai, I., Harada, T., Andoh, M., Yasutomi, K., Kagawa, K., & Kawahito, S. (2014). Optical vehicle-to-vehicle communication system using LED transmitter and camera receiver. IEEE Photonics Journal, 6(5), 1-14.

TRANSFORuM (2013). MIMM multimodal transport information management and payment systems roadmap.

TRL (2010). Door to Door Journeys- Parking Measuures and Policies Research Review.

Strasser, M., Weiner, N., & Albayrak, S. (2015). The potential of interconnected service marketplaces for future mobility. Computers & Electrical Engineering, 45, 169-181.

Uber Elevate (2016). Fast forwarding to a future of on-demand urban air transportation

VTT, (2016). Towards an open ecosystem model for smart mobility services - The case of Finland. VTT Technology 255

Yu, F. Q., & Guo, J. H. (2015). Design of Static Traffic Management System Based on GIS. In Applied Mechanics and Materials (Vol. 701, pp. 1112-1115). Trans Tech Publications.

Zhang, J., Wang, F. Y., Wang, K., Lin, W. H., Xu, X., & Chen, C. (2011). Data-driven intelligent transportation systems: A survey. IEEE Transactions on Intelligent Transportation Systems, 12(4), 1624-1639.

Zhou, M.; Qu, X.; Jin, S. (2016) On the impact of cooperative autonomous vehicles in improving freeway merging: A modified intelligent driver model-based approach. IEEE Transactions on Intelligent Transportation Systems