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FINAL REPORT

Road Authorities concerning Public Transport

Optimal role of road authorities in public transport

International research project

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Graduation Internship

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Preface

In front of you lies the final version of my research report, related to the Graduation Internship about National Road Authorities concerning public transport. This report gives an objective representation of findings and it provides a series of main conclusions and recommendations. Together with the presentation, it completes the research project.

The research project was carried out by a graduating student at the programme RO & Mobiliteit (Spatial development & Mobility) at the University of Applied Sciences Windesheim Flevoland, commissioned by the Conference of European Road Directors (CEDR) in Brussels. The project took place from February to May 2019.

Through this way I want to thank my supervisor Steve Phillips, who assisted me in CEDR during the research project. I would also like to thank my coach Sytze Rienstra for his coaching and coordinating help on behalf of Windesheim during the project, and the experts and stakeholders who have helped me to bring this research to an end.

Enjoy reading,

Pascal Boonstra

31 May 2019, Brussels

Summary

In collaboration with CEDR, European networking organization of national road authorities, a student from the Windesheim University of Applied Sciences in the Netherlands has carried out an inventory research on the role of road authorities in public transport infrastructure. During the start, CEDR and its members did not know how road authorities are involved in public transport and how role division in public transport infrastructure could be better organized.

This final report provides CEDR and its members insight in existing infrastructure projects, by giving an overview of road authority involvements in public transport infrastructure and an advice on better role division. The research has been carried out using a literature review on current public transport infrastructure projects in combination with a questionnaire among road authorities, interviews and an expert session with experts and stakeholders.

Not all road authorities are involved in public transport issues. The cutting edge of public transport and road authorities is mainly found in cities, where the pressure on public space is high. Local and regional road authorities are involved in public transport within five different themes; accessibility, energy & fuels, network planning, software & applications and transport modes. Role divisions are typically not similar in every project. In smaller projects on the local level, a collaboration between municipality and public transport operator is enough. For larger main projects on national level, national road and public transport authorities are also involved.

Based on the role divisions in public transport infrastructure themes, five different structures of national role division in public transport can be identified; separated authorities which are fully in charge of national infrastructure for specific modes, direct mode-related departments of transport ministries, ministries which are fully in charge of both infrastructure and public transport, business companies with the task to maintain roads, and transport infrastructure agencies that deal with all transport infrastructure including roads, railways and waterways.

Important reasons to consider authority structures for public transport infrastructure are duration time of projects, costs of projects, an easy to understand role division, the extent of matching EU regulations and the possibilities for innovation. Advantages on effectivity could be whether the goal is reached, if knowledge can be easily shared, the implementation time that changes in organization will take, the simplicity to find responsible contacts, and the extent of political sensitivity.

Different national authority structures for public transport infrastructure are causing difficulties for shared international projects. Not all authorities have the same tasks and influence, so the measurements cannot always be copied to other situations. It is important for road authorities to take this in consideration if they are about to implement projects in their own situations. Role division has no consequence for the multimodal European network, because the coordination of this network is done by member states instead of individual authorities. Important stakeholders are identified by member states of the European Union.

For many viewpoints in effectivity and efficiency, the most favourable way of role division is a transport infrastructure agency responsible for all transport infrastructure on regional and national level. However, organisation structures are closely related to national history, culture and identity as well as the transport network itself and therefore not applicable for every country. Roles and tasks should in every situation be adapted to the way it works the best for specific countries.

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1. Introduction

In this case, a Graduation Internship was carried out at the Conference of European Directors of Roads (CEDR) in Brussels. CEDR is a networking organization for National Road Authorities (NRAs) at the European level. It was founded in 2003 to improve the exchange of experience and knowledge between national authorities about specific traffic issues and solutions. This is achieved by three main activities; sharing knowledge and best practices, collaboration and sharing resources in joint projects, and professional networking with competence building (CEDR, 2017). In consultation with CEDR, an international oriented research about NRAs concerning public transport was set up. The focus of research was the role of road authorities.

The Graduation Internship of Windesheim Flevoland (University of Applied Sciences) describes that students of the programme 'RO & Mobiliteit' (Spatial Development & Mobility) must carry out an applied research project for a traffic-oriented organization. The research topic should meet a current demand for information of knowledge within the organization or their partners. This final Graduation Internship, which must be performed by students individually, is the latest part of the Graduation phase. After this internship, the study programme will be complete (Windesheim Flevoland, 2018).

This first chapter provides the basis of the research that was carried out. The first paragraph provides the motivation for research, while the second paragraph gives an exploration of known information during the start of project. The third paragraph gives the objective of research, followed by the research questions and research methodology in paragraphs 1.4 and 1.5. The final paragraph, 1.6, provides a reading guide for next chapters and paragraphs in this report.

1.1 Motivation

National Road Authorities (NRAs) in Europe are dealing with traffic congestion on roads. The CIVITAS initiative of the European Commission (EC) estimates that congestion costs nearly EUR 100 billion annually, and it expects costs will rise to EUR 200 billion annually if no changes in policies occur (CIVITAS, 2014). Because of the high costs, it is not remarkable that road authorities are searching for public transport optimisation. Road authorities are already realizing new developments on infrastructure concerning public transport. NRAs are interested in infrastructure developments concerning public transport in other countries, because some of these infrastructure projects may provide lessons for their own country too. The strategy of CEDR is to merge knowledge about public transport infrastructure projects and encourage road authorities to share best practices.

However, copying projects from other countries is difficult because roles and influence of authorities are not equal in every country. National governments have their own organizations managing roads, traffic and public transport (CEDR, 2019). Today the different organizations with different responsibilities are causing ambiguity about roles, tasks and influence in projects. Doing research about infrastructure projects for public transport and the role of involved authorities will make the views clearer for CEDR and National Road Authorities. In short- term, this creates a clear view for NRAs about roles and tasks of institutes in other countries' infrastructure projects related to public transport. In long-term, results could offer possibilities for new role divisions in public transport infrastructure projects.

1.2 Problem analysis

Worldwide, road authorities on all levels experience problems with capacity of infrastructure (Rodrigue, 2017). Intensities of traffic on existing roads are increasing, but the available space is insufficient to expand roads. In addition, expansion is often unwanted because it only means a displacement of intensity problems. Road authorities therefore experiment with new spatial projects that do not require more space. Think, for instance, of changing road layouts by transforming parking spaces to cycle paths. But also, different priority configurations of traffic lights and launching parking fees are used solutions. Another solution is to seduce travellers to use other modes than their car (Metz, 2013). Here, public transport is an interesting alternative because it can transport many people in a short period of time. Using public transport can (partially) answer the spatial challenge concerning increasing intensities.

In the image on the right you can see how this works. The first image shows how much space a full bus takes, the second image shows how much space the same number of users takes with bikes and the third image shows how much space the number of users will take in cars. It is clearly apparent that public transport is taking least space.

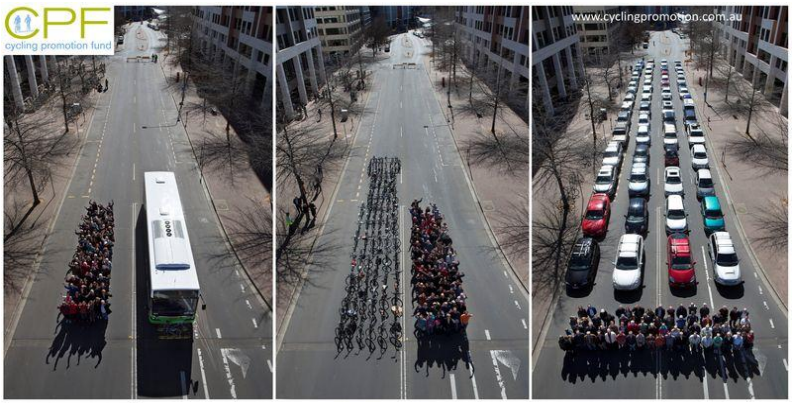


Figure 1.1; Space using of PT (Walker, 2012)

Public transport infrastructure

The spatial challenge is not limited to cars, trucks, bicycles and pedestrians. Public space is also used by public transport modes, so they are also hampered by increasing intensities. Because public transport can be a solution to spatial challenges, authorities see opportunities in this area. New physical and digital infrastructure projects are being set up to ensure traffic and thus public transport flows. Think of priority for buses at junctions with traffic lights, letting busses drive on emergency lanes at highways, adaptive routes in case of traffic jams or roadworks and more of these solutions. Because almost every authority must deal with these problems, it makes sense to seek cooperation with other authorities on this area (CIVITAS, 2018).

Cooperation and using abroad examples are difficult if (pilot) projects are unknown. Currently, road authorities are not informed sufficiently about infrastructure projects related to public transport in other countries. They need more information about the situation of abroad physical and digital infrastructure projects related to public transport before they can determine the right reference projects, because not all projects and cities are equal. For example, historic cities aimed at tourists have a different modal split than harbour cities aimed at transport (CEDR, 2016). Additionally, this information is also necessary to inherit best practices of projects. Which errors should be avoided by other road authorities, and more importantly; what lessons should they adopt?

More innovation with Horizon 2020

The new Horizon 2020 framework in the European Union provides opportunities for innovation and research that can have an effective impact on benefit of European citizens (European Commission, 2014). Mobility has an important role in the Horizon 2020 framework, because it allows for employment, economic growth, prosperity and world trading. This framework has already funded concrete Initiatives like the CIVITAS Initiative (City Vitality and Sustainability) , that has tested and implemented over 800 measures and urban transport solutions (CIVITAS, 2018). Parts of measures have to do with physical and digital public transport infrastructure. The city of Antwerp, for example, is providing P&R locations at the city border where commuters can switch from one transportation mode to a more sustainable mode to the port area. Another initiative funded under Horizon 2020 and a link to this research is Vital Nodes (Vital Nodes, 2018), which is more about hub locations. Urban regions are collaborating with NRA's to collect new hub-related insights there.

The role of road authorities

Besides, there is another problem. CEDR is bringing National Road Authorities (NRAs) together, but there are important differences between their tasks, roles and the influence of authorities in European countries. According to CEDR, this is causing levels in the definition 'road authorities'; is it just a Highway Road Authority or also a Rail Authority, Transport Authority or in some cases even a Communication Authority? Most NRAs are struggling to organize new infrastructure projects concerning public transport, because they would like to perform pilots with the acquired knowledge and experience of abroad partners while their roles are not the same as the role of abroad partners.

With increasing maintenance costs of roads and the launch of European infrastructure plans like TEN-T (European Commission, 2004), sharing experiences and working together becomes more and more important for National Road Authorities. TEN-T, which stands for Transnational European Network of Transport, distinguishes nine European corridors with underlying projects (connections). TEN-T aims to close gaps between transport networks in member states, remove bottlenecks that hamper the functioning of the internal market and overcome technical barriers in traffic modes.

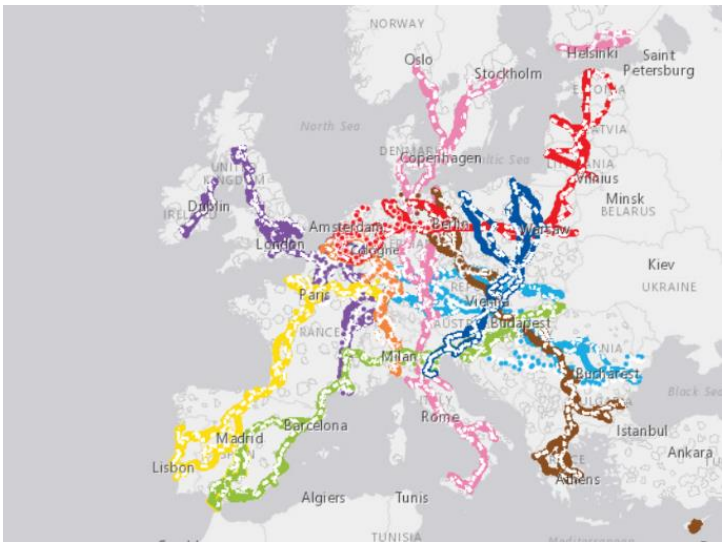


Image 1.1; TEN-T (European Commission, 2018)

Effects of roles on EU public transport

Next to problems of unknown projects concerning public transport and unclarity about role divisions of road authorities in other countries, there is another undiscovered part; the future of Road Authorities concerning public transport. It is unclear what impact taken roles will have on the development of the European multimodal network of transport, as described in the TEN-T development plans. Research about roles of road authorities and transport authorities in public transport in different countries gives the opportunity to assess the impacts of specific roles and tasks on working together on public transport infrastructure projects.

Finally, it is unknown what the right separation of roles and authorities could be. European countries have split roles and tasks between their different organizations in many ways. Projects will undoubtedly show examples of good or worse authority systems. Based on the projects that will be collected in this research and the results of the research, a new proposal can be made about the specific tasks that should belong to authorities in public transport infrastructure.

Problem definition:

Due to a lack of knowledge about projects in other European countries where road authorities are involved in public transport infrastructure projects and the difference between authorities' roles and tasks, National Road Authorities have insufficient insight in the role they should have. In addition, the possible impact of role divisions on the TEN-T transport system and the best way to organize the division of roles in European countries is unclear.

1.3 Objective

The main goal of this project is giving CEDR and its members more information about roles of road and transport authorities in public transport projects in different EU countries. It must be clear which organizations in EU countries are responsible for infrastructure related to public transport and what role division means for the European multimodal network TEN-T. Additionally, this research will give an advice about how separations of roles could be formed in the ideal situation.

Besides, CEDR and its members will get insight in existing public transport infrastructure projects and concerned parties. These insights can be used to examine these projects in relation to other countries and to research whether the best practices can be used in other countries too.

Image 1.2; Public transport infrastructure (Transdev, 2018)

1.4 Research questions

The research questions below were formulated to form and define the research project. This research consists of one main question and five underlying research questions, which have been prepared in consultation with the coach and supervisor at the internship location.

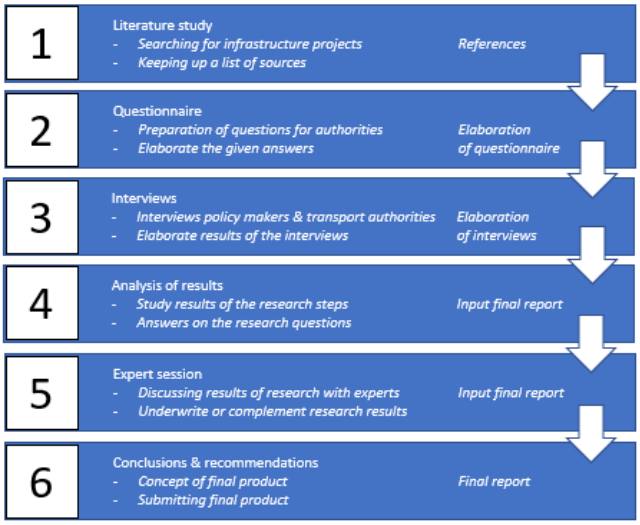
Main Question: What is the current division of roles between public transport and road authorities in current European projects, which advantages and disadvantages do these roles have and how should this be organised in future projects?

1. Which infrastructure issues of road authorities concerning public transport can be found in Europe?
2. Which types of road and transport authorities can be identified, based on the projects?
3. What is the role division between road authorities and public transport authorities in these projects?
4. What are the advantages and disadvantages of the taken roles of authorities?
5. How should the division of roles be organized, based on the results of this research?

1.5 Research design

The research project has been carried out applying different research methods, including a literature review, questionnaire, interviews and an expert session. The research design has been elaborated in a visual way, using a roadmap which consists of the six research steps. Below you will find this roadmap, which consists of the steps' number on the left side, followed by the name and main activities of the steps in the middle, and the delivered products on the right side. Some research steps have been performed simultaneously. For instance, the questionnaire was still running during the interviews.

Figure 1.2; Visual roadmap of research



Step 1 – Literature study

The first step consisted of literature review. This phase was aimed on compiling projects and cases where road authorities are involved in public transport. Data for this study were collected using mainly the CORDIS databank, which covers the project information and outcomes of all European subsidised research programmes. Because of the limited project time, the research has been carried out with solely information from this databank supplemented by the Dutch databank for university studies. By using search keywords including 'public transport', 'infrastructure', 'transport authority' and 'road authority', many EU framework projects were collected.

Thereafter, the found EU framework projects were checked on relevant topics as energy sources, network planning and new passenger transport modes. Sufficient information was not available for all projects. Therefore, eight specific projects were selected. Within these projects, all specific issues and road authority involvements have been aligned. More information was collected by asking road and transport related members in working groups of projects about their role in these projects. Ideally all members within the found projects should be contacted. Unfortunately, this was not possible, given the time of the project. An elaboration can be found in appendix 1.

Step 2 – Questionnaire

The second research step was formed by a questionnaire, which has been sent to 153 (local, regional and national) road authorities on the European continent. For every country, one national, regional and local authority was contacted. Respondents have been found in CEDR's network, but also road authorities involved in the literature review projects and in other countries to main cities, regions and ministries. From 153 sent questionnaires, 33 reactions were collected. This is a usual response rate for qualitative questionnaires. The results were covered from 22 different countries in different regions that confirmed each other, so outcomes can be seen as representative. The questions were focused on involvement in public transport projects, role divisions and responsibilities.

The intention of the questionnaire was to verify information from the literature review and to collect additional information for the literature review, especially of collaborations in public transport. It existed of start questions and main questions. The answers on start questions determined if the main questions were asked or if the questionnaire could be closed. This made it easier to collect only the useful answers and it saves time for other respondents. Although the best way to obtain qualifying information consists of personal interviews, this questionnaire was carried out using an online form because of the available time and possibilities. An elaboration can be found in appendix 2.

Step 3 – Interviews

The third step consisted of interviews. This step was about to discover what current role divisions mean and how role divisions can be better organized for new projects. Interviews have been held with road authority representatives at the national (CEDR), regional (AER) and local (POLIS) level and representatives for public transport (UITP). When interviewing these representatives, answers on the questionnaire were verified and assessed. Besides, interviews were held with members of the European Commission (DG MOVE) and the European Council (within the commission for Traffic & Transport) to collect more information of the European thoughts and concerning points.

During the interviews, questions have been asked about involvements in public transport, current problems around public transport, possibilities to organize public transport better and changes in public transport for upcoming years. Besides, questions have also been asked about current role divisions, thoughts about role divisions and new role divisions concerning road and public transport authorities. Especially the information about new public transport agencies, a new kind of authority structure, was an important part of interviews. An elaboration can be found in appendix 3.

Step 4 – Analysis

Step four was based on the analysis. During this phase, the results of former research steps (1, 2 and 3) have been studied. Some interviews and questionnaire answers delivered new topics that were not elaborated yet, so it was necessary to collect additional information. This was done by additional desk research, using specific keywords and abbreviations like BHLS, CFPT, PFPT and SMARTA, which were mentioned during the earlier research steps. Then, a multicriteria analysis was set up to determine the best role division for public transport infrastructure projects. The aspects considered in the analysis were based on the outcomes of literature review, questionnaire and interviews.

Besides additional desk research and the analysis, this step was also used to write the report itself. Chapter 2, 3 and 4 have been checked a second time and completed with additional information. Afterwards, the first answers were given on the research questions and a set of concept conclusions were written.

Step 5 – Expert session

After the analysis in step four the results were useful, but they could still be interpreted in different ways. In addition, it was not clear if the five authority structures were representative for public transport infrastructure projects and if the multicriteria analysis was sufficient. To supplement research results on the one hand and validate the multicriteria analysis at the other hand, an expert session was organized at step 5. The closest experts on public transport infrastructure were during the research in the working group on traffic management meeting in Cracow (Poland) at May 23.

The expert session was held with 12 experts from the working group members (Austria, Belgium (Flanders), Denmark, Germany, Greece, Hungary, Italy, Netherlands, Poland, Slovenia and Sweden). Of course, some other working groups are closer related to the research topic. However, because of the given time and the finishing phase of research, the working group on traffic management was for this research step the most interesting option.

During the expert session, the results of different research steps were briefly presented to the audience. Afterwards, experts were asked to vote live on different theorems. Theorems were related to specific research outcomes; the representativity of the five infrastructure themes, consideration of the five authority structures, the desire to change role divisions in their own countries, and the need for more collaboration. After voting, the experts were shortly asked to motivate their votes. Using such an online live-voting system had two advantages. It normally results in more attention from the audience, and it gives the opportunity to review the votes again after the meeting. An elaboration can be found in appendix 4.

Step 6 – Conclusions and recommendations

The expert session reinforced the research results and the analysis, but it gave also some interesting refutations and additions. This latest research step was introduced to adapt answers on research questions and concept conclusions. Adjustments to the conclusions were based on the outcomes of the expert session. Besides, the recommendations and discussion paragraphs were written, while some parts of the summary were changed. this phase has been used to check the whole report once again and to check it for possible adjustments.

Validity & reliability

Not all research steps were equally reliable and valid. Therefore, the research steps complement each other where necessary. Each research step had a verifying function for the preceding step.

The literature review is sufficient reliable. Information has been collected using sources of European institutions (EU websites, CORDIS) and the scientific databank of Dutch Universities. Given the time it was not possible to collect information from more sources, but the information from these sources can be seen as a sufficient large sample. The validity of the literature review is covered by other research steps verifying the information; the outcomes of the interviews and expert session covered that the information from the literature review was correct.

The questionnaire was reliable, because the respondents were selected in all countries in Europe. Unfortunately, there was no information collected from every country. However, the questionnaire is a good addition to the other research methods, because it has provided insight in projects and role division. The questionnaire was valid, because one single set of questions has been asked to all the respondents (by filling in an online form).

The information from interviews was reliable, because the outcomes are similar to the outcomes of literature research and questionnaire. The validity of interviews was also sufficient. Interviews took place at the workplace of the respondents, which probably led to answers influenced because of their environment. However, based on the responsibilities and expertise of the respondents on their work, it can be assumed that they were not influenced with this.

The expert session was rather reliable. One single group of experts with the same background was selected to have a look at research results and provide their thoughts. Although it might have been better to select experts with different backgrounds, this was the best option in the given time. The results of the expert session can be seen as valid, because the additional method (voting system) was the same for every expert.

1.6 Reader's guide

This final product is built up in three individual chapters and one concluding chapter.

Chapter 2 deals with physical and digital public transport infrastructure themes where road authorities could be involved. The current involvements of road authorities are demonstrated by various examples. The chapter concludes with an overview of responsible stakeholders in projects where road authorities are involved. Chapter 3 deals with European roles in public transport infrastructure. It starts with introducing European policy in general and giving the strategy for public transport in the European multimodal network. Afterwards, it describes European projects and the roles of EU institutes in public transport.

Chapter 4 deals with different types of authorities. It works out the different authorities and authority structures which can be found in chapter 2 and 3. Thereafter, it describes the different ways of collaboration within public transport infrastructure projects. Finally, the chapter concludes with a consideration of advantages, giving the most desirable authority structure. Chapter 5 provides the final conclusions for the report, followed by recommendations for CEDR and national road authorities. Besides, it consists of a discussion paragraph where used research methods are considered in detail.

2. Public transport infrastructure

This chapter covers various physical and digital infrastructure issues where national, regional and local road authorities could be involved in public transport. To find out where road authorities and public transport authorities meet each other, desk research has been carried out. The research was initially focused on eight public transport infrastructure projects in European frameworks, but additional information was collected by a questionnaire among road authorities. Detailed elaborations of desk research and questionnaires can be found in appendices 1 and 2.

These public transport infrastructure projects have been divided into five concerning themes, which have been checked on validity with interview respondents. Elaborations of these interviews can be found in appendix 3. Themes include accessibility, energy & fuels, network planning, software & applications and transport modes). Understanding collaboration areas makes it possible to identify existing authorities. By providing this information, the chapter sets out a basis for a European view on role division and public transport, which is elaborated upon chapter 3.

2.1 Accessibility

Accessibility is a broad concept in public transport. Of course, it is about (lack of) possibilities to enter stations or stops for public transport, but it has also to do with (lack of) possibilities to enter vehicles. Besides, the term ‘accessibility’ refers to digital accessibility; think of priority issues for traffic lights at crossings, which make public transport better accessible in the traffic flow. There are many ways of dealing with accessibility in European countries, mostly regarding public transport stops, public transport vehicles and other accessibility issues.

Designing public transport stops

In the most European countries, public transport stops or stations are part of ‘public road space’. This means they must be realized and maintained by road authorities. These road authorities are responsible for a reliable and safe location where public transport can stop. In some countries or cities, certain parts of public transport are referred as ‘private road space’. Then, the public transport operator or another business is the owner of space and therefore responsible to realize and maintain stops or stations. The latter is mainly seen in metro stations, for example in Hungary and Belgium, but it can vary between specific European countries (ERRAC, 2009).

In a small number of European countries, including the Netherlands (CROW, 2006), the design of bus and tram stops is regulated at national or regional level. By means of so-called ‘guidelines’ it is indicated how specific type of stations or stops should be designed, depending on characteristics like transport mode and location (city or rural). This listens very closely, up to a platform height and length in millimetres. Using these standards makes it easier for public transport operators to decide the correct heights and lengths of their vehicles, because they can easily adapt this to the guidelines. Guidelines are often used as requirements for tenders.

Take for example the new electric buses in the city of Eindhoven, which were set up during the Zero Emission Urban Bus System Project (ZEEUS, 2014). In this project, 43 new fully electric buses were attracted to provide transport on various lines in the urban and suburban region of Eindhoven. By considering common guidelines for bus stops in the Netherlands, it was possible for the operator (Hermes) to purchase new buses without discussing the right bus height and length to fit all the bus stop platforms with road authorities (CROW, 2006).

Apart from platform guidelines, many other issues of stops could also be determined by other guidelines or regulations. Think of, for example, the height regulations for viaducts, which are in Germany used for road overcutting bus/tram stops too. These overcutting bus stops, realized by the public transport operator of Berlin (BVG), are making it possible to cover boarding passengers if it rains (Signalarchiv, 2015). This is an innovation, because conventional bus stops are only covering (if there is a shelter) during the waiting time. It makes the waiting time, one of the most important journey parts (Brands, 2017), more attractive for potential public transport passengers.

In the city of Gothenburg, they went even further. Gothenburg, which claims that electric public transport can bring public transport closer to homes and working places, has been testing new bus stops while introducing a new electric bus line. Each stop was equipped with a single innovation, under among Wi-Fi, charging points via USB, new information screens and heated seats.

One on the stops, the one at Chalmers University of Technology, was placed inside a building. With two garage doors, a kind of greenhouse-like place was created with an opportunity to charge electric buses. Travellers were very satisfied with the new bus stop innovations, especially with the new inside bus stop at the Chalmers University in Gothenburg.

Image 2.1; Indoor bus stop (Toderian, 2018)

Designing public transport vehicles

For the design of vehicles, no specific rules are set, irrespective of European regulations on safety and about protection of passengers. This creates a situation where public transport operators can search for new opportunities to improve capacity, accessibility and modularity of public transport vehicles. Capacity is about the number of passengers that can be transported. In the ideal (most cost-efficient) situation, the capacity meets exactly the current travel need. Accessibility is in this case the way to let people board or leave the bus. Mostly this has to do with elderly people or people with disabilities, which must also be transported.

Modularity is a ‘new kid on the block’. During the second part of the project European Bus System of the Future (EBSF), a modular bus concept was tested in the city of Dresden (Germany). In order to have enough capacity during rush hours, operators in many German cities are driving whole days with articulated buses. Though, driving with articulated buses if there are only a few passengers is not cost-efficient. Therefore, the city of Dresden has been looking at solutions to adapt supplies better to the demands. One of these options was using a new bus, which consists of two articulated parts which can be coupled or uncoupled from the ‘main’ bus.

Image 2.2; Uncoupled bus (EBSF2, 2017)

Coupling and uncoupling of bus parts paves the way for a more cost-efficient product, but it demands also more from road authorities. Where common European roads are arranged for articulated buses (max 22 meters), these buses could be longer because of additional parts. Dresden shows that communication between road and transport authority are therefore necessary (ESBF2, 2018)

Designing vehicles is a task which often lies with the owner of transport vehicles, which is in most projects the transport operator. Operators determine which vehicles are purchased and sold, and she is responsible for maintaining the vehicles. Road authorities are less or not involved in the phases of purchasing and maintaining, so actually it is not their responsibility. However, with providing and maintaining infrastructure for public transport modes, they do have indirect influence on the design of vehicles. Think of physical infrastructure restrictions like maximum heights or lengths, and of digital examples like bus lanes or public transport priority options at crossings.

Because guidelines are often applied for roads and public transport infrastructure, public transport operators can assume that infrastructure is mainly build according to these guidelines. Derogations from guidelines should be properly discussed so transport operators are aware of the infrastructure. If guidelines do not exist or if they are not followed, operators of public transport automatically need to discuss the infrastructure with road authorities to prevent them from using vehicles that do not match the infrastructure. Guidelines make the process easier.

Other accessibility issues

Besides stops and vehicles, there are more public transport accessibility topics. These topics include additional services for passengers, (digital) interoperability with infrastructure and regulations instead of guidelines on accessibility issues. Of course, all topics are related to the public transport product, but it varies by topic which parties (road authority or transport authority) are involved. This also gives differences for how these parties are involved; organizing, contributing or supporting.

Sometimes, public transport operators need to organize additional services in order to provide their transport products. Depending on specific issues, road authorities must be involved or not within the issue. For example, take bus stops where no platform or bicycle parking opportunity is available. In these cases, road authorities need to contact transport authorities so they know the stop has no platform and it can therefore not be used by specific types of passengers. If there is no collaboration, passengers are faced with unforeseen circumstances.

Another accessibility issue is interoperability. Vehicles of public transport operators (particularly buses and trams) must be able to ‘connect’ with infrastructure. For example, take traffic lights giving priority to buses or trams at crossings or charging/fuelling points available for the public transport operators. In these cases, operators must install the right contact systems on vehicles to let them interact with traffic lights and charging/fuelling points. However, without any consultation with road authorities it would be impossible to adapt vehicles on the infrastructure.

The latest part, regulations on accessibility, is one of the most important. In several regions and countries, regulations on the accessibility of public transport and infrastructure are set up. By means of rules, specific additional requirements are worked out. Think of requirements of vehicles to make them available to wheelchair users, or requirements for platforms in city districts. These rules are related to both tasks of road authorities and public transport authorities. They could among other affect the design of public space and design of vehicles, which have been mentioned before. In many regions, for example in Flanders (Bertels, Van den Broucke, & Van Malderen, 2018), politics are trying to organize regulation for accessibility in public transport.

Accessibility in headlines

Mainly, three different forms concerning accessibility could be distinguished. The first form has to do with public transport stops. If stops are part of public roads and therefore property of the road authority, the road authority is directly involved in planning and building stops. If stops are property of the public transport operator, the road authority will be indirectly involved (because the road authority is responsible for the adjacent road which is used by the transport operator.

The second form has to do with vehicle designs. Road authorities are in most cases not responsible for purchasing and maintaining public transport vehicles, so they are less involved. If a road authority owns public transport vehicles (which is mostly the case in non-EU countries), they have more direct influence in vehicle design. Of course, they still need to discuss vehicles with the operator because the vehicles should match the infrastructure.

The third form consists of different issues, including services for passengers, interoperability between vehicles and infrastructure, and regulations on accessibility. Especially the latter one becomes more and more important, because various European politicians are trying to introduce regulations for accessibility. Involved authorities and the way of involvement are mainly depending on the specific issue and the owner of the related object.

Table 2.1; Road authority involved in accessibility

Designing stops	*Designing vehicles*	*Other issues*
Road authorities are involved in bus stops in public space, also in case of innovative stops	Road authorities are involved when it comes to compatibility of vehicles and infrastructure	Road authorities are involved by following requirements for platform designing

2.2 Energy & fuels

Besides the accessibility, energy and fuels are an increasingly important way of concerning. Costs of conventional fuels will rise further in coming years (Oxford Economics, 2010), so it surely makes sense to search for new ways to improve energy usage and to find new energy sources. In addition to rising costs, changing policies on environmental issues are playing an important role. Mainly urban (city) regions are faced with nuisance from air pollution and a too high level of noise production, which are considerably caused by traffic (CIVITAS, 2018). Authorities on different levels (national and international) are therefore giving preference to clean modes of transport, which are causing less air pollution and noise productions.

Of course, this has not only consequences for public transport, but also for other groups including private transport and freight traffic. It is important to realize there are more traffic groups where changing policies on environmental issues are causing consequences. These groups are briefly cited within this research report, but they are not worked out in detail because they differ from the research goal and questions which are focused on public transport.

Energy savings

One of the opportunities to reduce fuel costs and partially respond to environmental policies is to save energy used by public transport vehicles. There are three important ways how energy could be saved; reducing energy usage of auxiliaries, gaining power from driving, and changing driving style of drivers. Auxiliaries like heating, ventilation and air-conditioning are the most important energy consumers. For a comfortable trip, vehicles must have the right temperature. Especially if the vehicle is cold, the heating needs much energy to warm up the vehicle. Once the correct temperature is reached, it will be easier to keep the right temperature on the route by using small alterations. There are several small alterations available. For example, take the trams in Zurich which are equipped with automatic closing doors. Automatic closing makes it easier to keep the temperature, so the heating system may start fewer times (Verkehrsbetriebe Zurich, 2019).

In Stuttgart, the public transport operator managed to combine three most important auxiliaries (heating, ventilation and air conditioning) into one system. The system, called ‘HVAC’, was able to coordinate heating and cooling process and to limit energy usage by using different hardware and set-up programmes. The system has been evaluated and can be seen as a good alternative if it comes to energy consumption, because overall consumption of energy was reduced by as much as 35% to 40% (EBSF2, 2016).

In Helsinki, this system was extended with real-time data. Information about the current traffic situation, route and line characteristics makes it possible to use the auxiliaries more efficient. This data makes it easier to use auxiliaries on the right moments. For example, it is better to use auxiliaries when a bus is waiting so energy usage is more spread.

Image 2.3; Electric bus in Finland (Helsinki Business Hub, 2015)

Besides, it is very important to have a look at opportunities to gain new energy during driving. This can be done directly and indirectly. The direct way is to lower the weight of the vehicle, because the weight has an important influence on the used energy. For example, a lower weight can be established by downgrading batteries of an electric bus, which are very heavy. This has been tried, among others, in Helsinki. Using a less heavy battery was causing just a slightly lower action range, because a less heavy battery makes it possible to drive longer distances. Tests in Helsinki have provided insight into the influence of vehicle weight on energy usage (and therewith action ranges) of transport vehicles. In general, more energy is also needed if there are more passengers.

The indirect way is to collect energy through the driving. This is mostly about recovering already used energy, for example if there is no acceleration or if the brakes are used. In Brussels, local transport operator STIB and the University of Brussels have been working on a pilot project to explore the possibilities of using braking energy from trams for heat and ventilation systems. This project showed that the trams of STIB are already recovering energy of braking trams by saving this energy for a while and using it again in the next acceleration. However, these trams are very new, and energy recovery is not equipped in all European tram networks (ELIPTIC, 2015).

Finally, the driving style of drivers has an important impact on energy consumption. If a driver is unnecessarily accelerating and braking, the energy consumption of the vehicle will be higher. This causes more fuel usage, leading to higher costs for operators. Besides, unnecessary acceleration will cause unnecessary air pollution and high noise production. Problems for the environment and primarily the higher costs are causing more attractiveness of eco-friendly driving procedures among public transport operators. In Barcelona, for example, a project has been set up with two different eco-driving systems which have been tested. These eco-driving systems, also called ‘driver assistance systems’, were able to give the driver accurate information on his accelerating and braking.

One of the interesting points in this Barcelona project, was that driving data was also sent to the back office of the bus operator. This makes it possible to assess current impact of driving styles on the energy consumption, while comfort and safety aspects were automatically considered. By testing several ways of feedback, researchers found out the best ways to give drivers feedback on their driving style. At the end, the best possible way of giving feedback was to provide a combination of a small sound and indicating light. Feedback using a vibrating steering wheel seems to be a good way to make bus drivers aware of urgently problems (EBSF2, 2017).

New energy sources

New sources of energy are the most efficient way to reduce air pollution and noise production. By using energy sources that do not require a fuel engine, it is possible to drive without consequences for environment. In general, there are three major types of energy sources; conventional fuels (including diesel, gas and gasoline), electricity (in hybrid and fully electric variant), and newer sources like hydrogen and biogas. The conventional fuels diesel and gas have been the standard fuels for buses in many years. Later, the ‘green’ gas, a new gas which is based on biogas, was introduced. In recent years, however, this picture is changing. The second (electricity) and third (hydrogen) sources have been studied and tested as new energy sources for public transport buses.

Today, the most considered energy source in public transport is electricity. In train, metro and tram systems, electricity is already the usual energy source. However, this does not apply for the far more extended bus networks in Europe. There are mainly two reasons for this. First, electric buses are very expensive in purchase (mainly because of their battery packages). Public transport operators need much start capital for buying electric vehicles. Second, electric buses are not able to drive the same distances conventional diesel buses. Most electric buses can drive only 200 kilometres on a full battery, and just the half (100 kilometres) if the air-conditioning, heating or ventilation system is active during the whole trip on hot summer days and cold winter days.

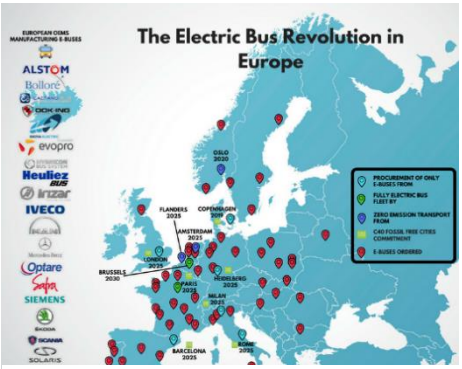


Image 2.4; Electric Bus Revolution in Europe (Bellona Europe, 2018)

From 2013 until 2016, electric buses have been introduced by various European public transport operators in Austria, France, Germany, Luxembourg and Norway (Duursma, 2016). After 2016, the number of electric buses has grown further. It is expected that costs for batteries in electric buses are eventually decreasing if manufacturers create more standard types by 2030. As a result of reducing costs, probably more operators will purchase and use electric buses in the long term (Bellona Europe, 2018).

Hydrogen buses, also called 'fuel cell buses', are another considered opportunity for eco-friendly public transport. The fuel cell bus is an electrically powered vehicle, running on electric power which is generated by a fuel cell. This fuel cell converts hydrogen into electricity. Fuel cell buses are as clean as electric buses; they are also not contributing to air pollution. Buses equipped with fuel cells are particularly a good alternative for longer distances in rural areas (with small amounts of charging opportunities), because their action radius is bigger than the radius of electric buses. Electric buses, however, are fitting better within cities, where generally more suited charging points are available.

New fuel cell buses have already been purchased and used for fifteen European cities, spread over seven European countries. Another twenty-one cities in the same countries and six other countries have been planning an introduction of fuel cell buses. It is important to indicate that buses are being purchased for city networks because they need to be tested first. If results of these tests prove to be sufficient, operators often make the step to use fuel cell buses in less urban (more rural) areas.

Image 2.5; Fuel cell bus Revolution in Europe (Fuel Cell Buses Platform, 2018)

One interesting example of biogas and hydrogen energy sources is situated in Norway. The public transport operator, 'Ruter', is increasing the proportion of biogas. This biogas is produced based on food wage and sewage. It causes massive reductions in greenhouse gas emissions. For a European program, a set of hydrogen fuel cell buses have also been tested. The operator expects that the share of fuel cell buses will increase further after 2020 (Roland Berger Strategy Consultants, 2015).

Charging and fuelling

Fuelling or charging does not apply for all public transport vehicles. Trains, trams and metros are constantly fitted with their own power supply by using catenary above tracks or by a so-called third rail. Of course there are some exceptions including trolley buses which have catenary above their routes, but mainly transport modes on the road like standard buses and taxis are not equipped with a constant electric power supply, so they needs to be fuelled or charged before their shift starts or on specific moments during their current schedules.

Procedures of fuelling conventional diesel buses are very common and can be done in a short time. Charging electric or hybrid buses asks specific knowledge of engineers and it takes significantly more time. Therefore, various projects have been launched to make bus charging more efficient in order to make electric and hybrid buses more competitive with conventional and diesel buses. These projects led to two forms of charging; 'fast charging' and 'slow charging'. Fast chargers can fully charge buses in a short time (about 15-30 minutes), while slow chargers need more time (about 5-6 hours). Slow chargers are nevertheless cheaper in purchasing and operating costs.

One of the usual options is charging or fuelling buses in depot. In this case, road authorities are completely not or just partly involved. Depots are usually privately owned by transport operators or authorities. They are responsible for the infrastructure inside and in immediate vicinity of the depots. If the operator is using private fuel stations in the depot, the road authority is also not involved. With the so-called 'opportunity charging' on streets, this is a very different story because road authorities are responsible for the infrastructure where charging points must be placed. In this case, it is often necessary that operators collaborate with the responsible road authority.

Energy & fuels in headlines

In general, three ways of concerning energy and fuels could be identified. The first way has to do with saving energy. Measures to save energy in public transport are usually not influenced by road authorities. However, this is different if the road authority is also functioning as a transport authority or if it is also responsible for public transport operation. In this case, they can work out new tenders in which they describe requirements for buses from operators.

The second way has primarily to do with energy sources. Although road authorities have no leading role in here, they still have an opinion on this because they benefit much from new energy sources which are causing less air pollution and lower noise production

The third way is about charging and fuelling. Road authorities generally have more influence on this, in case of opportunity charging if operators need to use charging infrastructure on public roads. Road authorities are managing the public space where charging infrastructure is placed and sometimes also the charging infrastructure itself.

Table 2.2; Degrees of road authorities concerning energy & fuels in public transport

Energy savings	*New energy sources*	*Charging and fuelling*
Road authority are involved if energy goes back to network (cables, pipes; roadworks)	Road authorities are involved if new sources will influence the public space (trolley networks)	Road authorities are involved if fuelling or charging happens in public space/on public roads

2.3 Network planning

Network planning consists of designing lines, situating stops and stations, and organize multimodal connections for public transport. Network planning is important, because it has benefits for both (public transport) authorities and travellers. Authorities will be able to have a cost-effective network of transport, wherein lines can be linked together and no distances are double driven. Travellers will be offered complete journeys from starting points to end points, albeit by a system with transfers but also with a good offer of departure and arrival possibilities.

Networks are planned on different levels; local (on city or village levels), regional (on province or region level), and national (nationwide networks). Nowadays the European Union has created new opportunities with policy on free movement of people and goods, making it possible to go further than national networks. Operators of different countries are now operating in other countries too, including the ICE concept which connects large German cities with other European cities in Austria, Belgium, Denmark, France, Switzerland and the Netherlands. Local networks, especially around cities, are mostly additional to existing (main) networks on a 'higher level'. As an example, the network of metro, tram and bus in Brussels is adapted to the national Belgian rail network (STIB, 2019).

Designing routes

Routes for public transport vehicles are not designed by public transport authorities or operators on their own. Of course, road authorities are much involved in the physical part, because they maintain public space wherein the transport infrastructure will be placed. Sometimes there is already a road that should or should not be adjusted, but in almost every case also new infrastructure (think of platforms for bus stops or adjustments on traffic light systems) must be built.

Sometimes public transport needs their own infrastructure. This is especially the case in very busy places or in places where buses are using shorter routes which may not be used for other traffic. Dedicated infrastructure mostly consists of dedicated bus lanes or supporting measures 'blocking' the route for other traffic. Examples are barriers that open only for buses or so-called 'bus locks', which are physically designed to let only buses through.

Image 2.6; 'Bus lock' in Houten, the Netherlands (Streetview, 2018)

One city with completely dedicated bus lane infrastructure is Almere, a so-called 'new town' in the Netherlands. Exchanges with other traffic are solved with traffic lights. The opportunity to build the whole city from scratch provided possibilities to develop public transport very close along important buildings and centre locations. Bus Rapid Transit routes are running along train stations with Park & Ride facilities in the city, creating opportunities for switching between bus, train and car.

However, involvement of road authorities in physical route infrastructure is not only limited to buses. Also, in case of tramways and even train connections, road authorities are involved. In case of trams, rails are placed on city roads so local road authorities are naturally involved. Crossings of trams and other traffic in urban areas are mostly organized with traffic lights or tramway crossings. In addition, many European countries organized regulations about dealing with trams in traffic laws.

Crossings of trains with other (especially car and bicycle) traffic are organized with railway crossings. These crossings are often equipped with bells and lights, sometimes also with barriers. When a train passes, all other traffic must give priority. Railway crossings are preferably used only on regional or local roads. Crossings can have big impacts on traffic flow and road safety, so the responsible road authorities are obviously involved in railway crossings. In these projects there is often a collaboration between road authority, railway manager and rail transport operator.

Rail transport is, beside transport by road and transport by water, an important pillar of the TEN-T network. In order to make rail and road connections safer and less prone to malfunctions (which are mainly appearing at crossings), many railway crossings on the network are replaced with viaducts or tunnels. One country where this has been done is Belgium, where around 11 level crossings have been removed in relation to TEN-T (INEA, 2018). Another country where a replacement study for level crossings has been done is Germany (INEA, 2013). In addition, many other countries are also closing or replacing level crossings on non- TEN-T corridors. With these solutions, risks of accidents or malfunctions between rail and road, causing many delays for both modes, could be minimalised.

Situating stops

Stopping places for public transport are not invented from scratch. In many cases, there is an existing building or function that must be reached. Think of public locations as schools, libraries and hospitals. But also amenities such as cinemas, swimming pools and local shopping centres are places that offer opportunities for public transport stops. These locations have an important value for the neighbourhood and are therefore connected in the network. Stops are often designated by a local government; in the European countries, this is a municipality. In consultation with the transport authority, municipalities determine where stops will be situated.

Road authorities are much involved in situating public transport stops and stations, because they can experience consequences of stops on their roads. Halting buses or trams, for example, can cause traffic delays for following vehicles. Therefore, road authorities are involved in the planning phase, so they can give their opinion on stop locations. Besides, public transport vehicles need a safe place to stop and let passengers board. Road authorities can help to find safe locations, because they know what the main traffic flows are and whether a halting vehicle can safely fit in.

On one hand, road authorities are involved because of consequences from regulations. For example, in Germany, a bus stop means that it is not allowed to park vehicles 30 metres before and after the bus stop (Bundesministerium für Verkehr, Bau- und Wohnungswesen, 2001). In case of many bus stops, this can reduce available parking space on streets, which is a responsibility of road authorities.

Image 2.7; Bus stop in Berlin (Streetview, 2008)

This can for example be seen at the busy bus stop ‘Kürfurstendamm’ in Berlin, where cars can be parked on the right sides of busy roads. The picture on the left shows exactly how this works. Road authorities must be involved because of the effects on their streets. Besides, road authorities must be involved because they own the public space where stop(s) will be placed.

On the other hand, road authorities are involved because of their role in spatial planning. European municipalities are responsible for planning urban regions, which means they must designate locations for functions and facilities. Of course, public transport plays an important role in spatial planning, because it is a determining factor in accessibility of facilities. With linking public transport stops to specific functions, the network could be organized more efficient. Therefore, it is important that road authorities are involved in situating public transport stops.

Designation of locations for public transport stops is in most European countries a shared task between road and public transport authority. In western European countries, local road authorities (EG cities or municipalities) have an advisory role in this process. Sometimes, for example in Russia, the road authority is only involved in bus stops and in the network. There, the transport authority is only responsible for transport on designated routes.

Image 2.7; Locating stops is in most European countries a shared task (STIB, 2019)

Multimodal networks (P+R)

Previously, different modes including cars, public transport, bikes and pedestrians, were strictly separated. Nowadays, a network approach of all modes is becoming more and more important. This network approach calls for more extensive collaboration between road authority and transport authority. Road authorities need to organize new components in the network in coordination with transport authorities. Separated trips with one single mode are increasingly changing to chains of different trips, by two different changes;

First, this has to do with a social related change. Previously different modes including cars, public transport, bikes and pedestrians were separated because they 'belonged' in some way to specific groups of society. Low educated workers were mainly using public transport (buses) because they were not able to afford a car, while high educated workers were mainly using cars. Nowadays, this has been changed. You can find people from different society groups in all modes. Besides, it has to do with availability of public space and environmental policy. In busy city districts there is not always enough space for car parking, with high parking fares as a result. Because of the pressure on public space and environmental objectives, cities are forced to look at chains of transport trips instead of trips with single modes.

Using different modes for door- to door trips asks for new solutions. Exchanges between different modes means that new elements are needed in the system. For instance, think of enough parking places for bikes and cars at public transport stops, carpool locations where people can switch to travel with others, and new transport systems which provide quality transport if necessary like PRT, CTS, and others. More information about new transport systems can be found in paragraph 2.5.

One of the most common components of multimodal networks are Park & Rides, which are placed at boundaries of many European cities (Zarząd Transportu Miejskiego, 2019). Park & Rides are places where travellers can park their car, and then travel further by public transport. Although Park & Rides are often applied to the edge of urban areas, there are also examples of locations in other (more

rural) areas. Attractive train connections are often available from this location to city districts. Park & Rides offer an alternative if cars are not allowed in urban districts. Park & Rides can be found in many European cities, spread over Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, Luxembourg, the Netherlands, Spain, Sweden and Switzerland (Car Parking Europe, 2018).

Another variant of multimodal combinations are Kiss & Rides. Kiss & Rides are mostly situated at important railway stations and airport terminals. The difference between Kiss & Rides and Park & Rides is that parking for a long time is only allowed on Park & Rides. As the name already suggests; they are specifically designed to allow other people to stop, step out and drive further. For Kiss & Ride locations is, instead of Park & Ride, no parking loft needed. This means less public space is needed. Often, one lane for Kiss & Ride seems to be enough. Sometimes, especially in case of big airport terminals, more space is needed. But they still do not need as much space as Park & Ride locations.

Using Park & Ride or Kiss & Ride locations is only permitted if users are travelling with a mode of public transport too. However, checking could be difficult because road authorities do not know where car drivers are going. Sometimes, for example in Russia, CCTV on Park & Ride or Kiss & Ride locations is used to check which passengers are not using public transport (The Moscow Times, 2019). For other European countries, this may be hard because of privacy regulations.

Network planning in headlines

Network planning in public transport consists of three main aspects; designing routes, situating stops, and establishing multimodal networks. Road authorities are involved in all of them in various ways. In route design, route authorities are most involved in the physical part. They need to maintain roads which are used by public transport operators. Roads can be open to all traffic including modes of public transport or they can be available to only public transport. Road authorities are involved in planning different modes of public transport; mostly bus, tram and train.

The second aspect has to do with situating stops. Especially local (city) authorities, responsible for roads, are involved in situating the stops for public transport because of two reasons. Firstly, road authorities are involved because they will face consequences of public transport stops, like a lower capacity on roads or new safety issues. Besides, road authorities are involved in stops because of their spatial planning role. Cities are responsible for locating buildings and facilities, so they can create combinations with facilities and transport, like schools, houses, etc.

The last one, establishing multimodal networks, is one of the most important. Road authorities are responsible for public spaces and therefore responsible for locating, building and maintaining places where travellers can transfer to other vehicles or change between modes. This can be organized in forms of, for instance, locations like, Carpools, Park & Rides and Kiss & Rides.

Table 2.3; Degrees of road authorities concerning network planning in public transport

Designing routes	*Situating stops*	*Multimodal networks (P+R)*
Road authorities are involved in case of dedicated routes or if roads are crossed (trains)	Road authorities are involved in designating stops (because they are public space owner)	Road authorities are involved in situating and building Park & Ride locations

2.4 Software & applications

Software and applications, also ‘digital infrastructures’, are becoming a more and more important issue for both road authorities and public transport stakeholders. However, currently they are not collaborating much in this area. In most cases, data is not shared because of privacy regulations or because this is unusual. The expectation is that this will change in the future. Broader and more intensive data sharing may increase new possibilities of cooperation in future, but also today road authorities are already cooperating in digital public transport infrastructure.

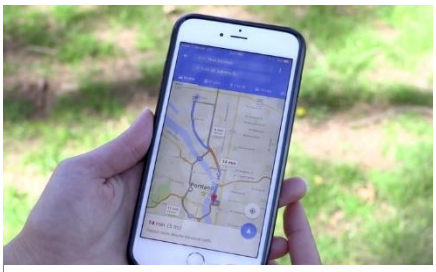


Image 2.8; Smartphone navigation (Digital Trends, 2018)

There are several ways of concerning digital infrastructure in public transport. The most common way exists of smartphone applications, which are set up by operator or authority to provide help for users. Secondly, software is also used to create facilities for providing a better public transport flow. Finally, developments in software and applications are creating new opportunities for combined systems, linking different modes of transport together.

Smartphone applications

Today, different applications are available for public transport, road transport and other modes. Public transport applications consist of information about departure times, route networks, schedules and additional services. Road transport applications consists of information about the current routes to a filled-in destination, parking information for city districts and advising on locations like nearby restaurants, toilets or speed checks along the route. Applications for other modes like cyclists and pedestrians are mostly focused on sport, like Strava and Step counters.

Public transport applications are mostly created by specific transport operators. GVB in Amsterdam, STIB in Brussels, BVG in Berlin; all operators created their own application. These operators are only providing their own public transport information in their application, because this is the only product they offer. This is causing difficulties, because there are several applications which can be used. For example, think of the situation in Belgium, where DeLijn, STIB and TEC all have their own application. Together with the app from the railway operator you need four applications only for public transport.

In a few countries, including the Netherlands and Sweden, public transport operators are forced to provide their data in open source. This means that different applications can use this open data, making application developers available to organize different operators into one application. As a result, these public transport planners are no longer containing information solely for the train, but they can plan a door-to-door journey with also the routes of other operators. One example of a door-to-door journey planner is ‘Peatus’ in Estonia, of which a travel advice is provided below.

Such applications for public transport, which are based on open source data from operators, are very common in European countries.

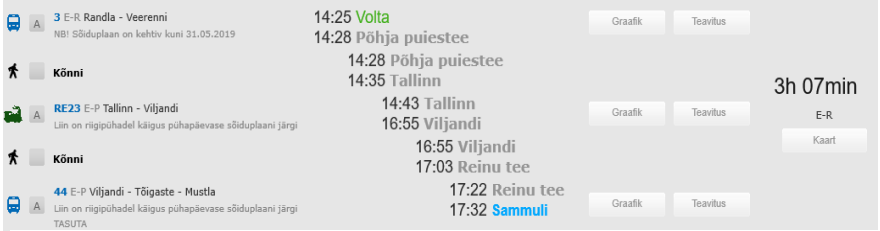


Image 2.9; Peatus public transport planner (Peatus, 2019)

In road transport, different types of applications are common; applications based on one specific purpose (route planner applications like Google Maps and TomTom), and applications related to specific vehicles (in-build applications for brands like Audi, Mercedes and Volvo). The first group of applications consists already of different modes. In addition to the car, also the modes pedestrian, bicycle and public transport (using open source data of operators) are added to the application. These apps are mainly about providing and collecting (traffic) route data.

Road transport applications related to specific vehicles are currently separated from public transport applications because of two reasons. Firstly, car manufacturers (who create these applications) do not want to share their vehicle data open source. They want to protect their products and ideas and keep them away from competitors. Secondly, specific car-related applications are made for car users and these users do only use it for the car. Travel information for public transport will not be used by their customer group, even if the possibility exists in applications.

Applications for road users are mostly made by private companies. Name recognition of huge brands like Google Maps and TomTom makes them usually most used applications in countries. In some cases, for example in Finland, road authorities are developing and maintaining their own application. However, these applications cannot be used for navigation; they are based on other road authority related topics including requests for car licences, MOT inspections, etc (Trafikom, 2019).

Changes regarding car data policy and possibilities for cars to 'talk' with roads are inducing car manufacturers to use open data more in the future (TRL, 2017). In the longer term, in-vehicle data must be shared better and more effectively. However, in the short term this may be hard to reach because other legislation (particularly European legislation related to security, privacy and free market) must be changed too.

Flowing public transport

Besides the launch of applications there are also improvements in software providing better public transport flows. This can be categorized in three main involvements, including Intelligent Transport Systems (ITS), improvements on traffic light systems and automated toll systems. Although ITS is new and therefore the most mentioned one, but it also includes improving traffic lights and toll systems. Both systems are not applied in all European regions.

Intelligent transport systems are a collective name for transport systems based on data collection, analysis and using analysis results in operations, control and traffic management research concepts where locations are important. In many cases, an intelligent transport system is seen as a specific elaboration; think for example of buses in Glasgow giving regular information to commuters about timings including time to reach destinations, passenger density within the bus including seat availability, current bus location and next location of bus.

ITS is mainly focused on six application areas; ATMS (Advanced Traffic Management System), ATIS (Advanced Traveller Information System), AVCS (Advanced Vehicle Control System), APTS (Advanced Public Transportation System), ARTS (Advanced Rural Transportation System), and ACVOS (Advanced Commercial Vehicles Operation System). The followed application area depends on capabilities of sensors, information processors and systems for communication, but also on messages along the road, updates for GPS and automated prioritization of signals.

Improvements in traffic light systems have mostly to do with ITS. Demand- depending schedules with priority for emergency service vehicles are already applied in some European traffic light systems. With including a direct flow of public transport in these schedules (by giving public transport vehicles also priority), public transport flow can be maintained. Practically this means that the waiting time for public transport at intersections is shorter than the waiting time for other traffic modes, including cars, trucks, etc. This is another example of seducing people to use public transport instead of cars.

Another innovation on applications and services has to do with automated toll systems. Many road authorities, mostly on regional and national level, are introducing ETC's (Electronic Toll Systems) on toll roads. The system works with an electronic reader which is placed above the road and scans the registration plates of vehicles. Every registration plate is automatically detected, and costs will be charged later. This causes a better traffic flow, because vehicles do not need to stop at booths. Especially for buses, which consume a lot of energy with acceleration, this is a good alternative.

Automated toll systems are already implemented on some European toll roads, for example in Ireland. Electronic tagging creates a much faster, smoother and fuel-efficient journey via toll roads (TII, 2018). The main advantage for public transport in here is that operators do not need to wait for toll booths, causing unnecessary waiting times and derogations from schedules. This makes sense, in particular for long-distance coaches which pass several toll systems during their routes.

Image 2.9; E-toll system in Ireland ((Tripsavvy, 2019)

Combined systems

Better transport cannot be established with single innovations including smartphone applications and better flows of public transport on their own. Sometimes, the best solution is to provide a combination of different modes in trips instead of providing one single mode for the whole trip. There are different solutions which can solve this problem.

Of course, smartphone applications could play an important role in here. More than half of travellers say they use at least one app for their trip (Travelport, 2018). These applications may, for example, give travel schemes based on best modes for current time and locations. For example; if at one specific time all shared bikes are occupied the metro will be included in travel advices, and if the metro is too busy taking the car could be an advice.

Technically, all data related to schedules and information about location can be used. In Finland, a smart mobility application has been launched which combines public transport with flights based on data from different airlines (Perille, 2019). Regarding to the research department of the European Parliament, steps like these are the start. They believe a combination between (both public or private) car, bicycle, public transport and walking will be advised in future.

Besides, also software plays an important role. With innovations in traffic light systems, flows of all transport can be organized better. In the Netherlands, tests are carried out in the regions Brabant and Flevoland to give cyclists faster green at traffic lights if they use a specific smartphone app which connects with the traffic light software. Traffic lights can 'see' app users approaching and they adjust the green time on them. This ensures that traffic can be settled more effectively (Vialis, 2018). It could be interesting to add shared public transport (like bike sharing) to such systems.

Although it sometimes seems like digital infrastructure can solve every problem, also physical infrastructure keeps necessary. The most important parts that must be organized are locations facilitating transfers between modes. For instance, think of park & rides or bike sheds at train stations. These places must not only be sufficiently present, but they must also be safe and interesting. It must be a pleasant location to wait, even in case of small waiting times.

Combinations between transport modes and therefore needed (open source) data will become more important in the future, according to Scandinavian authorities in a carried-out questionnaire. In order to create new applications which include all modes, data should be shared and used more efficient. Authorities, transport operators and manufacturers need to provide more of their data open source in order to establish concepts like MaaS.

MaaS, which stands for 'Mobility as a Service' is a new concept in the transport chain. This concept creates a platform above transport operators where different modes are clustered and provided to clients. Scandinavian countries are trying to introduce this in pilots. According to ABI Research, MaaS will have huge effects on the way how transport modes are currently organized, reaching revenues of $1 Trillion by 2030. It provides opportunities, but therefore it also needs to overcome resistance from private and public players (Marketwatch, 2016).

Software & applications in headlines

Road and transport authorities and operators are working on software & applications in different ways. First, they are developing smartphone applications. This is mostly done by private parties like car manufacturers, but sometimes road authorities are also involved in creating applications. Applications of private parties are mostly vehicle bounded, while applications of authorities are focused on car administration.

Another important software influence has to do with flowing public transport. This is established by Intelligent Transport Systems (ITS), traffic light system improvements and automated toll systems. The second and third ones (traffic lights and toll systems) are listening very closely to the first one (ITS). This is because an ITS system could be equipped with these innovations.

However, combining different modes into multimodal trips is seen as the most important solution within software and applications based on software. With new software opportunities for MaaS applications, road and public transport authorities will be able to solve problems on their networks. Road authorities and public transport authorities need to collaborate to establish these applications.

Table 2.4; Degrees of road authorities concerning software & applications in public transport

Smartphone applications	*Flowing public transport*	*Combined systems*
Road authorities are involved in creating car-related apps and building multimodal apps	Road authorities are involved in flowing measures (priority at crossings, automated toll)	Road authorities are involved in new multimodal trips (innovations & MaaS)

2.5 Transport modes

This latest category consists of other transport modes which are currently not widely used but are still examples of projects on public transport infrastructure where road authorities are involved. Transport modes collected from these projects can been divided into three different categories, including the 'Rapid Transit Systems', 'On-demand vehicles' and 'Guided systems'. Other transport modes like these are used in specific regions. Rapid Transit Systems, for example, are a widely used in city districts but not in rural areas. On-demand vehicles, however, are widely used in rural areas and less in city districts. This already shows that there is no standard mode for every situation; therefore, the use of these other transport modes should be a custom-made process.

Guided systems fit most in urban regions. Some European cities realized guided PT systems on streets; think of trolley buses and trams which are following a decided route on infrastructure. Besides, also metro and train could be important. However, they are currently not seen in rural locations, except some touristic locations, like the train connection between Zürich - Uetliberg in Switzerland (Switzerland Tourism, 2019).

Rapid Transit Systems

Systems for rapid transit do exist in many ways and transport modes. They could be organized in many public transport modes, including tram or light rail, train, pre-metro and metro, monorail and bus. Shared bikes and cars are currently not seen as rapid transit, but because of the increasingly important role they play in city transport and their autonomous future, they will probably be seen as rapid transit in the future (OECD, 2015). First, there are two different systems of rapid transit; MRT (Mass Rapid Transit) and PRT (Personal Rapid Transit). MRT is based on mass transport, where many people can be moved in a single moment. PRT, on the other hand, is based on private transport, where the rapid transit system will be based on moving one person in a single moment.

Tram or trolleybus systems, which have also been mentioned in paragraph 2.1 too on behalf of their energy source, are an important mode of Mass Rapid Transit. They normally use road infrastructure, particularly in cities. With very short waiting times between (departure of) vehicles and high vehicle capacities, we can speak about a rapid transit system. Also, metro, pre-metro and train are examples of Mass Rapid Transit. Times between departures are at most urban stations very low. Therefore, they are a good alternative for small and long-distance trips in cities. However, we need to realise that metro, pre-metro and train do normally not use road infrastructure, but their own (track) infrastructure. BRT (Bus Rapid Transit), however, usually needs to interfere with traffic (COST, 2011).

Personal Rapid Transit systems are currently less used in Europe. This has to do with the relatively density character of European countries. People live relatively close on each other in comparison to other continents, and therefore mass transit is more interesting. Besides, mass transit is more interesting because implementation and maintaining is cheaper than personal transit (Jaffe, 2014). However, authorities have been experimenting with personal rapid transit. For example on Heathrow Airport in London, where a PRT system was used to transfer passengers between a car park and Departures Lounge at one of the terminals (CityMobil, 2017). Although the system was intended to expand in case the project was a success, this has not happened because of high costs.

Image 2.10; Hyperloop (Hardt, 2015)

According to many scientists, one of the most important rapid transit systems towards the future is the hyperloop. Although the system will in her current state not be interesting for small distances in cities, it could instead be interesting for travelling long distances. Currently a new initiative, called 'European Hyperloop Project', has been set up to establish hyperloop connections between European cities.

On demand vehicles

Transport is solely needed if there is a demand. Public transport is commonly driving on behalf of a schedule. Vehicles arrive at stops on a specific route on in advance scheduled times. This is very different in case of on demand vehicles. Vehicles on demand are not driving following a fixed schedule, but they only drive in case they are needed by a passenger.

The most classical form of on demand vehicles are taxis. Taxis are currently used as a transport mode in many European cities. However, this transport mode is not preferable in European cities, because taxis are often parked at standard locations where waiting for customers. Automated taxis, however, can keep driving without parking on standard locations. Automated demanding vehicles can be part of a PRT system, following the example at London Heathrow. However, they are not always part of such a system, because vehicles on demand can also operate without their own infrastructure.

Another concerned on-demand system is CTS, which stands for Cybernetic Transport System. This system is not implemented yet, but tests has been running in software since 2007. CTS could be responsible for first and last miles of door-to-door journeys, and therefore it appears to be a way to resolve congestion and pollution in cities (Boissé, Benenson, & Bourao, 2007).

Guided systems

Another way how transport can be organized is with a guided system. Guided systems are public transport systems where vehicles are directly linked to infrastructure. Tram, metro and trolley buses are well known examples. They are all equipped with (mostly electric) power supply. This does not apply for hybrid or conventional buses, because they are able to deviate from their routes because they use an on-board energy source.

Image 2.11; Transport in Wuppertal (Schwebebahn, 2016)

One of the most famous European systems with own infrastructure is the so-called 'Schwebebahn' in the German city of Wuppertal. This system, developed as an elevated railway since 1887, was meant to create transport options in a densely built environment. At that moment, the river 'Wupper' was the only place where space was not occupied yet. Therefore, they decided that the new transport system should be built above the river.

However, infrastructure does not always belong to one single mode. Sometimes different modes can use the same infrastructure. Especially the new innovative modes, which can drive on 'common' streets, are mostly using the same infrastructure as (standard) buses or cars. For example, think of personal rapid transit vehicles using 'standard' infrastructure. Shared infrastructure for buses (asphalt) and trams (rails) is a very common example. They are sometimes able to use the same stops/platforms.

Near the metro station 'Kralingse Zoom' in the Netherlands, public transport operator Connexxion, innovator 2Getthere and the municipality of Rotterdam developed a test route for the 'Park shuttle'. The Park Shuttle system is almost the same as the PRT system in London, but in this situation, vehicles are driving on standard (private) roads instead of dedicated infrastructure. (2Getthere, 2019). Last year, plans have been launched to expand the system also to public roads and drive between normal cars.

Transport modes in headlines

Current transport modes are being improved, but new modes of transport are also in testing and development phases. By now, it is difficult to point out which transport modes will be available in the long run. Therefore, this research part on new transport modes is exclusively focused on today's first examples and the involved stakeholders in here.

Currently, there are three main directions for new public transport modes. The first direction, which is rapid transit systems, provides fast transport in predominantly city districts. However, rapid transit systems can also be applied in suburban areas, for example to complement public transport journeys. The second direction, on demand vehicles, is a good alternative on more rural areas.

Due to a lower number of travellers it is more interesting to only drive the vehicle when it is needed. The third direction, guided systems, could be about 'closed systems' (no interaction with other modes) or 'open systems' (interacting with other transport modes). In an open system with any interaction with other vehicles or roads, road authorities are involved.

Table 2.5; Degrees of road authorities concerning new transport modes in public transport

Personal rapid transit	*On-demand vehicles*	*Guided systems*
Road authorities are involved in PRT vehicles (by designing infrastructure)	Road authorities are involved because on-demand vehicles have impacts on their roads	Road authorities are involved if guided bus systems are planned in public space

2.6 Overview

Road authorities are currently involved in many public transport related projects. However, they are not always responsible for the elaborated tasks. Tasks do still differ in specific situations, but these involvements of road authorities are overall most common in Europe. This depends on the scale and integrated modes in projects. Roles and tasks are not the same in every European country. Different types of country structure and culture cause different authorities and responsibilities for road and transport. Based on the European examples altogether, we could draw a line about most common situations in case of different themes. Below you will find the elaborated version of the different involvements, related to themes.

Table 2.6; Degrees of road authorities concerning various themes in public transport

Accessibility	**Designing stops** Road authorities are involved in bus stops in public space, also in case of innovative stops	**Designing vehicles** Road authorities are involved when it comes to compatibility of vehicles and infrastructure	**Other issues** Road authorities are involved by following requirements for platform designing
Energy & fuels	**Energy savings** Road authority are involved if energy goes back to network (cables, pipes; roadworks)	**Energy sources** Road authorities are involved if new sources will influence the public space (trolley networks)	**Charging and fuelling** Road authorities are involved if fuelling or charging happens in public space/on public roads
Network planning	**Designing network** Road authorities are involved in case of dedicated routes or if roads are crossed (trains)	**Situating stops** Road authorities are involved in designating stops (because they are public space owner)	**Multimodal networks** Road authorities are involved in situating and building Park & Ride locations
Software & apps	**Phone applications** Road authorities are involved in creating car-related apps and building multimodal apps	**Flowing transport** Road authorities are involved in flowing measures (priority at crossings, automated toll)	**Combined systems** Road authorities are involved in new multimodal trips (innovations & MaaS)
Transport modes	**Personal rapid transit** Road authorities are involved in PRT vehicles (by designing infrastructure)	**On demand vehicles** Road authorities are involved because on-demand vehicles have impacts on their roads	**Guided systems** Road authorities are involved if guided bus systems are planned in public space

In the following chapter, the above results will be placed in a European point-of-view. Do these individual issues represent the situation in all European cities? And what changes are expected by European institutes, that may influence the role of road authorities in upcoming years?

3. Transport on European level

This chapter places public transport involvements in a European point of view. To understand this view on road authorities and public transport from a European perspective, first it needs to be clear how European policy and strategies are organized. This information has been collected using a literature review on websites of the European Commission, Council and Parliament. Information has been validated by interviews with policy makers and researchers in these institutes.

European policy and network strategies are elaborated in the first paragraphs, based on information collected in interviews with European institutions, POLIS and AER. Thereafter, a relation with public transport infrastructure is described. In the end, views of European institutions on public transport infrastructure and role division are elaborated. With this information, the chapter provides a view on the last research part, chapter 4, wherein different authority structures are discussed.

3.1 European policy

Public transport is not necessarily a European concern. Most projects are solely carried out in specific cities, regions or countries. However, sharing knowledge and best practices on European level has an important value. Cities and municipalities working together on shared projects paves the way to find new solutions which can be applied in different regions at the same time. Besides, transport has a relation with important European goals like free movement of passengers and goods, which makes it necessary to develop policy on transport networks on European level too (Baldwin, 2019).

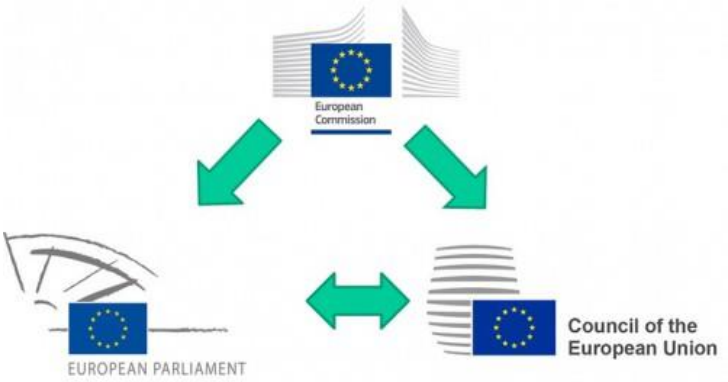
The EU follows the principle of conferral responsibilities, which means it is solely responsible for areas agreed by member states. Officially there are three levels of EU responsibilities; the exclusive EU responsibilities, shared EU responsibilities and additional EU responsibilities (EUR LEX, 2007). Issues in the first category are only organized at EU level, while issues in the second category are organized by both EU and national governments. By third category issues, the EU has no decisive role. Policy issues where EU is not responsible are automatically responsibilities of member states.

Transport and Trans-European networks are organized the same way as many other policy areas following the second category; the EU has a shared responsibility with member states. This means that both EU and member states can develop new policy in this area. Although European legislation does take precedence over national legislation, many policy (under which role division of authorities) are completed or supplemented at national level (European Union, 2012).

Table 3.1; Clarification of European policy levels

Exclusive EU responsibility	Shared EU responsibility	Additional EU responsibility
Only the European Union can develop policy and concluding trade agreements on these areas	Member states can't develop regulations and law that will impair the agreed European regulations	Actions of the European are only allowed to coordinate, support or complement the national policy

Figure 3.1; Institutions of the EU (Vandenkendelaere, 2015)



Institutes of the European Union

The European Union consists of three different institutes; the European Commission, European Parliament and European Council. The Commission is responsible for developing new policy, clarified in proposals. These proposals are made by Directorate Generals (DG's) for every policy field, which can be seen as ministries. For mobility and transport, the responsible Directorate General is DG MOVE. The Parliament and Council decide about acceptation or rejection of the given proposals.

In the following table (4.2), the policy topics of European Union and member states can be found. Traffic and transport are an important part of European policy, because it interferes much with other policy areas as the internal market, social cohesion and environment. Poor accessibility of regions leads to a less strong internal market and cohesion. Or building roads in nature reserves, creating problems with the environment. Therefore, Transport & Trans-European networks (TEN-T) are a shared responsibility of EU and member states.

Table 3.2; Policy topics of the European Union

Exclusive responsibilities for the European Union	*Shared responsibilities of EU with the member states*	*Additional responsibilities of the European Union*
Customs Union	Internal market & Social policy	Protecting and improving human health
Competition rules of internal market	Economic, social and territorial cohesion	Industry
Monetary policy for Euro countries	Agriculture & fisheries, excluding common fishery	Culture
Common fisheries policy	Environment & Consumer protection	Tourism
Common commercial policy	Transport & Trans-European Networks	Education, youth, sport, vocational training
Conclusion of international agreements	Energy, freedom, security & Justice	Civil protection (disaster preventions)
-	Common safety concerns in health matters	Administrative cooperation

Source: Policy, information and services (European Commission, 2019)

Framework programmes

Since 1984, the European Commission is creating so-called 'Framework Programmes' for supporting and fostering research in the European Union's member states. These programmes, which provide funds for specific projects, are encouraging new developments in line with the EU responsibilities. Some of these projects do only consist of exploratory research on a specific theme, but projects can also consist of real pilots. Among others, the examples of first electric buses in European cities (ZEEUS, 2014) and research on Hyperloops (Hardt, 2015) are funded by these programmes.

Framework projects should always be in line with main European goals, including free movement of persons and goods, common legislation on justice and internal affairs and one internal market. In official statistics, research is carried out by national institutes, research centres, and universities. European Institutions detected a need for experience and expertise sharing. The European statistics agency, Eurostat, plays an important role in distributing results and implementing this research.

One example of these projects is the consortium 'Vital Nodes', which is led by Rijkswaterstaat, the National Road Authority of the Netherlands. This project is focused on last mile issues in city districts where the corridors of the Trans-European Transport Networks change into local networks. There are many collaborations needed, not only between (national, regional and local) road authorities but also with transport authorities and operators (Vital Nodes, 2018). The Vital Nodes consortium has led to multiple research fields, including road authorities and public transport.

The current framework programme, called Horizon 2020, is running from 2014 until 2020. This programme will probably be followed by a ninth program, Horizon Europe (running from 2021 until 2027) (European Commission, 2014). The frameworks lead to many collaborations sharing knowledge and best practices. Most issues in the aforementioned chapter are examples of these collaborations.

Image 3.1; Horizon 2020 (DG Research & Innovation, 2013)

European transport policy in headlines

On European level, three types of responsibilities do exist; exclusive EU responsibilities, shared EU responsibilities and additional EU responsibilities. Transport and Trans-European Networks are shared responsibilities, which means that both the European Commission and national ministries can develop policy in this field. In case of difficulties, EU policy is leading.

European Institutions are not responsible for policy on national road and public transport issues in countries. These issues and related policy are tasks belonging to national governments like ministries or other state departments. However, the European Commission does have the possibility to fund current projects allowing the launch of new innovations.

Framework programmes have been set up since 1984 to support and foster research in European member states. These framework programmes include among others different opportunities for road transport research. This can be very wide; from research around electric buses to research around Hyperloops. The current program is Horizon 2020, which is running until 2020.

3.2 EU Multimodal network

Based on the European goals of free market and borderless transport of passengers and goods, the strategy for a Trans-European Transport Network (TEN-T) has been set up. TEN-T, which is policy of European Commission, is about to implement and develop a European network of roads, railways, waterways, seaports, airports and rail-road terminals. Within TEN-T, two different planning layers are specified. The first layer is the comprehensive network, which covers all European regions and closes gaps between regions. The second layer is the core network, which consists of most important connections in the comprehensive network (European Commission, 2004).

Main objective of TEN-T is to close regional and national gaps, remove bottlenecks and eliminate technical barriers between networks of member states. It covers a better social, economic and territorial cohesion of European countries and it contributes to a European transport area. This is mostly done by constructing new physical infrastructure and modernisation or upgrading existing infrastructures and platforms. However, also the adoption of innovative technologies, alternative fuels and standards within the network is part of TEN-T.

Following a TEN-T review in 2013, nine corridors for the core network were identified; Atlantic (1), Baltic Adriatic (2), Mediterranean (3), North Sea-Baltic (4), North Sea-Mediterranean (5), Orient/East -Mediterranean (6), Rhine-Alpine (7), Rhine-Danube (8) and Scandinavian-Mediterranean (9). In addition, two horizontal priorities (ERTMS deployment and Motorways of the Sea) were established to provide strategic implementation of Core Network objectives in line with the funding period. (European Commission, 2004). TEN-T projects are funded by the European Commission from three funds; the Connecting Europe Facility (CEF), the European Structural and Investment Funds, and the European Fund for Strategic Management. However, national, regional and local authorities do also fund parts of costs. The explanation here is that they also benefit from the network.

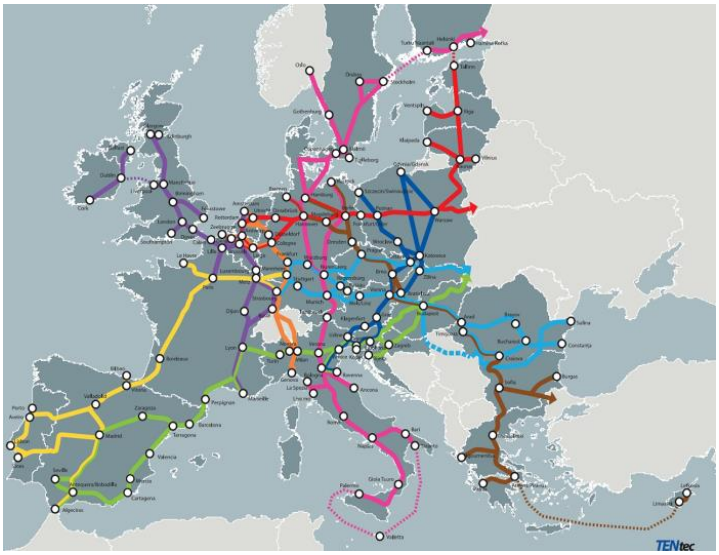


Image 3.2; Overview of all TEN-T corridors (European Commission, 2018)

Working plans

Oversight of corridors and implementation phases of priorities is a task of European coordinators. These coordinators present every two years a work plan, which contains characteristics of corridor, market analysis, projects within corridor, future challenges, infrastructure implementation, an overview of pilot initiatives and future policy considerations. In 2018, the third work plans for TEN-T corridors were presented. Conclusions of these plans outline the importance of multimodal and sustainable transport, especially towards a better climate (Cox, 2018).

Another important conclusion in these plans have to do with digitalisation. This appears in different forms, varying from mobility itself (smart infrastructure, vehicles, autonomous, robotic, seamless mobility) to software (big data, IoT, artificial intelligence) and users (connected citizens, client and consumer). A keyword in here, also mentioned in the interview with Pedro Barradas (responsible for traffic management in European Commission), is interoperability. This is done with for example by introducing ERTMS on European Railways, making international railway transport possible.

Every TEN-T corridor consists of a so-called Corridor Forum, where the coordinator from European Commission and national authorities of member states are involved. Following the Working Plans, corridor forum members from member states need to assist by identification of partners, which could be governmental, regional, municipal, academic, commercial, and more (Cox, 2018).

Public transport

Public transport can be an important solution for traffic congestion within cities, leading to a cleaner environment with less pollution. Therefore, public transport is also an important part of TEN-T. A European network of qualitative highway and railway connections provides not only opportunities for freight, but it provides opportunities for long distance coaches and international train routes too.

First, as mentioned, this provides an opportunity for long distance coaches. However, this is not seen as the most important goal of TEN-T, these buses use also the TEN-T connections to transfer passengers. With long distance transport operators as Eurolines, Flixbus and Ouibus, reaching over 1000 destinations in Europe for low prices and better on-board services as toilets and Wi-Fi, long distance coaches are used by more and more Europeans (Mellet, 2012).

Besides, the multimodal TEN-T network provides an opportunity for international train routes. By finding solutions for important bottlenecks, trains can drive (if equipped with the right system) longer distances to other countries, without any passenger transfers. One of these examples is the new Brenner Base Tunnel, part of the fifth corridor from Finland to Malta. International trains will become more interesting because of route improvements.

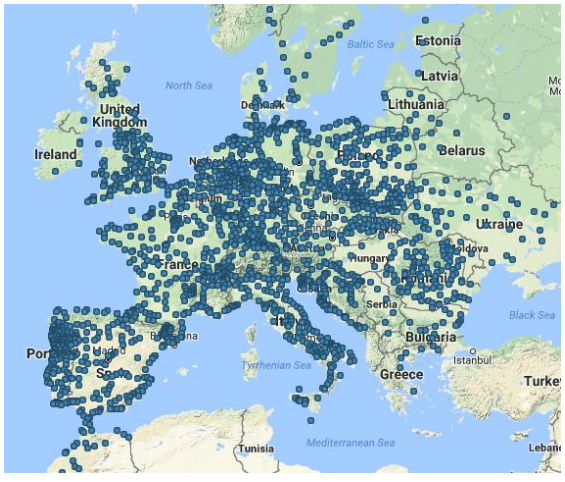


Image 3.3; Long distance coach destinations in Europe (Mellet, 2012)

Horizontal plans

Beside the nine core network corridors, there are also two horizontal projects for all corridors. The first project has to do with ERTMS deployment. ERTMS, which stands for European Railway Traffic Management System, is a new interoperable system replacing current national control and command systems. It consists of a European Train Control System (ETCS) and a Global System for Mobile Communications on Railways (GSM-R), which will be installed on TEN-T corridors. By using ERTMS, trains are available to drive in other European countries too (DG Move, 2019).

The second project is based on Motorways of the Sea. This project consists of short sea-routes, ports and important maritime infrastructure. Main goal is to achieve a clean, safe and efficient transport system by providing shipping as a good alternative for overcrowded land transport. Motorways of the Sea has already led to success in environment, logistics and traffic management, and safety.

National road infrastructure authorities are not always involved in horizontal plans. Sometimes they are only involved in TEN-T on behave of national roads. However, in case of different authority structures or in huge projects like the construction of Highspeed Railway Connections, infrastructure authorities could be involved in rail networks or waterways. The interview with Trafikverket, the transport infrastructure agency of Sweden, shows that the national ministry is involved together with Trafikverket in case of an important highspeed rail connection. It is important to note that they could be involved in these parts of TEN-T.

Multimodal networks in headlines

The strategy of TEN-T is about to implement and develop a European network of roads, rails and waterways in order to close gaps, remove bottlenecks and eliminate technical barriers between member state networks. This is being done on behalf of nine identified corridors. Also, two horizontal projects, including ERTMS deployment and Motorways of the Sea, are part of TEN-T.

Works on TEN-T corridors are identified within so-called Working Plans. These Working Plans provide information about the current state of corridor projects and outline conclusions and recommendations for the upcoming period. Important recommendations for upcoming TEN-T periods are the importance of multimodal and sustainable transport and the need for digitalisation.

Public transport is an important concern within TEN-T. It provides an opportunity for long distance coaches and international trains. With ERTMS deployment on European train connections, it will be easier for train operators to drive international routes. Although this has less influence on road authorities, it is important for authorities concerning more transport modes.

3.3 Roles in European projects

Important to realize is that current solutions in chapter 2 are solutions in EU framework projects. Following Pedro Barradas, seconded national expert at European Commission, these solutions are therefore examples about how situations could be solved; so-called 'showcase situations'. They are good examples of road authorities concerning public transport, but they are not representative for public transport infrastructure in all European countries, because of three different reasons.

First, authorities could be involved more in innovation than others. Some road and transport authorities are front-line in innovation. However, this does not apply for all European cities. There are also cities which are not innovating at all, and it can take much time to innovate within these cities. For example, traffic light priority for public transport was applied in Burgas, a Bulgarian city by 2016 (GTT, 2016), while the Netherlands did this two years earlier already for cyclists (Graham Richard, 2014).

Besides, authorities can sometimes not implement new innovations because of another policy or culture. Road authorities are sometimes faced with regulations that block the way towards an innovation. For example, think of a new overcutting bus stop placed into a building, like they did in Gothenburg. This could be hard to implement in the Wallis canton in Switzerland, because regulations on constructions will indicate this building as a 'garage', which is not allowed to build on bus stop locations (Kanton Wallis, 2016).

Finally, sometimes authorities do simply not have enough budget. With low budgets and high expenses, it can be hard to provide money for innovations. Although some money can be offered from the European Commission, it still might be hard to find retaining funds. Another important issue is that public transport needs to 'fit' in locations. Local authorities should ask themselves questions about transport interfaces. Which areas must be connected in the city? And how fast should connections be? These questions will help cities to organise a good transport system.

Framework programmes

Role division is causing difficulties in framework programme projects, because not all cities or authorities involved have the same role. This is one of the reasons why just one or two measurements are deployed in a city during these framework projects. Other reasons are the need for measurements (sometimes cities do not need a specific solution, for example if they simply not have the issue) or difference between connections.

In the CIVITAS consortium, which is a combination of different European cities working on cleaner and better transport in cities, cities created an interesting solution for the role division problem. The consortium is divided into different sub-consortiums, the so-called CIVINETS, which is based on different regulation cultures and languages. Think of a CIVINET for German countries and a CIVINET for the Netherlands and Flanders (CIVITAS, 2019).

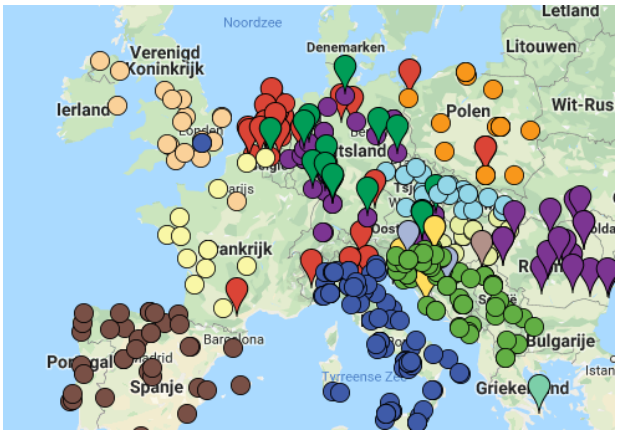


Image 3.4; overview of CIVINET networks (CIVITAS, 2019)

Not all funding options are used

Finally, cities are not always available to organise projects because of difficulties with EU funds. Following the Research Service of the European Parliament, this happens because of two important reasons. The first reason has to do with permitting problems. Funding procedures cannot be followed by cities due to inconvenient procedures. The European Commission has started to make these procedures easier so the threshold will be lower. The second reason has to do with funding problems. There are differences between EU financing schemes. All TEN-T works are based on estimated costs, while other (framework) projects have a certain amount of funding. In the framework programmes cities or regions need to fund other project parts which could be surprisingly high at the end. Cities and regions do not always want to take this risk.

European projects in headlines

European framework projects are mostly showcase-projects, which mean they are very innovative and not applied in other European regions. This happens because some authorities are involved in innovation than others, because authorities cannot implement measures because of other culture or policy, or because authorities do not have sufficient budgets.

To eliminate the problem of other cultures and policies, consortiums are placing cities together with other cities in similar countries. This makes it easier for cities to find measures which they can apply too. An interesting advantage is that countries can usually communicate in their usual language with others, as in the German speaking countries and Dutch speaking regions.

Finally, currently not all funding options in the frameworks are used. Cities experience the current funding procedures as inconvenient and they are unsure about the costs in the end of the project. The European Commission is therefore making these procedures easier, so more cities can apply for specific research projects and measurements.

3.4 Future developments

European Institutions are (except from the TEN-T) not involved in public transport infrastructure, only in the funding part. However, in interviews was indicated that the European Commission has been working on general issues in public transport which could be important for the upcoming years. This paragraph covers the most important themes on public transport infrastructure expected by the Commission for the upcoming years.

Infrastructure & traffic management

Currently the main concern is providing the infrastructure. Especially in Central Europe, new roads are being built to complete the network. Years earlier this has been done in southern countries like Spain and Portugal. Before countries can focus on management issues, it is important that roads are available and in good quality. Afterwards, the focus can be on new topics. Another interesting issue will be traffic management. East-European member states who recently joined the EU are not as far with traffic management as West-European countries. These Eastern countries are currently working on the 'traditional' topics like improvements for real-time traffic information and information about dangerous goods. Western countries have their focus currently on car automated driving and smart traffic flow innovations.

Main coordination and regulation of national transport is nowadays done by national governments. The Commission had already experienced it is hard to start a conversation about shared missions in public transport or authority roles. However, this does not apply for intelligent infrastructure and data sharing. Data sharing is a key element for developments like Mobility as a Service. Digital services need to be combined, so a shared data collecting/providing service could be an important addition. By using same standards for traffic and transport, for example with Datex II, it will be easier to connect and provide data in the future (Datex Forum, 2018).

The European Commission has one important focus point for public transport infrastructure in the upcoming years; interoperability. With interoperable they mean literally digitalisation and exchange of public transport data. Following the Commission, institutions need to focus on this point and European rules and guidelines should be set up. This makes it possible that all shared data will be in the same formats, causing new software & applications can be built on the European level.

New transport modes

One of the most important thoughts is that the future will exist of new transport modes. Various framework projects cover already attention for new modes. Personal Rapid Transit will maybe not have the form as thought (Jaffe, 2014), but other initiatives are also in research. Following UITP, a BRT system is interesting for urban regions. So, for less urban and rural regions, the greater part of Europe, other alternatives should be found. One project related to transport in rural regions is SMARTA (Smart Rural Transport Areas), covering alternatives from carsharing to a regional taxi. These alternatives reduce the costs of public transport areas and make them sustainable.

Sustainability on different levels

The last important factor for the future is sustainability. Both in the Trans-European Transport Network and in Framework Programmes the focus lies more and more on sustainable possibilities. A concrete outcome of this focus are the Sustainable Urban Mobility Plans (SUMP), which are introduced in many European city districts (ELTIS, 2019). These policy plans describe a concrete approach with themes and to reach a sustainable city or municipality.

Beside the urban mobility plans, plans are also set up on the corridors of the European transport network. Think of other fuels for ships, and charging points among the road network of TEN-T. Although this has not consequences for local public transport, it could be important for other types of public transport like the long-distance coaches. If operators are able to charge or fuel among roads, they will possibly change energy sources for their buses.

However, the need for sustainable transport lies not with all operators. Following an interview with UITP, often there are differences between Commercial Financed Public Transport (CFPT) and Public Financed Public Transport (PFPT). In case of the first one, the operator is responsible to make profit and does not receive any public funding for providing transport. This is especially the case for long distance operators. The costs for improvements are for the operator too. If an operator has the chance to choose between an affordable new bus using less diesel or a very expensive bus using electricity, the operator will of course choose the affordable bus.

In case of Public Financed Public Transport, the situation is totally different. The operator is than less responsible for making profit because the operator receives public funding for providing transport. This is the case in cities or regional public transport. Especially in rural areas, where operators are not able to make profit without public funding. Sometimes, public transport authorities are even able to fund some parts of bus improvement.

Role divisions in public transport

Another important concerning is the priority of different operators before other operators. Road or rail authorities having also their own public transport company have the possibility to give priority for their own company over other companies. Nowadays, stop posts are sometimes farther from the stops or times from other transport operators are not shown in departure information. This can for example be seen in Belgium, where the Flemish government is still responsible for both public transport operation and owning the network.

The other example happens for example with regional trains in Sweden. Regional trains are public funded and therefore less important than not-funded national trains. If national trains are too late, regional trains are usually also too late because they must wait a few minutes. This means that travellers who want to change to the bus after the regional train miss their bus. To avoid these situations, road authorities and public transport operators must always be separated from the public transport operator to avoid unfair competition. The competition rules of the internal market are main EU responsibilities, so the EU will try this in the future.

Future developments in headlines

The European Commission expects in main lines developments in three different themes for upcoming years; on infrastructure & traffic management, on sustainability and on role division. In infrastructure and traffic management a European approach will be important. Countries must work together and use the same data formats to exchange their data.

Sustainability will be important too. This is already done by approaches with SUMPs of municipalities and cities, but also transport operators and companies should be aware of sustainable energy source initiatives in the future. Although this depends on whether it has to do with CFPT or PFPT, the EC should keep the framework programmes used for sustainability developments.

Role divisions are currently not fair in every situations. In some countries, companies operating both as infrastructure manager and operator give their own company priority before other companies. Depending on specific examples, this can be in contravention of new regulations. It is something that needs to be monitored in the coming years.

In the following chapter, the results of chapter 2 and 3 will be used to get more information about authority roles. What type of authorities and authority structures can be found in these themes? What are the different roles within public transport infrastructure? And what authority structure is most efficient and effective? Questions that will be answered in chapter 4.

4. Different types of authorities

This chapter covers the different authorities involved in public transport infrastructure projects. First, different authorities are divided into different authority types. Authorities have been found during the literature study, by searching project reports on involved parties for every measure. Then, the authorities are described on the base of five identified authority structures. Structures have been set up using information from the literature study and they have been validated during the interviews.

After these five authority structures the current roles of different road authorities are elaborated. These roles in public transport infrastructure have been collected using a questionnaire, which is elaborated in appendix 2. Then, the exact collaboration ways of different authorities are described further, based on additional questions for questionnaire respondents. Finally, the chapter concludes with a consideration of structure advantages in a multicriteria analysis, leading to the most effective and efficient authority structure.

4.1 Authorities in projects

Based on the mentioned projects in chapter 2 and involved partners, various stakeholders could be identified. With the outcomes of the interviews and questionnaire, these stakeholders can be divided into two different categories; authorities and enterprises. Authorities are always public, while enterprises can be public or private. Whether and when an authority of enterprise is chosen depends on political, historical and socio-economic reasons (European Commission, 2016). Authorities and enterprises can both be set up at national, regional and local level. Even on international level these authorities and enterprises can be found, despite most traffic and transport related issues are the responsibility of member states (see also paragraph 4.1).

Public authority

Public authorities, also mentioned as statutory authorities, statutory boards, regulatory agencies, or independent government agencies, are authorities with a more bureaucratic role. Examples of public authorities are municipalities, provinces and ministries. Sometimes special departments within these organizations are responsible for roads or public transport. But usually, a road authority institute, rail authority institute or water authority institute has been set up as an underlying public organization. Based on examples in the second chapter, two types of public authorities can be identified; public road authorities and public transport authorities. Public road authorities are mostly responsible for building, managing and modifying roads. Public transport authorities are usually responsible for developing and maintaining the public transport product. This is achieved by drafting policy and checking whether rules are compiled by builders, operators and users.

Besides special departments within public authorities, some authorities do share responsibilities with other organizations. For example in the region of Amsterdam, where fifteen municipalities have combined their tasks in traffic and transport into a joint organisation (Vervoerregio Amsterdam). This organization deals with road improvements and public transport tenders in the name of these municipalities (Vervoerregio Amsterdam, 2015).

Examples of underlying road authority institutions can for example be found in Austria (ASFINAG), Latvia (Latvian State Roads), Poland (General Directorate National Roads and Motorways), and Switzerland (Federal Roads Office). These institutions are specific organizations created by the responsible ministry. All those institutions are solely responsible for building and maintaining national roads in their country. Sometimes, roads are not the only concerning. In case of Malta (Authority for Transport in Malta), Cyprus (Public Works Department), Belgium Flanders (Agentschap Wegen & Verkeer), Iceland (Icelandic Road and Coastal Administration), Andorra (Area de Mobilitat) and Finland (Finnish Transport Infrastructure Agency) the institute is beside roads also responsible for other topics including other transport modes or water management (coast protection).

Public owned company

Besides public authorities also public owned companies can be defined. These companies, also called state owned enterprises (SOEs) are seen in both roads and public transport. Degrees of influence and governance varies across countries and sectors. In some cases, governments own only a small share and the company has much organizational autonomy. In other cases, companies are more owned by governments and they need to follow governmental instructions (European Commission, 2016). Public owned companies are mainly applied in some countries recently joining the European Union; Croatia, Poland, Romania and Slovenia. However, public companies do also exist in EU15 member states like France, Italy and Sweden. Among road management, public companies are not a widely seen phenomenon (they are mostly public authorities). However, one example can be found in Hungary, where the public road company (Kozut) is responsible for operation and maintenance of national roads. Besides, Kozut is responsible for road inspections, vehicle inspections at weight stations, operation of traffic advisory, databank of national roads and a road museum (Kozut, 2019).

Public companies are more usual in public transport. Public transport authorities are responsible for organizing public transport in specific regions, so-called ‘concessions. This is done following a strict tendering process, wherein operators can apply for a contract (and on this basis provide transport in a specific period of around 6 to 15 years). However, authorities can decide to award the contract to a local public transport company if sufficiently motivated. This happens mostly in bigger European city districts like Rotterdam and Den Haag (Netherlands) and in capitals like Amsterdam, Barcelona, Berlin, Brussels, Helsinki, Madrid and Rotterdam (Van der Blij, 2017). Unlike private companies, public companies are non-profit organizations, which means they directly use their profits to maintain the company and provided services. This is especially seen in energy and rail sectors, because these sectors have only recently been open for competition. Therefore, looking at member states where SOEs are more dominant across different sectors, returns of equity in private firms are substantially higher than in SOEs. However, profitability of public companies has been more resilient to the economic crisis (European Commission, 2016).

Private company

In civil engineering private companies are very common. Much engineering is tendered by road authorities to private engineering companies. Examples of these companies are Arcadis, Arup, Bechtel, MottMacDonald and Skanska (McClements, 2019). In public transport, private companies are usually responsible for transportation of travellers or goods; they are so-called ‘operators’, who need to transport passengers in specific regions (so called ‘concessions’).

Examples of international public transport operators are Arriva, First Group, Go Ahead, Grupo Barraqueiro, Keolis, National Express and Stagecoach. These private companies need to deal with public transport authorities, road authorities and/or other companies (EPTO, 2019).

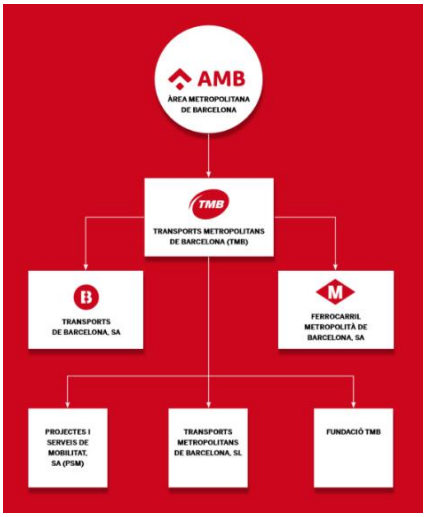
The market for public transport has been increasingly shifted to private companies in recent years as an answer on European regulations related to organisation and financing public transport in member states (European Commission, 2007). These regulations are complementing general rules on public procurement, by laying down conditions under which compensation payments in public service contracts shall be deemed compatible with rules of internal market in the European Union. Nowadays public transport operators are in most cases private companies with the exclusive right (gained with a contract) to provide public transport in specific regions.

Other authorities

Transport authorities and companies are not the only stakeholders in public transport. Also, other parties, road authorities, water managers and rail managers, have an important role in providing public transport. In a clear-cut situation there could be found a road authority for roads, a rail authority for rails, a water authority for water, etc. However, today there is no clear-cut situation; public transport authorities are not always limited to public transport, while road authorities are not always limited to roads.

Involvement of specific authorities listens very closely with authority structure. Without any European regulations about task and role divisions for public transport projects, the current situation is resulting in different authority structures causing various authority structures in European member states (CEDR, 2008). However, also non-EU-countries do have their own authority structures for public transport. It is of great importance to first know the authority structures before saying anything about roles of authorities in public transport.

Sometimes, local transport operators have an overarching agency, which is responsible for main public transport issues in a specific city region. In these regions, this agency has the role of underlying transport operators. Different to public authorities like the municipal cooperation in Amsterdam, these overarching agencies consists of public transport operators instead of authorities. Obviously, the public transport authorities also benefit from this cooperation.



These agencies, consisting of different (local) public transport operators, are seen in most bigger cities of Austria, Germany and Switzerland. Their main objective is to create integrated ticketing between various operator and make the network easier to maintain with one contact and publications office for all transport operators in the region (RIS, 2019). Over past years, this system has been adopted by other regions in Europe, for example in Barcelona, which structure can be seen left.

Figure 4.1; Metropolitan region of Barcelona (TMB, 2018)

Involved authorities in headlines

Three different types of authorities can be involved in public transport problems; public authorities, public owned companies, private companies and other authorities.

Public authorities are authorities with a bureaucratic role, such as municipalities or cities, provinces or regions and ministries. These organizations have usually set up two institutes or departments, one road department and one railway department. Public companies, also state-owned enterprises (SOE), are also seen in projects. Although they are usually not used among roads, they are more common in public transport.

Private companies have, instead of road authorities, a profit-making goal. Private companies are usually responsible for transportation of travellers and goods. In public transport they are mentioned as 'operators'. Other authorities with a managing role for roads, rails or waterways are not divided in a clear-cut model with one authority for every mode. Activities of authorities can be different for every country.

4.2 Authority structures

As discussed earlier, European countries have several authority structures. These structures are based on cultural habits and history in various dimensions; authority distance, individual vs collective, masculinity vs femininity, avoidance of uncertainty, and preferences for short-term and long-term projects (Walraad, 2016).

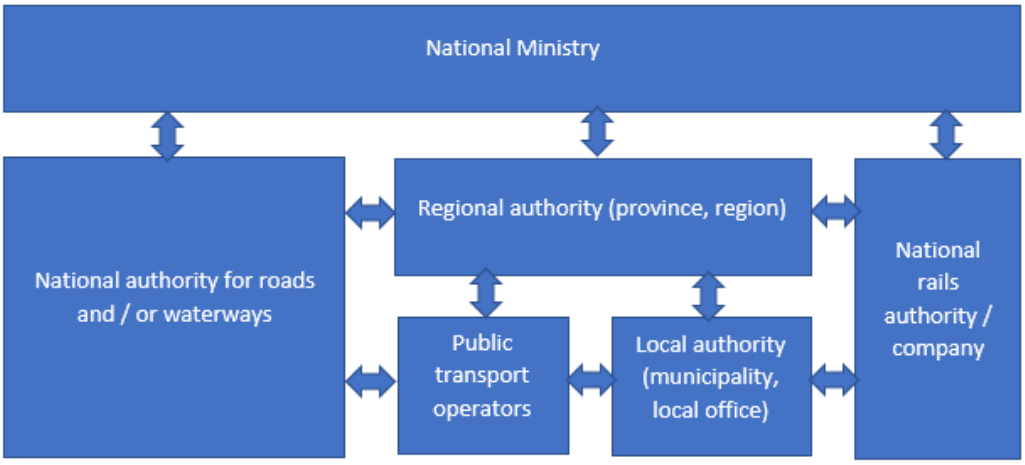
Based on outcomes of the projects from chapter 2, these authority structures can generally be divided into five types of structures; structures with separated road authority for national roads (1), direct department of ministry for national roads (2), ministry fully in charge of public transport and roads (3), national companies founded for maintaining roads (4), and infrastructure agencies for transport networks (5). These five authority structures are elaborated in this paragraph.

Separated road authority

In this case, the national ministry has set up a self-operating road authority for national roads and waterways. This national road authority is solely responsible for maintaining national roads, or in some cases also for waterways. They need to keep in contact with regional authorities about the current state of their roads and possible workings. Sometimes national road authorities need to collaborate with regional road authorities, or in very rare cases, also with public transport operators. This happens for example if a bus stop, located near a highway, will be out of service because of roadworks. Or if there are any problems with buses on motorway roads.

The structure of a separated national road authority is used in among others Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Iceland, Italy, Netherlands, Norway, Poland, Romania, Slovakia and Slovenia. Due to specific legislation on public transport in these countries, local city or municipality authorities do sometimes have a little influence too. However, this influence is in most cases very small. For example, in the Netherlands and Belgium, local authorities can advise on new PT developments, but the authority in charge (the region) usually only takes this in consideration.

Figure 4.2; Structure in case of a separated national road authority

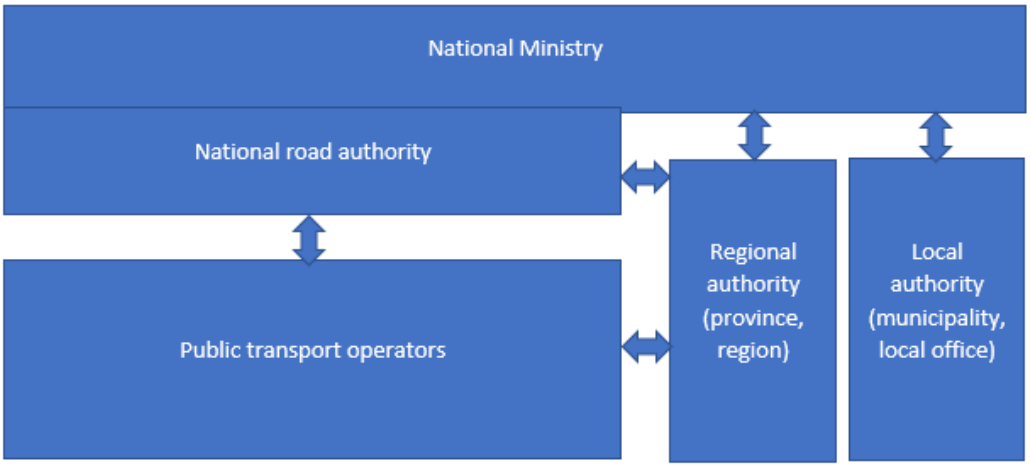


Direct department of the ministry (only roads)

In the second authority structure, the national ministry has created an internal (not self-operating) department which deals with national roads. In most cases, there task is solely related to national road matters. They are not responsible for regional or local roads. The department commonly deals with regional authorities as well as transport operators. Regional authorities are within this structure responsible for regional roads, so collaboration between the national road department and regional road authority takes place on transitions between national and regional roads.

This structure is used in smaller countries like Cyprus and Liechtenstein, but also in other countries like Croatia, France, Germany, Greece, Liechtenstein, Lithuania, Montenegro and Spain. They have in common a significant culture-related value towards authority (Walraad, 2016). Local and regional authorities expect and accept national roads are a direct matter of the ministry. Public transport operators deal with the regional authority, and for road infrastructure with road authorities.

Figure 4.3; Structure in case of an internal national road authority department

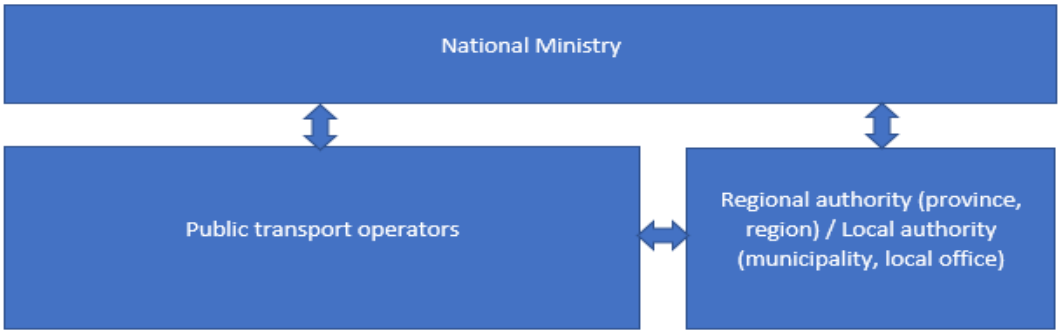


Ministry in charge

The third structure is typical for a few smaller countries in Europe. Within this structure, national road authorities are least involved in public transport. Though the ministry has mostly created a national road authority, this authority is not dealing with public transport. The ministry directly communicates with public transport operators and regional authorities, and it is responsible for providing transport in the countries' regions. Therefore, the ministry is deciding about the national infrastructure network, all public transport routes and all other issues related to roads or transport. (Ministry of Mobility & Public Works Luxembourg, 2019). Regional and local authorities normally have an advisory role in tenders for public transport and public transport infrastructure

This structure is used in smaller countries, for example in Andorra and Luxembourg. Public transport is directly organized by the ministry, and common agencies with all operators can be set up for the whole country instead of regions. This usually means one agency which is responsible for public transport in the whole country (Mobilitéitszentral, 2019). Operators do work together within the transport agency, but only the common transport agency must deal with the ministry.

Figure 4.4; Structure in case of ministry in charge

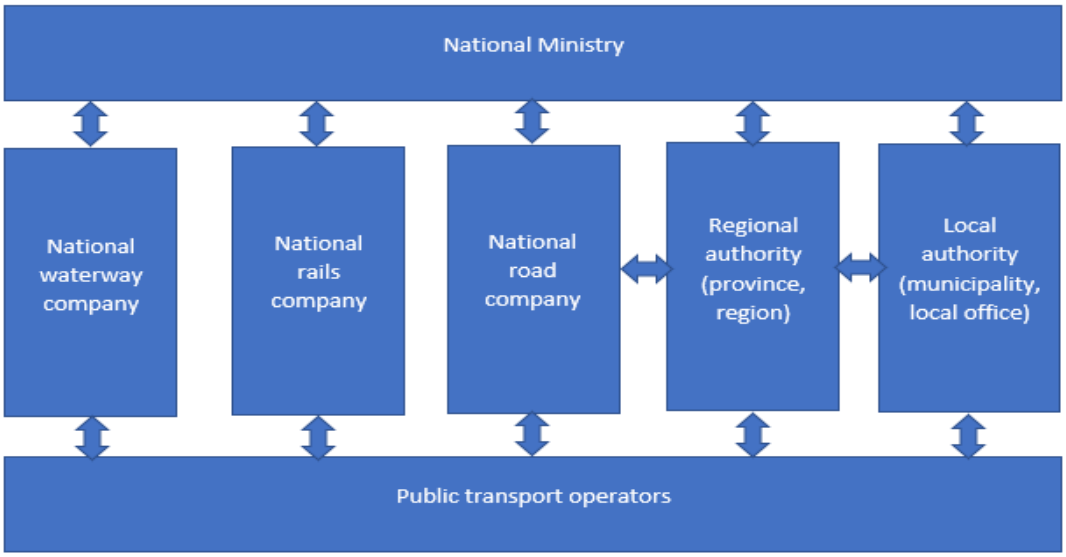


Companies in charge of roads

In the fourth structure national roads are also owned by the ministry, but instead of other structures they are maintained by a national company. In this case, the national company must deal with public transport operators using their roads. On the regional and local level, road authorities have the same position as the second structure (direct department of the ministry). However, regional and local authorities must discuss the interference between highway and regional / local traffic with the national road company.

The structure is mostly used in countries having a business or company related background, for example in Hungary and in the United Kingdom (Business Culture, 2019). Hungary has a national road company (Kozut), which has underlying companies for regional roads (Budapest Kozut). In the United Kingdom, the national government created also a national company (Highways England), which is responsible for highways in seven HE-regions (Gov UK, 2019).

Figure 4.5; Structure in case of national road companies

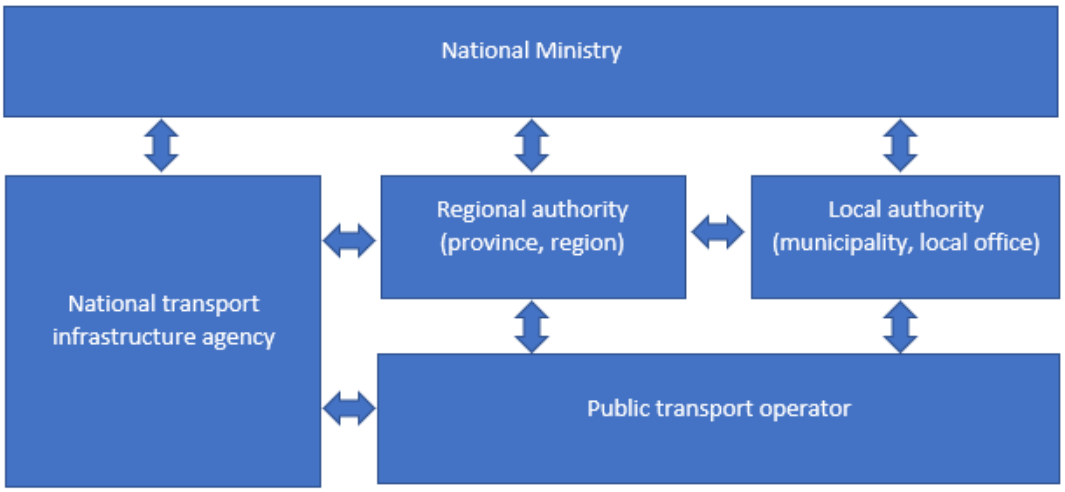


Transport infrastructure agency

The fifth structure is a combination of the structures. In this structure, the national ministry created a so-called national transport agency which maintains all transport infrastructure in the country (in most cases roads, rails and waterways). Sometimes this agency is only responsible for national networks, but they can also be responsible for regional or even local roads.

Depending on the level/scale of their works, they collaborate intensive with regional or local authorities. Also, a collaboration with public transport operators is important for the transport infrastructure agency, because the operator is using the network. This structure is used in Finland, Portugal and Sweden.

Figure 4.6; Structure in case of national transport infrastructure agency



Research from three Greek public transport experts on roles and tasks for the Transport Research Arena in 2012 endorses these five structures in headlines. They distinguish basically three public transport models: authorities which have been created by public authorities and are responsible for the strategic and tactical levels, historic operators which turned gradually into public transport authorities responsible for the tactical level, and authorities in charge of several metropolitan issues, with public transport as main part. The first model is mostly used in Spain, Germany and France, the second model is mostly used in Milan, London, Rome and Brussels, and the third model is mostly used in Copenhagen and Helsinki (Naniopoulos, Genitsaris, & Balampekou, 2012).

Authority structures in headlines

Involved authorities do fit in different structures. Although every country has its own structure, in mainlines five different structures can be distinguished; separated road authority, direct department of the ministry, ministry completely in charge, companies as road maintainers, and the so-called transport infrastructure agencies.

In one of the structures, a separated road authority has been set up by the ministry. This authority operates autonomously and is (depending on the country) responsible for national roads or roads and waterways together. In another structure, the ministry created a direct ministerial department for national roads. Ministries have more influence on the authority's strategies in this case.

Sometimes, the structure goes further. In smaller countries like Andorra and Luxembourg, the ministry itself is the direct contact person for national transport networks. Another option is that transport concerning is responsibility of a company, where different companies are set up for every mode. The latest strategy consists of a transport infrastructure agency, which is responsible for all transport networks in a country.

4.3 Current roles in public transport

Authorities can be involved in public transport in many ways. The authority structures have shown the involved parties in public transport in different countries. However, roles of authorities are still different within these structures. A sample among road authorities during the questionnaire has shown that most road authorities have organizing / leading roles within projects on public transport. Followed by contributing / working roles and organizing / funding roles. This paragraph elaborates which stakeholders are involved in every type of role. This applies for both national, regional and local road authorities.

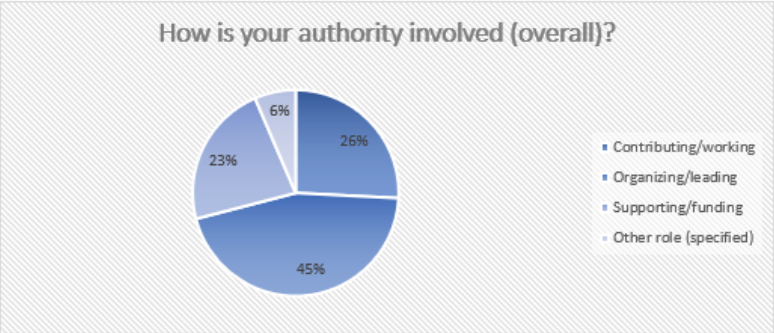


Figure 3.1; Road authority involvement

Usually there is an unwritten rule that the paying stakeholder is the deciding stakeholder. However, in public transport not all countries and regions have the same system. Furthermore, roles and tasks including responsible authorities are in some countries also legislated. Therefore, it is very important to realize there are several roles that could be taken by different stakeholders.

Contributing / working

Some stakeholders have a contributing role in public transport, which means they are not leading the project. Usually they are involved because of their responsibility. This applies for example for Area de Mobilitat (Andorra), Public Works Department and City of Limassol (Cyprus), Aalborg Komm. (Denmark), Transport Infrastructure Agency (Finland), General Directorate on Roads & Motorways (Poland), Urban planning Institute Belgrade (Serbia), and Verkehrsplanung Bern (Switzerland).

In case of accessibility projects, this role is mostly given to transport operators. They are not deciding about new stops and regulations, but they must cooperate. Depending on the freedom in tenders they could have influence on public transport vehicles. But also, road authorities could be involved in a contributing way. For example, they could be responsible for the roads which are used by public transport. In case of energy & fuels, this role is mostly given to road authorities. They are not involved in issues related to energy & fuel, unless projects need to be carried out in 'their' public space. For example, in case of electric buses that must be charged on roads, the corresponding road authority is responsible for it.

Within network planning the contributing role lies also with road authorities. Depending whether responsibilities are set up in a transport department or into specific departments for every mode, road authorities have a contributing or deciding role in this point. In case of software & applications the contributing role lies in most cases with the transport authority. However, sometimes an operator creates their own application, wherefore it needs to take a more leading organizing or leading role. Besides applications, contribution takes also place concerning on-street software. For example, in case of priority for buses at important crossings.

Finally, private companies and consultancy firms do have a contributing role in new public transport modes. Private companies work for projects, because they invent and realize the systems mentioned in paragraph 2.5 and sell them to the authorities and operators in public transport. Consultancy firms do also have a contributing role because their research contributes to the projects.

Image 3.3; Working role (McBride, 2012)

Organizing / leading

Other stakeholders have an organising role in public transport, which means they are leading the project. They usually work together with implementers (like contributors) and supporters (funders). This applies for example for City of Graz (Austria), Agentschap Wegen & Verkeer (Belgium), Capital region (Denmark), Department of Infrastructure Aland and Föli (Finland), Citta Metropolitana Bologna (Italy), Riga city council (Latvia), Gemeinde Vaduz (Liechtenstein), Byplankontoret Trondheim Komm. (Norway), Ministry of transport & Infrastructure and Municipality of Bratislava (Slovakia), Generalitat de Catalunya (Spain), Urban transport administration in Gothenburg City (Sweden) and Administration communale de Clervaux (Luxembourg).

In case of accessibility projects, the organising role is mostly taken by public transport authorities, or within another separation, by transport infrastructure agencies. They are responsible for planning public transport connections as bus lines. Sometimes, the planning and maintaining task lies with a regional authority which is solely responsible for the tendering and planning process. In this case, the transport infrastructure agency is solely responsible for providing the network. With energy & fuel issues the organising role lies with even the (public) transport authority or the transport operator. On the one hand, transport authorities can lay down requirements for clean vehicles and using of other fuels. But on the other hand, transport operators can technically also change their vehicles or fuels by themselves if they want to lower the fuel costs (see also paragraph 2.2)

By network planning, in most cases the public transport authority has the organising role. They need to point out the network together with road authorities. Road authorities are involved in this point because they have the right specifications of roads (maximum curves and ranges, speed limits, etc). These specifications could be of great importance by deciding routes for and locations for bus stops. Within software and applications, there organising role lies now mostly with the transport authority. Transport authorities see it as a service for customers (travellers) to provide information about transport. However, as said, sometimes this is also done by the operator. This is especially the case if an operator is forced to create an application, based on requirements in tenders.

In case of new public transport modes like rapid transit systems and others, the organizing / leading role lies with transport authorities. Usually public transport authorities take this role because of their public transport role. However, this role can also be applied to road authorities or the transport infrastructure agencies, because they must realize (adjustments for infrastructure) on these roads. In this situation the paying stakeholder is the deciding stakeholder.

Image 3.3; Leading role (CNE, 2019)

Supporting / funding

Beside contributing and organising roles, stakeholders could also have a supporting role. In most cases this role technically exists of funding (parts of) a public transport project. Mostly no other role is taken, but sometimes a supporting stakeholder can also have a smaller advising task in projects. This applies for example also for ASFINAG (Austria), Stad Gent (Belgium), Road Administration (Estonia), Public Road Co (Hungary), Road & Coastal Administration (Iceland), Gemeente Eindhoven (Netherlands) and Federal Roads Office (Switzerland).

Within accessibility issues the supporting role is in most cases not applied to any national, regional or local authorities. However, this role is a typical role which is in EU countries taken by the European Commission. They are not allowed to create policy regarding transport issues in member states, but they can support projects within the member states (see also paragraph 4.1). In case of energy and fuels, the supporting role is mostly taken by either public transport authorities or the Commission. Infrastructure and vehicles for new energy sources are currently very expensive for operators. With extra subsidies from transport authorities and European programmes these buses can be bought.

In network planning, the supporting role is taken by the transport authority. Running costs for the public transport system are paid by transport authorities based on a contract. They need to provide money to operators to establish the service. With software and applications, the supporting role is taken by both transport authorities and road authorities. Depending on who is realizing the application or who is implementing the software, the road or transport authority needs to support.

For new transport modes, this is a more complicated situation. Nowadays most information about new transport modes is only based on research and a couple test cases. However, implementation of these modes may cost a lot. To test more cases and eventually lower the implementation costs, more research is needed. Therefore, more research opportunities, especially together with universities and study institutions, are funded by the European Commission together with national ministries.

Image 3.3; Funding role (FOWF, 2019)

Other roles

Contributing, organizing and supporting are main pillars of involvement, but they do not stay on their own. Also, other involvements do exist. For example, some European countries have organised so-called 'consumer focus groups' or 'traveller boards', which are giving their opinion on new transport issues. They could be involved during concessions of public transport, in case of new timetables for public transport or for example if transport authorities or operators need more information from a specific user group in public transport.

Besides the involvement of consumers, also a regulatory role is of great importance. In all European countries, the national government decides about general issues related to public transport. Besides, national governments are responsible for creating policy in the field of public transport. Sometimes, role divisions are very different. This is for example the case in Malta, where the National Authority for Transport has a far-going regulatory role in public transport. They are the transport authority, but their responsibility consists only of the regulations. Another interesting role is the role of Trafikverket in Sweden; they are responsible for maintaining and improving the transport network, but not for other public transport tasks.

Finally, there are authorities who are completely not involved in public transport. Of course, buses are still using their roads, but they do usually not communicate with the organisations. This is the situation of State Roads (Latvia) and Regio Arnhem Nijmegen (Netherlands).

Image 3.3; Other roles (FPNG, 2018)

Authority roles in public transport

Public transport covers many items. Therefore, authorities and companies are and can be involved in many ways. First, there is a contributing role. Authorities are involved because of their responsibilities. Road authorities (especially on the local and regional level) do mainly have a contributing or working role, because they technically own streets and public spaces.

Another involvement is the organizing or leading role. During projects, this role is mostly taken by public transport authorities or transport infrastructure agencies. They use policy for operators about data provision and vehicle measurements. In case of a supporting or funding role, authorities do fund parts of the project. This is normally done by EU institutions, as the European Commission.

Besides these three roles, there are also other roles. Some European countries have organised focus groups or traveller boards where representatives of consumers give their opinion on transport issues. Another role is a regulating role, where authorities do create national policy around public transport. Usually this is done by national ministries.

4.4 Collaborating authorities

Road authorities collaborate on different topics in public transport. To gather the most important collaborations, authorities have been asked to select points where they work together. The question existed of four main collaborations which have been indicated as important issues in earlier CEDR research projects. These collaborations include planning public transport networks and park & rides, enabling public transport for dedicated signalling, working together on developments of MaaS and sharing traffic and public transport information.

Following road authorities that filled in the questionnaire, one of the most extensive collaborations is sharing traffic and public transport information. Answers to additional questions do especially refer to the points mentioned in paragraph 2.4 (software and applications). This is in line with new policy ideas of the European Commission, which are about to integrate data from separate authorities and operators into one data standard.

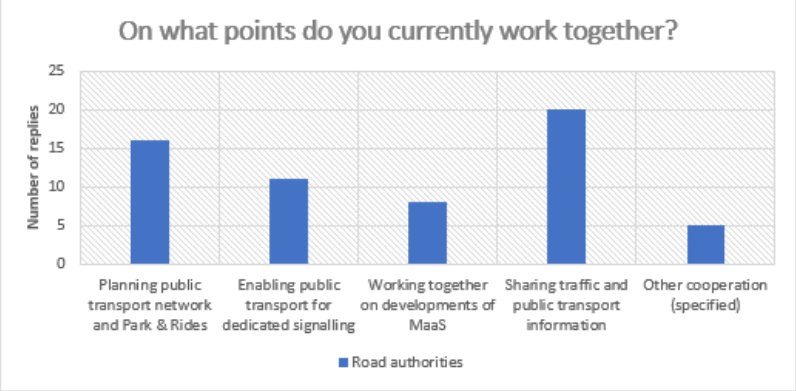


Figure 3.2; Collaboration in PT infrastructure

Data sharing is not limited to the European continent. Authorities outside Europe, for example in Asia, are also going to integrate data from private vehicles in their public transport. Global Navigation Satellite System (GNSS) technologies and installed in-vehicle units will make it possible to collect real-time data on road traffic in Singapore. This real-time data is used by the Land Transport Authority to develop more accurate pictures of real time traffic and to adjust traffic light timings to provide a better flow for buses (Business Times, 2017).

Another information sharing and collaboration example can be found in Europe. For the Transport Systems Catapult in the United Kingdom, a group of UK governments, business and universities created a catalogue of over 200 datasets for transport. They identified 11 transport-related gaps which could be filled with this data. Think of weather data, current disruption information, and the standard schedule, which have all influence on the accurate departure time of the next bus (Integrated Transport Planning Ltd, 2014).

Next to sharing information, planning the public transport network and Park & Rides is seen as a common way of collaboration. It is not a surprise that road authorities work together with transport authorities and operators at this point, because parties certainly need to collaborate here. The road authority often builds the physical location (parking places, bus platforms, lightning, etc), while the public transport authority organises the IT (travel information displays, interaction signalling, etc).

Though Park & Rides are mostly situated at train stations, they can also be placed at highly frequent bus stops or near so-called BHLS (Bus with High Level of Service) systems. Collaborations do include but are not limited to Park & Rides. Following Research of the European Cooperation in Science and Technology, also infrastructure adjustments are necessary to establish BHLS services (COST, 2011).

Most road authorities indicate that the current role division works for all their involvements in public transport projects. However, still 36% of the authorities say the current division works only in specific projects or does not work at all.

Public transport operators (and authorities) experience the same situation as road authorities. They see the problems with roles and tasks especially occur in charging electric buses. To establish public charging points, many different stakeholders must be involved. Public transport parties do not only need to work with road authorities, but also with electricity cable operators, energy suppliers, safety guidelines and more. They indicate that a solution is needed to solve the problem of this unclear market.

Collaborations in public transport

Collaborations between road authorities and public transport exist in different ways. The most common collaboration is working together on sharing information. However, this has particularly to do with standard information, because sharing traffic and transport data is currently not widely introduced between these authorities.

Another important collaboration is planning the public transport network and Park & Rides together. This is an obviously result, because road authorities do usually own the Park & Rides and public transport authorities do own the transport network. If they were not collaborating here, Park & Rides would not exist because there is no transport connection (Ride) or parking facility (Parking).

Other important collaborations are enabling public transport for dedicated signalling. This has to do with priority for public transport at traffic lights, tolls and barriers. This option is mainly mentioned by regional and local road authorities, because traffic lights are mainly applied in urban regions.

4.5 Consideration of advantages

Every structure has its advantages and disadvantages. Although authority structures are usually based on national identity and culture, there are still projects where roles are not optimal. The questionnaire among road authorities shows that current role divisions do not work in 36% of projects. Following the interview with UITP representative Arno Kerkhof, longer duration is especially common in case of charging infrastructure projects in public space. Looking at these projects, it does make sense to consider other role divisions and compare authority structures with each other. This paragraph deals with various advantages and disadvantages of the authority structures.

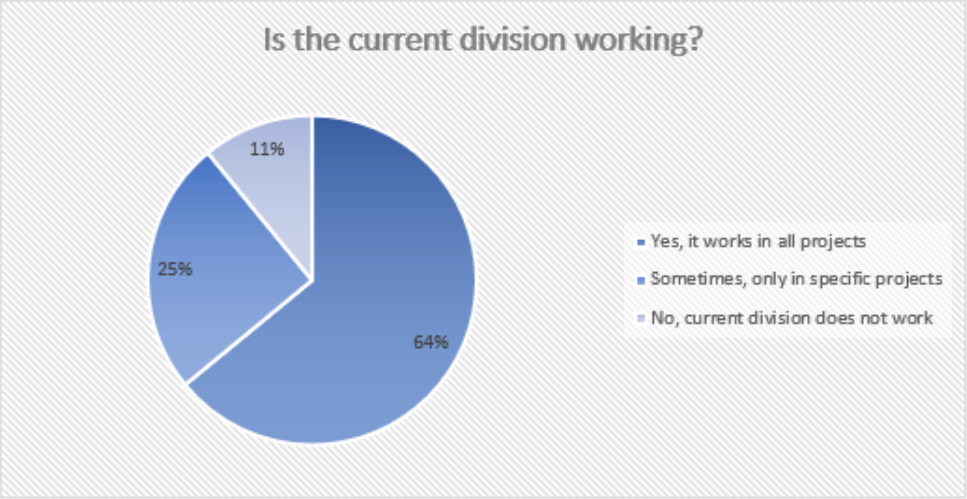


Figure 3.3; Current division thoughts

Efficiency considerations

Efficiency of authority structures listens very closely. One of the first points concerning efficiency is duration time. In case of ministerial departments there is a smaller need to respond directly, because they will not be judged on this. Projects will take longer because of bureaucratic procedures. This is different for companies or separated authorities and agencies, because they are more driven to keep deadlines (L'institut d'administration publique du Canada, 1980). Another point has to do with the organizational costs; specific organizations or businesses requires several HR facilities, while one HR facility is enough in case of a ministry or transport infrastructure agency in charge.

The third important efficiency concerning is a logical role division. Following research of PIARC, the World Road Association, responsibilities of different authorities are reflecting applicable legislation (PIARC, 2019). Although the research of PIARC was focused especially on road safety, the note that projects could be complicated in situations where responsibilities are divided between authorities or departments does apply for role division in general. With other functions which are carried out by a different authority, there is a new challenge of reaching agreements with other authorities about consistent practice in projects. Easy to understand role divisions could make this easier.

Besides, the authority needs to match with current EU regulations. This does apply for all structures except the structure with a company in charge. In that situation, the company may possibly award contracts or priority to their partners without taking an objective neutral role. Following interviews with the commission about TEN-T, this happens for example in case of national railway companies that own also the railway network in their country. The latest efficiency concerning is innovations; the authority structure should provide easy opportunities for innovations. Companies are naturally driven to come with new innovations, while this is less the case with governmental authorities.

Effectivity considerations

Of course, it is very important that the project goal must be reached. After completion of projects, it can be assessed whether the goal has been reached. Based on the literature research in the projects of chapter two, goals were reached in all projects. Thus, reaching the project goals is not influenced by the structure, making all structures fit in this consideration. The second concerning has to do with knowledge sharing. In a separated authority or department, there are limited or no insights about developments in other transport modes. This does also apply for companies, which do normally keep their information private. However, following the interviews with Trafikverket and AER, it makes sense to merge different knowledge from organizations to come to new insights.

The third concern has to do with organizational development. The implementation of the new transport infrastructure agency in Sweden took easy almost ten years, developing a new separated rail transport company in the Netherlands took the same time (ProRail, 2019). Changings in direct ministry departments are usually easier to implement than in separated authorities or companies. Another point of view is related to the stakeholders. In order to let projects, succeed, it is important to have the right contact. In case of transport infrastructure agencies or ministries it is not necessarily clear which person or department you need to contact for issues relating roads.

Then, the stakeholders involved need to be involved in the right way. Their tasks, knowledge and work need to fit the project steps. The collaboration of road and transport authorities within a multimodal application based on a direct ministerial department is a good example of stakeholder involvement. However, this is not possible in all structures. In case of companies in charge, there is not always a need to share data. Sometimes road or transport authorities do even keep their data private in order to prevent their products and information from competitors. Different interests can make it difficult to serve the public interest.

Finally, political influence on organizations can be too much or less. Ministries and politicians have direct influence on ministerial departments and ministry issues. In case of companies, separated authorities, or transport infrastructure agencies, the ministry is still the deciding but there is more space for interpretation. Experts in these organizations can judge many things themselves. This means theoretically less work for the ministry, because they are not involved in small decisions, for example adapting nodes or renovations of bridges.

Analysis

Based on the considerations in efficiency and effectivity, we can create an overall analysis of the different structures. Using a multi criteria analysis with values between - - and + + makes it possible to create an unbiased view of every advantage on behalf of the authority structure, without calculating the values into costs. Expressing these relative values in costs is impossible.

The authority structures including the results of this analysis have been discussed and validated during an expert session. Experts rated the five structures as representative for public transport infrastructure. However, one expert did not agree because the role division could be different in practice. In most countries clear goals are set up on the national level, but in local projects role division could still be different. Besides, the expert group noted that a transport infrastructure agency could still exist of different departments, causing a less knowledge sharing effect.

Table 4.1; Multi criteria analysis of authority structures

	Structure 1 *Separated authority*	Structure 2 *Direct min. department*	Structure 3 *Ministry in charge*	Structure 4 *Companies in charge*	Structure 5 *Transport infr. agency*
Efficiency	**+**	**-**	**-**	**+**	**+**
Duration time	+	-	-	+	+
Actual costs	-	-	+	-	+
Easy division	+	+	-	+	+
Matching EU	+	+	+	-	+
Innovations	-	-	-	+	-
Effective	**-**	**+**	**+**	**-**	**+**
Goal reached	+	+	+	+	+
Knowl share	-	-	+	-	+
Org. develop	-	+	+	-	-
Stakeholders	+	+	+	-	+
Sensitive (pol)	+	-	-	+	+
Overall	+-	+-	+-	+-	+

Following the analysis above, the 'best practice' authority structure is the transport infrastructure agency. Although things can be said about advantages and disadvantages of specific structures, it is important to realize that these structures are based on national identities and cultures. Changing them could therefore be difficult. In addition, it is important that all involved stakeholders in public transport infrastructure projects are involved in authority changes. They also need to agree with the new structure, because projects will not work at all if the necessary stakeholders do not collaborate.

Besides, governments need to anticipate on long turnaround times before new structures are really functioning. Following the interview with Trafikverket, the realisation of the structure with new transport infrastructure authority instead of separated authorities went fast, but the time before the new organization finally started effective working was almost nine years.

Consideration of advantages in headlines

Different structures have different advantages, which can be separated into efficiency advantages and effectivity advantages. Efficiency advantages are the influence of authorities on project time, actual costs of organization, extent to which role division is logic, whether the structure matches EU regulations and extent to which innovations can be set up.

Effectivity advantages are whether the project goals are reached, extent to which knowledge can be shared within the organization, the simplicity and duration of adjustments in structure, possibilities for data sharing (interoperability) and political sensitivity.

If the different authorities are considered in a multi criteria analysis, all authority structures could be the right way of implementation. Though the transport infrastructure agency is the only structure with a good efficiency and effectivity score, this cannot be seen as the best structure because national identity and structure could be different in every country.

5. Conclusions & Recommendations

This chapter provides the conclusions and recommendations based on previous research steps. It starts with the final conclusions which provide the answers on the research questions. The second paragraph contains recommendations for CEDR and national road authorities. The latest part of this chapter consists of a discussion paragraph, which evaluates the used research methods and the outcomes of different research steps.

5.1 Conclusions

Conclusion 1: Road authorities are involved in five different themes

Road authorities are involved on five themes related to public transport; accessibility, energy & fuels, network planning, software & applications and transport modes. Within these five themes different involvements can be found; covering innovative bus stops, combinations of park & ride, personal rapid transit. Also on the European level, international research projects are set up on public transport infrastructure. In these projects, road and transport authorities in European areas (mostly cities) collaborate on mentioned themes, while sharing knowledge and best practices with other cities' authorities.

Conclusion 2: Role divisions are different for specific projects

Role divisions and involved partners are different for every project. In case of small projects related to bus stops within urban areas, municipalities usually collaborate with the local transport operator. On the regional level, also the public transport authority is involved. Depending on the country, public transport authorities could beside public transport also be responsible for regional road or railway infrastructure. In case of national projects, the national only-road concerning authorities are solely involved if roads must be temporary closed to let projects succeed or if the project has influence or consequences for road traffic safety and road traffic flow.

Conclusion 3: Role divisions cause difficulties in shared projects, but not in TEN-T projects

Road authority's involvement in infrastructure happens in particular by regional and local authorities. With international shared research projects, authorities try to collect best practices from each other and share their knowledge. Currently there are no European regulations about role division in public transport infrastructure. Therefore, it is not always clear which tasks specific partners have within a project, causing that copying the best practices of other authorities could be difficult. Role division between different authorities has no consequences on the European multimodal transport network (TEN-T) and his hubs, because TEN-T corridor coordinators have only to do with the member states. It is up to member states to involve other authorities and stakeholders in the projects.

Conclusion 4: Five authority structures can be identified in public transport infrastructure

Road authorities own the roads and public transport authorities own the public transport system. However, this is not the way how roles are organized in all European countries. Three types of authorities can be identified; road authorities (at different levels), transport authorities and transport infrastructure agencies. Following these roles, five different structures of authorities in public transport can be found: separated authorities which are fully in charge of specific transport mode infrastructure, direct infrastructure departments of ministries, ministries fully intern in charge, business companies with a road maintaining role, and transport infrastructure agencies that develop and maintain infrastructure for all transport modes.

Conclusion 5: Transport infrastructure agency is generally the best option

Separated road authority organizations and companies in charge are efficient, because they are able to react fast on questions of other authorities and they have an easy to understand role division. However, a separated authority could be less innovation-driven and a structure with state-owned companies does not match legislation if transport operators do have also the responsibility to coordinate the network. Infrastructure managers and transport operators should always be separated to avoid any unfair competition. Direct departments of ministries and ministries in charge are more effective because they have an organizational focus with very clear objectives. However, they are less able to react fast on questions of other authorities. Based on the project outcomes, the transport infrastructure agency seems to be the most effective and efficient way.

Conclusion 6: Structures are based on national culture and identity

Though a transport infrastructure agency for all transport modes is considered to be the most effective and efficient way, authority structures are closely related to history, culture and identity. In addition, countries have their important practical reasons why the current structure has been chosen. This makes it impossible to advise a new role division for public transport infrastructure projects which should be implemented in all European countries. Divisions that might work in a specific country will not work in other countries. Some countries prefer a national company only for roads, while others prefer a transport infrastructure agency which maintains also railways and waterways.

5.2 Recommendations

Based on the conclusions and research that has been carried out, the following recommendations are given about the role division in public transport.

Identify authorities during the start of projects

To understand what influences the involved authorities in projects have, it is important to know the structure which is used in the country. Besides, it might be useful to discover the history, identity and culture of other countries or regions too. This is important to understand because it clarifies whether different measures could be taken in other countries or not. With this information, road authorities have background information for deciding which measures could be taken or not.

Monitor the effectivity of current role division

It is also important to monitor the current effectivity of the used roles in projects. If projects go wrong on one of the consideration reasons (duration time, project costs, easy to understand role division, extent of matching EU regulations, possibilities for innovation, reaching project goal, knowledge sharing, how much time changes will take, simplicity to find responsible contacts and extent of political sensitivity), one needs to consider if the project roles should be changed.

Provide more attention to this topic

In current framework projects and their approaches, the role of road and transport authorities is a less mentioned aspect. To provide any problems by copying best practices, project partners should note that roles could vary if authorities from different countries are involved. The approach of the CIVINET concept where authorities with the same structure are combined is an interesting option if authorities want to collaborate easier.

Further research

This research provides important conclusions about public transport infrastructure and suggests a better role division. To implement role divisions in specific countries, more information on aspects like history, culture and national transport network is needed. Another recommendation is to organise further research on this field to see if better role divisions are possible for these projects, especially when it comes to sharing public transport and road data.

5.3 Discussion

The research consists of different research steps (expert session, interviews, questionnaire) which have contributed to outcomes in large and small scales. However, a few steps have had a different effect or result than was previously foreseen. This section deals with the results of research steps and the extent to which they have contributed.

Literature review extent

Public transport is a very broad term. To delimit the literature review and make it manageable, it was necessary to keep the research limited to a few sources. Because of this, most mentioned examples of public transport infrastructure have been collected in EU frameworks. This caused that only the EU funded projects were involved in the research. To avoid this, I decided to use for examples during the questionnaire and interviews too.

Overall, the literature review took me much time. Especially in the beginning, where I studied the first parts directly after delivering the plan of actions. In new projects it will be useful to define the research questions more specific. Then, it can be prevented that the research becomes too wide. However, in this project and on this abstract (European) level it was not possible to define the questions further without skipping important steps.

Questionnaire goals & response

The questionnaire has been set up as a supplementing research step. Sending it to all respondents was difficult, because I received a lot of 'undelivered' e-mails back. Probably because the e-mail addresses were not up to date anymore. I decided to find other contacts for these respondents, until every potential respondent has received one mail. A better way was to interview all respondents in person, but there was not enough research time.

From 153 sent questionnaires, 33 reactions were collected. Probably this was happened because the mails were sent to EB-members of CEDR. I heard from one of the interview respondents that EB members are very busy and could therefore have no time for the questionnaire. However, because the given reactions were spread over several countries and different levels of road authorities (national, regional and local), the results were sufficient.

Interviewing possibilities

During this project, many interviews were organised with experts and representatives. Because of differences in knowledge and experience, it was necessary to adapt interviews to the specific persons and organizations. This took a lot of preparation time before the interviews, especially because the project consisted of eight interviews. Henceforth it will be easier to work out different formats of interviews with standard questions which can be used for all persons.

Some interviews were held using a Skype connection. Unfortunately, the connection was a few times lost so a couple topics need to be discussed several times. Next time it would be better to speak everyone in person. In these situations, there was no other way because the persons were during the interview in another country.

Expert session approach

The expert session was a good way to validate the research results and the outcomes of the multicriteria analysis. Although the experts were more experienced on traffic management than public transport and role division, they knew something about their organization and structure. Within the given time, this was the best working group to collect information.

I decided to set up four theorems to let the experts vote live on their phone. Because I was not fully familiar with the technical situation, I selected a Likert scale with five answer options. This caused that some experts chose predominantly answers around the middle. If I use a digital system like this again, I need to select three answer options, so the results can be discussed easier. Besides, it will be important to check the quality of the internet connection beforehand.

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Appendices

Many appendices have been produced during this research. Below you will find the elaboration of the various appendices.

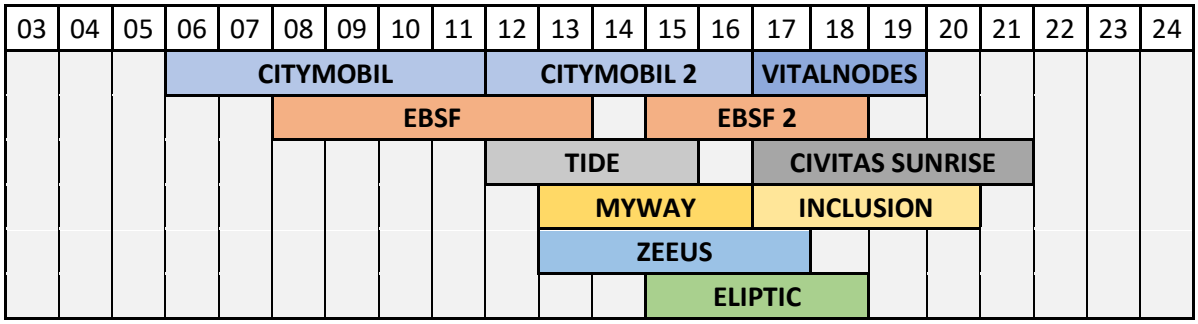
Appendix I	Elaboration of literature study
Appendix II	Elaboration of questionnaire
Appendix III	Elaboration of interviews
Appendix IV	Elaboration of expert session
Appendix V	Overview of involvements

Appendix I – Elaboration of literature study

In order to achieve specific physical and digital infrastructure projects, several cases and studies from eight EU collaboration projects have been used. Cases and studies were collected using the CORDIS databank, which provides information about European research projects and their results within the Horizon 2020, FP7 and earlier frameworks. Besides, the VITAL NODES project (in which CEDR is also involved) has been used to explore the design and developments in research projects. This appendix provides a detailed overview of the used European projects and their outcomes (results).

The EBSF and ELIPTIC projects are, because of their wide scale, elaborated in detail. Their sources are elaborated in the reference list. The other projects (CITYMOBIL, INCLUSION, MYWAY, SUNRISE, TIDE and ZEEUS) have been used and analysed but not elaborated in detail.

Table 1.1 (Timeframe of research programmes)



PROJECTS OVERVIEW

CITYMOBIL	Advanced Transport for Urban Environments	2006-2011	2012-2016
EBSF	European Bus System of the Future	2008-2013	2015-2018
ELIPTIC	Electrification of Public Transport in Cities	2015-2018	
INCLUSION	Accessibility and Inclusiveness of Public Transport	2017-2020	
MYWAY	European Smart Mobility Research Manager	2013-2016	
SUNRISE	Sustainable Urban Neighbourhoods Research	2017-2021	
TIDE	Transport Innovation Deployment for Europe	2012-2015	
ZEEUS	Zero Emission Urban Bus System	2013-2017	

EUROPEAN BUS SYSTEM OF THE FUTURE

The European bus system of the future projects, also EBSF or EBSF2, were two EU funded projects during September 2008 - February 2013 (EBSF) and May 2015 - April 2018 (EBSF2). Although the projects have the same name, they differ slightly in their interpretation and implementation. EBSF (2008) was mainly aimed at improving the image of bus systems. At that time, in many European cities the bus had to deal with a bad image, causing low attractiveness.

The newer EBSF2 (2015) was more aimed at improving the efficiency of bus systems, which could be improved in this time. In the pilot cases of Barcelona, Dresden, Gothenburg, Helsinki, Lyon, London, Madrid, Paris (region and city), Ravenna, San Sebastian and Stuttgart, innovative solutions have been tested that makes the public transport system more efficient in terms of capacity, exploitation costs and social awareness for (different types of) passengers.

Barcelona (EBSF2)

In Barcelona (Spain), the EBSF2 project has been testing technological solutions to increase the efficiency of fully electric buses. Besides, the project was about to promote fully electric buses as the best zero-emission transport solution for cities. In the older ZEEUS test project, two buses of 12 metre have already been operating on different routes through the city centre. The final results of that project showed that electric buses could be even operate more efficient, so the test was extended in EBSF2 with new technological tests, which were mainly based on extending the driving ranges and reducing the energy consumption of the electric bus (ESBF2, 2018).

The two electric buses were equipped with an intelligent self-learning management system that optimises the energy demand between various the auxiliaries of buses. In addition, the storage units for energy have been developed, for making it possible to stage more energy. The cycles on specific routes were similar for the electric buses. Using the same routes makes it possible to test and follow the self-learning system that should optimise the energy requirements.

Besides the learning system, the buses were equipped with a driver assistance system. This system was sending information to the back office of the bus operator, making it possible to assess the impact of the driving style on energy consumption. Comfort and safety were automatically considered by the system.

Image 2.1; Electric bus (Electrific, 2016)

Using the energy management system for the auxiliaries caused an average saving of energy of 57%. Especially the air compressor and steering pump were running more efficient by the system. Using advanced climate software in combination with all-in-one heating, ventilation and air-conditioning increased the efficiency with 11,5% and even a part of maintenance costs. The assistance system was also assessed well under drivers, who said it helped to prevent abruptly starts and stops by half.

Dresden (EBSF2)

Driving with long buses while there are a few travellers does not make sense. In Dresden (Germany), the EBSF2 project has been testing a new way to improve flexibility of public transport vehicles in relation to the demand. Combining bus segments by coupling and uncoupling parts of the bus in the depot was an option to increase flexibility. In this case the test was not only focused on the technical challenge, but also on the added value for public transport operators.

The research was also about the needs-based adaption of bus lengths in operations. It was proposing to split a multi-unit bus to make the trailer detachable at articulation points. The remaining part of the bus can be used independently. The aim was to check if the process could be carried out easily, quickly and safely, both physically (with coupling and uncoupling the physical bus parts) and digitally (with connecting and disconnecting electronic devices, cables, etc)

Image 2.2; Uncoupled bus (EBSF2, 2017)

The results of this test were promising. Fully coupling or uncoupling buses is, following test results, possible with two workers in about 7 minutes. This was not only for the physical process, but also for the digital process (levelling, docking, etc). Coupling of bus parts is a good opportunity to make the offer equal to the demand.

Gothenburg (EBSF2)

The third test of the ESBF2 project was performed in Gothenburg (Sweden). According to the city of Gothenburg, electric buses can bring public transport closer to homes and working places. A shorter distance to the nearest bus stops ensures that the public transport network can be further integrated in the city than it was previously. The main purpose of the test in Gothenburg was to check whether electric buses would let to more use and wider acceptance of public transport.

Gothenburg has been testing three technological innovations on a completely new bus line, which was integrated in the cities public transport network. The first innovation consists of four electric buses and seven plug-in hybrid buses with a new design. The second innovation was about new bus stops, each stop with innovations. The third innovation was a new heating system on one of the buses that uses only an air-to-air heat pump, trying to reduce the energy consumption.

Bus stops were equipped with Wi-Fi, charging points via USB, information screens and heated seats. One of the bus stops, at the Chalmers University of Technology, is placed in a building. This indoor bus stop was able to regulate the temperature, based on the number of passengers waiting. The test showed that many travellers were happy with the electric buses, because buses are quieter and better moving than diesel buses. That also applied to the innovative bus stops, for the indoor bus stop. Using the feedback of passengers, the interior has been improved further. The heating, ventilation and air conditioning needed 60% less energy because of the air-to-air heat pump.

Image 2.3; Indoor bus stop (Toderian, 2018)

Helsinki (ESBF2)

The Helsinki (Finland) experiment, with two battery-electric buses, was mainly focused on using less energy. Using less power can make the distance that can be travelled much longer, which means that a smaller battery is also enough. A smaller battery weighs less, so the mass of the vehicle is reduced and the distance to drive. This kind of indirect cost savings can be even more important than savings in direct use costs, because of the efficiency of electric vehicles and the lower price of energy.

Main goal of the trial in Helsinki was to find out the potential of reducing energy systems for fully electric buses. In the experiment, the auxiliaries of the bus were controlled depending on real time bus data. This real time data consists of the bus's position on the route, the current traffic situation on the current route and the line characteristics. Besides, a new assistance system for the bus drivers was introduced. This system was not only providing information about energy using (like the case in Barcelona), but also the system was giving guidance and feedback about the current speed, the current valid speed limits and the travelling comfort of passengers by advising on acceleration and deceleration. A back office hit the data real time and used it to provide the real time data.

Effects of speed profiles and management of auxiliaries was in advance estimated using computer models. Therefore, the expectations in the beginning of the experiment were overrated, because models were calculating with maximum possible energy savings. However, by driving less fast on specific points and flattening the driving style, the energy savings were still 4,5% during each route.

Image 2.4; Electric bus in Finland
(Helsinki Business Hub, 2015)

London (EBSF2)

In the London (UK) experiment, during from June 2017 until April 2018, onboard bus equipment from different suppliers has been testing at the same time. Most buses were always equipped with own systems for ticketing, vehicle location logging and radio communication. These systems can be supplied by the bus manufacturer, but also by other suppliers. If it is possible to have different systems on one bus working together, operators have more products to choose and could pay a better price. This makes open competition for innovate solutions in public transport easier (UITP, 2017).

Image 2.5; London IT-experiment
(UITP, 2017)

Besides, using a standard IT system instead of the common systems of bus manufacturers could mean fewer cables and smaller adapters in buses. This remaining space can be used to improve the travel experience or to increase the capacity of the vehicle. Therefore, it makes the use of the buses more efficient then it was previously.

The London experiment shows that connecting systems from different providers into one vehicle is possible. Using standard and open-data systems ensures interoperability between different systems and equipment. This makes it possible to use different systems, communicating with each other, at

the same time. Besides, with applying standard IT infrastructure instead of advanced equipment, the installation time of the systems can be shortened by 40%.

Lyon (EBSF2)

With the experiment in Lyon (France), it was examined whether expanding the use length of the Zero Emission mode can be a good solution for driving in urban areas. In addition, an improved version of the eco-driving system (like the system in Helsinki) was used on both hybrid (4) and conventional (40) buses.

Officially the experiment contains two main tests; one was about placing a new energy management system; the other was about with eco-driving. During the test, route data was used to determine when to enable and disable the zero-emission mode. This happened, for example, in smaller tunnels and in environmental city zones. The consumption and condition of vehicles were checked during the trips, so a new approach for Zero Emission modes could be devised.

According to the results, it is possible to drive an average distance of 2,3 kilometres in fully Zero Emission mode. If the route is only a few obstacles and no altitude differences, in combination with only a few passengers, the ZE mode can be used up to 4 kilometres. The eco-driving system shows 3% savings on fuel in the conventional buses and 13,5% savings on fuel in hybrid buses.

Madrid (EBSF2)

The Madrid (Spain) case mainly had to do with the eco-driving systems. Where the other tests in the ESBF2 project mainly tested the possibilities of advising drivers about their driving style, this case was more detailed. Following the view of bus drivers, eco-driving systems are not the only factor that has an impact on the driving style. Especially schedules of buses and drivers are an underestimated factor. Taking a different speed by departing or braking at bus stops can prevent the bus for being late at the next stop, and this can save money too.

The system in Madrid was launched with two innovative features. Firstly, a quantitative indicator was used to check the driver's opinion on the eco-driving system at various conditions. Think, for example, of their opinion on different bus lines, on different demand periods and in multiple vehicles. Experts were used to test whether the advice to drivers had to do with their driving style and not with other factors. Secondly, an eco-driving system was used that considers other important factors of tight schedules, various demands and the specific vehicles.

Image 2.6; Eco-driving buses (EMT Madrid, 2019)

Even though the case was only running in six weeks, the results were clear enough. The eco-driving system was leading to a short saving of fuel, but much more fuel could be saved by controlling other factors which are not related to the driving styles of drivers. Moreover, lots of insights are gained about the acceptance of eco-drive systems among bus drivers. This case shows an eco-drive system should not be used as a solo innovation, but that acceptance should also be considered.

Paris Region (EBSF2)

In public transport, a lot of information is gathered. Not only about the network and the route, but also about the technical situation of the vehicles themselves. In the urban region around the city of Paris (France), this technical data was used to determine when vehicles must be placed to the depot for checks and possible issues. Technical maintenance staff in the garage were able to manage the public transport fleet better.

Currently, many bus operators are sending buses to the garage according to a fixed schedule to be checked to prevent potential technical problems. Using a fixed schedule makes the procedure quite work intensive and not cost-effective. In the project, information about the equipment and error codes of the IT systems were used to set up the garage planning. This, in combination with feedback of drivers (different engine sounds, vehicle behaviour, etc), makes it possible to plan maintenance.

This experiment shows that the experiment causes lower costs, thanks to decreasing breakdown moments. Moreover, the overall availability and reliability of the different vehicles was increased. Due to a better timing of maintenance moments, the system is even increasing the life span of the public transport vehicles. This means the global service quality of transport is improved, while the costs of owning vehicles are significantly reduced (EBSF2, 2017).

Paris (EBSF2)

In the city district of Paris there has been another experiment, also focusing on the garage. When parking buses, there is always a certain margin between two buses to prevent damage or accidents. This margin, also known as ‘free space’ or ‘free zone’, is the space that bus drivers need to use. After parking, this space will remain, and nothing is done with it. RATP (transport operator in the city of Paris) has therefore carried out a test with self-parking buses in the bus depot. After arriving at depots, the bus gets information about available parking spaces and was autonomously parking.

Besides, a completely different test took place at the field of bus terminals. This second test was aimed at an engineering simulator that could help to plan new bus terminal architectures with the involvement of decision makers using a new approach. This way of involving local decision makers has never been used in spatial planning projects before in Europe, particularly not in bus terminal projects. The idea behind the plan was that a bus terminal is not only about transport operation, but it has also an urban function.

The test with self-parking buses in the RATP depot was successful. All cameras, sensors, localization software and guidance system did their job, making autonomous bus parking a good addition to bus depots in European cities. The test with the bus terminal has initially led to a presentation indicating how decision makers should be helped to choose right configurations for bus terminals.

Image 2.7; Autonomous parking (Mauboussin, 2018)

Ravenna (EBSF2)

In Ravenna (Italy), a project was carried out in almost the same way as the Paris Region, also in the field of predictive maintenance. Many bus operators, especially the smaller bus operators which are operating in small regions which means they have less staff working in the garage, are using reactive maintenance instead of predictive maintenance. This means that maintenance is only performed when parts of the vehicle are broken. The operator in Ravenna, START Romagna, has noticed that preventive maintenance could be a good way to improve their quality. Therefore, during the test period of one-year, predictive procedures have been used instead of reactive procedures.

Using IT infrastructure for collecting data about the vehicle state and predicting possible problems that may occur are about to reduce the costs of warehousing, staff, and diagnostic costs. In case of smaller operators that do not have many employees, this has high potential. The most important difference between the Ravenna project and the Paris Region project was about the parts or liquid. In the Ravenna case, the aim was to measure the oil level and oil temperature. Using an innovative sensor that detects alterations in the oil quality makes it possible to predict when engine parts are ready to maintenance moments. Then, the schedule of maintenance could be aligned to this.

Installing a special oil filter on two testing vehicles, based on the results of this test, makes it so far possible that only one oil refreshing for ten thousand kilometres was enough. Main outcomes were the improvement in the maintenance process that could be achieved and the anticipation possibility for dangerous problems in the operation performance.

San Sebastian (EBSF2)

San Sebastian (Spain) has also been testing various innovations in order to make the public transport system better. The first innovation had to do with the eco-drive system. The buses in San Sebastian were already equipped with a type of this system, but this system was made simpler and more effective now. This new system had seven visual indicators on a small tablet in the dashboard that is also used for keeping the schedule information. Besides, another eco-driving system was tested on another group of buses. This system gives feedback with sounds and vibrations; the systems gave a small sound when driving eco-friendly and it vibrates steering wheels when driving not eco-friendly.

The second innovation was about a more efficient procedure for maintenance. Instead of the other experiments, it was not the vehicle which determines when buses were ready for maintenance. In San Sebastian, the mechanic staff got an app with necessary information about the vehicles and they

could fill in the checks on their report. The ability to also add photos and videos of vehicle parts to the checklist was an interesting way to make their work easier. The third innovation was a tool for analysing the current bus layouts, making it possible to make new designs which considers the accessibility for all passengers and making boarding and leaving times faster.

Results indicate that a combination of both eco-drive systems would suit the best. In case of both eco-driving systems, this led to 30% less accelerations. This has also an effect on the perception of bus passengers and bus drivers. Passengers assessed the trips with 8,3 out of 10, while drivers assessed the trips with 8,1 out of 10. The new application for maintenance staff increases the exchange of information between colleagues with 50%, and the tool for bus layouts proved to be an effective way to shape urban city buses.

Stuttgart (EBSF2)

The use of heating, ventilation and air conditioning is of great importance for energy consumption, especially for electric buses. Using these auxiliaries has a bigger impact on the distance that can still be made in case of electric buses than in case of conventional buses. The experiment in Stuttgart (Germany) was designed to test an innovative more energy-efficient system that could manage all the three things (heating, ventilation and air conditioning). This system, which is called 'HVAC', has also been tested in other EBSF2 projects (see the projects above). The test experiment consists of a completely new refrigerant compressor and heat pump technology, powered by electricity.

The HVAC system has proved to be a very good alternative when it comes to energy consumption. Although this of course depends on the season, the overall energy consumption for heating, cooling and ventilating is reduced by as much as 35% to 40%. These huge changes in energy consumption are showing that it does make sense to act on these auxiliaries. This applies to both the hardware that is applied and the programs that are set up in the hardware.

Image 2.8; Three-in-one system … (Daimler, 2018)

ELECTRIFICATION OF PUBLIC TRANSPORT IN CITIES

Electrification is an important theme in public transport. In the ELIPTIC project, new concepts were launched to improve current electric infrastructure belonging to public transport and public transport vehicles. The main goal of the concepts in ELIPTIC was to save energy and money at the same time. The ELIPTIC project made the role of electric public transport more important, what could let to less conventional fuels and to a better quality of air within urban city areas.

The role of ELIPTIC has mainly focused on using the current public transport systems for the electric charging of different modes in urban and less urban regions. An expansion of electric vehicles can be provided by using existing electrical public transport infrastructure for multiple solutions. During this project, tests took place in Barcelona, Bremen, Brussels, Eberswalde, Gdynia, Lanciano, Leipzig, London, Oberhausen, Szeged and Warsaw.

Image 2.9; Using energy systems of public transport for other modes (Wong, 2018)

Barcelona (ELIPTIC)

The most important challenge of Transport Municipal de Barcelona (public transport operator in Barcelona, Spain) was to achieve an efficient e-bus system for the city. In the ELIPTIC project, the operation of e-buses in Barcelona has been tested. Besides, a test was carried out with two charging systems; a fast charging system on the city streets and a slow charging system (that can be used overnight at bus depots). One point of the fast charging system was connected to the cities metro network, in order to test the opportunities to use overages of energy. Based on these individual fast charging test, the city has also investigated whether scaling up is possible in the metro network.

Both systems (fast charging and slow charging) have been fully tested. The system for fast charging fits best with the operational needs of the transport operator. Buses must be used 16 hours a day and that proved impossible with slow charging during nights. However, fast loading on the streets encountered resistance in the municipalities' council because the charging points on the street could technically also be used for private electric vehicles and parking managers. Connecting these points with the electricity network of the metro is limitedly possible, because Spain has many regulations on metro traffic and electricity networks.

In the future, the current fast charging point will be retained and kept in use. Transport Municipal de Barcelona wants to make four bus lines electric as well. The research has also produced five points which can be used by the city to reach its public transport goals.

Bremen (ELIPTIC)

In Bremen (Germany), two electric urban buses have been tested on various urban bus lines. Both buses were equipped with the same parts and auxiliaries as conventional buses, to make the best comparison as possible. Electric buses in Bremen were only charged in the depot using the energy of a local energy supplier. In this case, no own charging infrastructure was purchased because the two buses with which the test was carried out needed a specific charger from the same manufacturer. The buses have been running on two different routes, the first bus (solo bus) was driving on line 51 and 53, the second bus (articulated bus) was driving on line 20 and 63.

Both the passengers and the drivers were satisfied with the operational level of the electric buses. The sound that buses produced, especially at the time of halting, was significantly less than in case of diesel buses. The sound of buses while driving proved to be no different from the diesel buses,

especially because of the same sound that the wheels produce on the asphalt. The relatively long charging times at the depot (5-8 hours) means another fuelling planning was necessary. The test showed in the city of Bremen that having private charging infrastructure makes the procedures easier than public charging infrastructure.

In the end of 2019, the buses will go back to the leasing party. This also applies to the depot charging infrastructure, which was leased too. Because of the positive experience with electric buses, Bremen wants to work from 2019 onwards to make its fleet electric. In 2025, according to the objective, 55 buses of the transport operators' fleet must be electric. This fits the e-car sharing scheme, which will also be extended in the coming years.

Brussels (ELIPTIC)

The public transport operator of Brussels (Belgium), STIB, has been working on two ELIPTIC projects. The first was about energy recovery in light rail. The aim was to make energy consumption of light rail in the city of Brussels more efficient. In this case, trams 7, 19 and 94 have been investigated and there has been looked at how these solutions look in simulations. The second case was about applying new hybrid buses that are powered by tram and metro infrastructure, which consists of a study with the University of Brussels (VUB). The results of this study, that is focused on operational and financial outcomes of electrification, will affect future bus tenders for the cities' network.

Case 1 started with the amounts of energy used by resistors and the resistance to brake (how is this restrained to the energy). After being put into a model, the results could be analysed. Results were showing that most of the braking energy is already reused. This has made clear that collecting energy from braking is not interesting and that it is better to look at the consumption of auxiliaries, which used more energy according to the models. The second energy measures the energy consumption at three bus lines. On this basis, a model was set up to measure the energy consumption of the fleet. It turned out that the network is suitable for charging all electric or hybrid buses at night.

In the future, STIB will look more at the auxiliaries because there can be gained more. For example, regulating heating and cooling in tram vehicles by doors that close automatically when no one else gets in. New trams will be equipped with an automatic system that automatically balances energy consumption. In addition, based on the second case, STIB will focus on stability of the energy network, the (maximum) age for batteries and interoperability between chargers and buses.

Eberswalde (ELIPTIC)

In the areas Barnim and Märkisch Oderland (Germany), the Barnimer Busgesellschaft wants to replace its diesel buses with fully electric buses. First, in the ELIPTIC project the line between Eberswalde and Finowfurt is converted to hybrid trolley buses. Using hybrid trolley buses means a large storage is needed to store the collected energy. The main advantage of these buses is they can charge while they are driving under the trolleybus electricity network, so there are not blocking any depot, road or stopping place during charging. With the current network in Eberswalde the buses can be recharged without the need for depot charging.

The study in Eberswalde has shown that hybrid trolley buses can drive without catenary. Operators of public transport in cities with catenary can expand their current network without the need to expand the catenary network, which means less expenses. However, it should be noted that the challenge lies in the parts of the network where catenary is not available. Depending on the operator's network and route duration, buses may need to be charged for these parts. Under normal conditions there are no problems, but in the winter more energy is needed by the heating system. It is therefore important to bear this in mind.

Results of this study have led to a second, more detailed research on energy storage. Extending the batteries also increases the distance that the vehicles can make in one run. Due to the successful results, the batteries have been installed on the entire bus fleet between 2018 and 2019.

Gdynia (ELIPTIC)

In Gdynia (Poland), the goal was to study expansion possibilities of electric public transport in the city and the next located area; Sopot. In a collaboration between the public transport operator (PTK) and the university of Gdansk, a case has been set up in the field of in-motion charging of hybrid trolley buses. In addition to extending existing lines outside the catenary area, they have also been looking at the possibilities of removing existing catenary on certain parts. During the additional study, consideration was available for the benefits of a dual power supply system. The software for such a system was placed on two points in the network at substations.

Based on the results, it is envisaged to broaden previous trolleybus plans and make their routes longer. A successful extended line is for example line 29, which started providing the quiet district Fikakowo of public transport in 2016. Moreover, the results show that installing the dual power system provides improvements on the energy network by 2 to 5%. Several existing and new lines are being considered where the hybrid trolley buses can be deployed too.

The results of the case were so promising that the city bought more hybrid trolley buses in 2018 to replace diesel buses. Gdynia is currently engaged in adding these new hybrid buses in its network. Besides, the city is changing the old types of batteries in the first trolleys for newer batteries, which will give them more power in order to let them drive more kilometres. Intention is to drive all routes with trolley hybrids, making it possible to remove parts of the current catenary network, which is extremely costly in the maintenance.

Lanciano (ELIPTIC)

The city of Lanciano (Italy) has evaluated the possibilities to run a tram-train service in rural area on the Sangritana railway route. The idea is to use the system for connecting the different cities lying in the rural area; the possibilities were aimed at an existing route that was abandoned, running from Marcianese and Lanciano via Santa Rita to Marina San Vito. An additional extension between the cities Marcianese and Crocetta (municipality Castel Frentano) is already planned. This will be implemented in another phase of the project. The tram-train service on the old Sangritana railway in Lanciano will approximately have effects for more than 45.000 inhabitants.

Results are currently not known because planning the railway takes much time. Though the system is expected to be the new backbone of local public transport because of high frequencies and short travel times. The development expects a modal shift to public transport because of the frequencies and times, improved urban quality due to changes at the old abandoned infrastructure and a better perception about public transport in the city. Due to the experiences of the rail operator that will provide the transport, no technical problems are expected.

The next step is the actual development of the project. This step can be separated into two different parts. The first part lies in the scope of the ELIPTIC project, and is about combining electrical installations, reclaiming energy and interactions with other electricity systems. The second part lies outside ELIPTIC, and is about new and inexpensive technological solutions to provide a good and safe operational system (with for example crossings, satellite using, etc.

Leipzig (ELIPTIC)

Charging electric buses using tram infrastructure is an interesting measure that may be a good solution for urban environments. In Leipzig (Germany), the Leipziger Verkehrsbetriebe (also LVB) was evaluating all their bus lines, which were served with conventional 12m buses. By combining the data of existing bus lines with a German guideline for electric buses, it was possible to determine what a network of electric buses would mean for the operation in Leipzig. This study sought to gain insight in both economic and technical terms, which together with information on energy legislation and questions about the energy network were needed to drive with electric buses.

The study brought Leipzig some interesting insights. Firstly, the use of the right schedules determines how much vehicles and charging points are necessary. This can be considered when replacing diesel buses with batteries. Secondly, the construction of the charging point network needs to match with the demands, but much points are not needed. Charging points with fewer than three buses per day are economically not justifiable. Thirdly, using substations of the tram's electricity network will is accompanied by many policy recommendations. But at the end of the day, it is possible in Germany.

LVB will introduce her first electric bus in 2019. It is feasible to replace around 35 conventional buses with electric buses over the next five or six years. Although, using the tram network for charging electric buses remains a challenge due to various legal agreements about the tram network.

London (ELIPTIC)

In London (UK), the transport operator (Transport for London) was studying on opportunities around charging electric buses or hybrid buses using not the tram infrastructure, but metro infrastructure. This was mainly to clarify the requirements for provisioning planned services with fully electric buses. Besides this first study on charging electric buses with metro infrastructure, there was another study about charging other electric vehicles (for example electric cars, vans and zero emission taxis).

Charging electric buses and hybrid buses with the metro electricity network is, following the results of this project, an interesting opportunity. Therein it makes sense to charge buses at night in depots and during the day at the end of each route. The bus line used in the case, operating 24 hours a day, can suffice with the same number of buses than before, even if external factors like charging times and weather are taken into consideration. Also, for the electric vehicles, charging with remaining energy of the metro network was a success. Therefore, the city has decided to roll out this concept for the longer term, mainly because it proved to save a lot of CO2 in the city district.

Transport for London decided to discuss the opportunities for an experiment on a larger scale than ELIPTIC to load even more electrical buses. If this project is successful, there are more possibilities to use the electricity network of the London Underground for charging electric buses. Though using a metro substation to charge electric vehicles other than buses proves to be successful, the bus is currently seen as a more important player at the points, because they need more electricity.

Oberhausen (ELIPTIC)

Stadtwerke Oberhausen, the public transport operator in the city of Oberhausen (Germany), has introduced electric buses on two full lines of 15,6 km and 13,3 km. The vehicles, two SOLARIS Urbino 12 buses, were equipped with low-floor technology and an advanced electric air conditioning system. Two charging points were realized to charge the buses on streets. One charging point was located at the train station of Sterkrade (using the tram catenary), the other point was located at the station of Neumarkt (using a substation). During the day the buses were charged at the end of the route, and during the night the buses were charged at the depot.

An evaluation among drivers and passengers showed that both groups were satisfied with the electric buses. Especially when it comes down to driving style, noise production (inside and outside the bus) and technology, people are very satisfied. In addition, electric driving has for the operator an economic advantage. Costs for using electricity were approximately €8.600 for 2017, while the costs for using diesel were around €15.000. Nevertheless, drivers and employees need training to get acquainted with the vehicle types. Besides, the route must be flexible and needed is a permanent available option to load present.

From the end of 2018, four new buses have been started on another bus line, that is shared with another public transport operator (Vestische Strassenbahnen, also VB). Three of these buses are owned by STOAG and one is owned by VS. Because the buses were originally built by VDL, they have another charging system than the other ones. Therefore, all buses will charge at the train station of Sterkrade from now. The Neumarkt charging point will only be used by the first buses.

Szeged (ELIPTIC)

In the city of Szeged (Poland) the local public transport operator has started an experiment with 13 articulated buses. For this experiment, the energy from existing collectors has been used. The local operator (Szegedi Kozlekedesi, SZKT), has organized two trial periods for both 15 days. In these two periods, students of the University in Szeged have performed passenger surveys too check the social acceptance of hybrid technologies. The SZKT has opened the first multifunctional charging station for hybrid trolley buses in 2018. The main goal is to connect the charging points with the commercial energy grid in the future, in order to make the network more stable.

Surveys have shown there is a broad social basis for the use of hybrid trolley buses, and this applies to developments for electrical public transport in general. The experiment in Szeged was a huge success; almost 14.000 on test runs and without major technical issues. The articulated buses are too long (they have too much capacity) for connections outside the city area, so smaller buses may also be purchased by the operator. Although in principle it was assumed that loading points would also be available for electric bikes and cars, this has not been done yet.

With the EMET 2.0 project, SZKT is planning to test new prototypes of composite-frame hybrid trolley buses with an extended range. The next step for the development of these buses is to design a test line of autonomous charging trolleybuses. This new project can pave the way for more innovation by testing and demonstrating in-motion charging and charging at the end-stations with multimodal charging, making the charging points able for more transport modes.

Warsaw (ELIPTIC)

In Warsaw (Poland), the municipal bus operator (Miejskie Zaklady Autobusowe) was assessing the multipurpose use of electric infrastructure of other transport operators. It was intended to use infrastructure of the tram to charge electric buses. The project leaders have avoided as many problems as possible, particularly in the legal and technical fields. Since 2015, Warsaw has a fully electric bus line running through the main part of the city. By working on the ELIPTIC project, the buses in Warsaw did not have to drive back to the depot to charge, because charging was becoming possible on other (new) places.

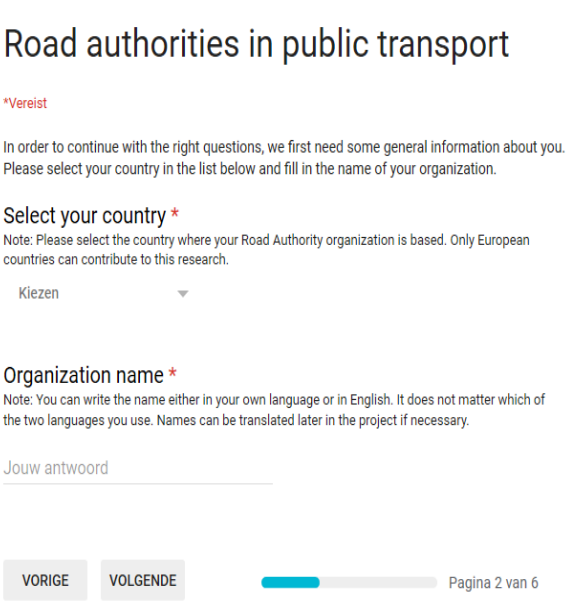
The case study in Warsaw fits in the long-term city development strategies, so major investment in developing and exploiting benefits was possible. Testing new models for on-street charging was essential, as this allowed the extra trips to the depot to be eliminated. By developing more places where buses could charge and by further developing the current charging points, it was possible for the operator to continue their strategy. As predicted, using the electric infrastructure of the tram network to load buses is a cheap way to provide energy. In addition, the experience with procedures and administration has also provided some lessons for the future.

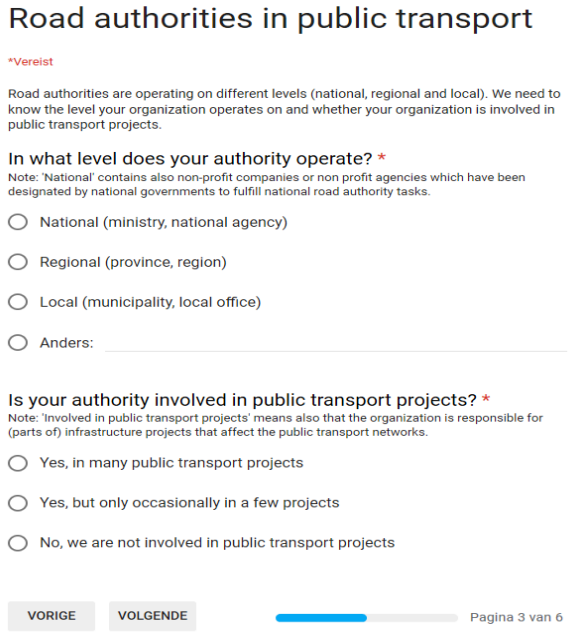
Warsaw must deal with air pollution problems. The city council's strategy is to reduce and prohibit car use in centre, especially cars that are driving on conventional fuels. The idea is to increase the number of low emission buses on the streets. In 2018 there will be more than 30 electric buses in operation. In 2019 and 2020, this amount must grow with 160 vehicles more. This will make it possible to set up the bus as a good alternative to the traffic in the centre.

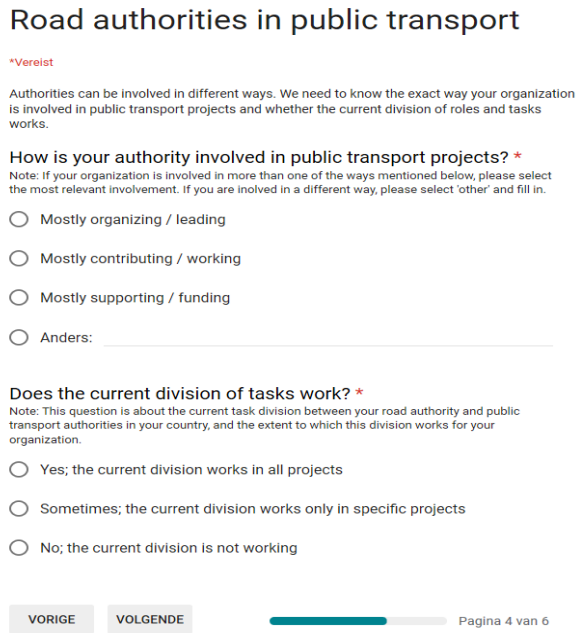
Appendix II – Elaboration of questionnaire

During the research, a questionnaire was set up between March 13 and April 18 to collect information from European road authorities. The questions were proposed in English, while buttons and progress were available in other languages, depending on the settings of respondents' web browser. This appendix contains a detailed elaboration of the questionnaire and its answers.

The questionnaire started with a front screen providing information about the questionnaire and wherefore results will be used. Then, some main questions were asked to collect main information (country of responding road authority, name of road authority, level of authority and whether the authority is involved in public transport projects).



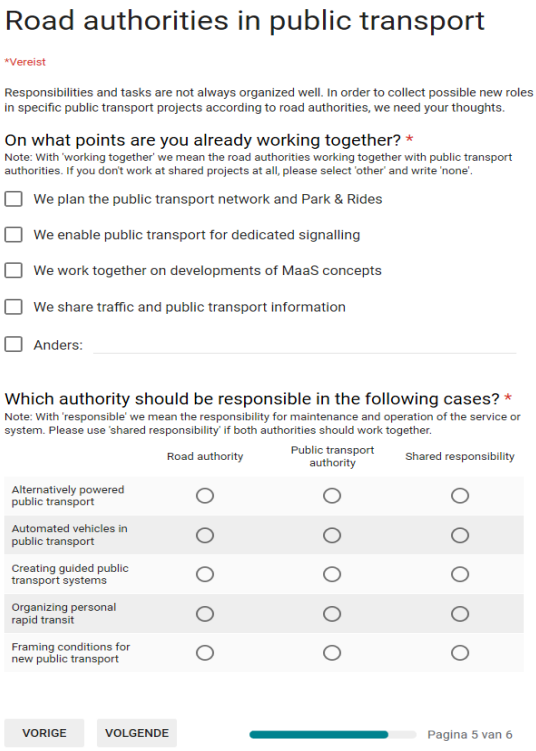


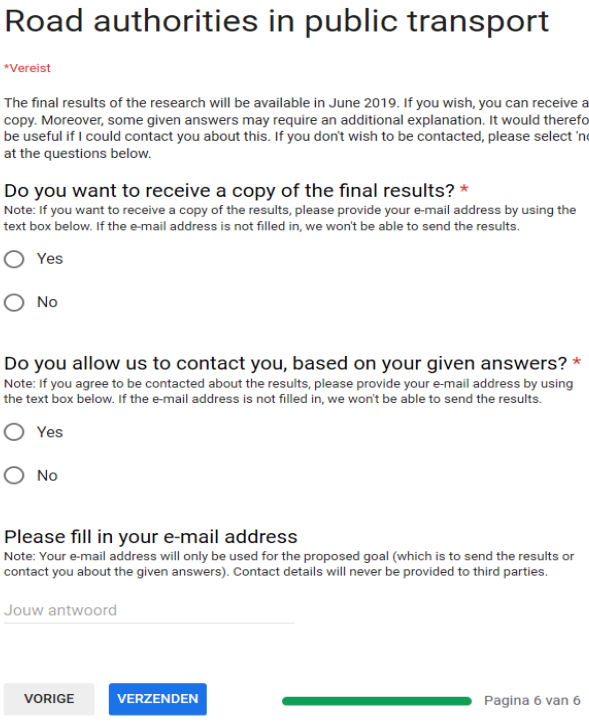


After responding the first questions, road authorities indicating an involvement in public transport projects have been asked about ways of involvement, divided into an ‘organizing’, ‘contributing’ and ‘supporting’ role. These three types are based on the outcomes of the earlier literature review. The following question had to do with the tasks and whether the division of their country works fine.

After answering the involvement questions, road authorities have been asked about points where they work together in public transport. Four standard options, based on current developments in CEDR working groups, have been set up. Besides, there was an option ‘other’, where road authorities could give their own examples of points where the authorities are working together.

On this page was also a question with which the thoughts on responsibilities under road authorities could be measured. On the left some examples were given, based on developments foreseen by the European Commission. Road authorities had to indicate for each example if the road authority, public transport authority, or both authorities should be responsible for this example.





In the end, respondents were given the opportunity to receive a copy of the final research results. In addition, they could indicate whether they allow further contact because of their given answers. In some interesting cases, with Trafikverket in Sweden and Generalitat de Catalunya, it was necessary to ask further questions. These results have provided additional information for this research.

However, it should be said that some road authorities chose the option to receive a copy or allow to contact but did not fill in their e-mail address. Following the text below the questions (describing that the e-mail address must be provided in order to receive a copy of results of information), these respondents will not receive a copy or further contact.

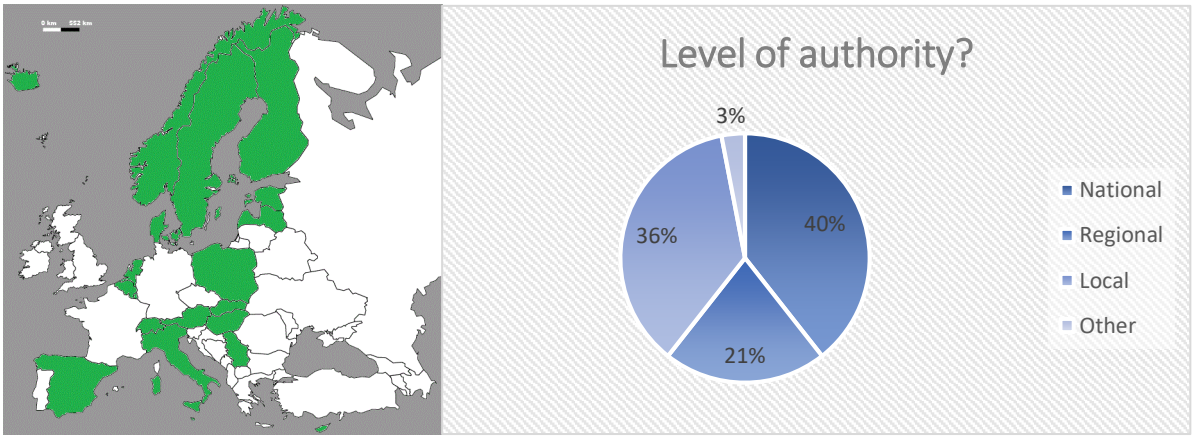
Main information

The questionnaire was sent to 150 authorities. It has been filled in by 33 different road authorities, and it collected information from 22 different countries in Europe. 12 of these authorities are operating on local level, 7 on regional level and 13 on national level. One authority, Trafikverket in Sweden, has technically a national character but it operates at both national and regional level.

- Andorra 1, national
- Austria 2, national, local
- Belgium 2, national, local
- Cyprus 2, national, local
- Denmark 2, regional, local
- Estonia 1, regional
- Finland 3, national, regional, local
- Hungary 1, national
- Iceland 1, national
- Italy 1, regional
- Latvia 2, national, local
- Liechtenstein 1, local
- Luxembourg 1, local
- Malta 1, national
- Netherlands 2, regional, local
- Norway 1, local
- Poland 1, national
- Serbia 1, local
- Slovakia 2, national, regional
- Spain 1, regional
- Sweden 2, national, local
- Switzerland 2, national, local

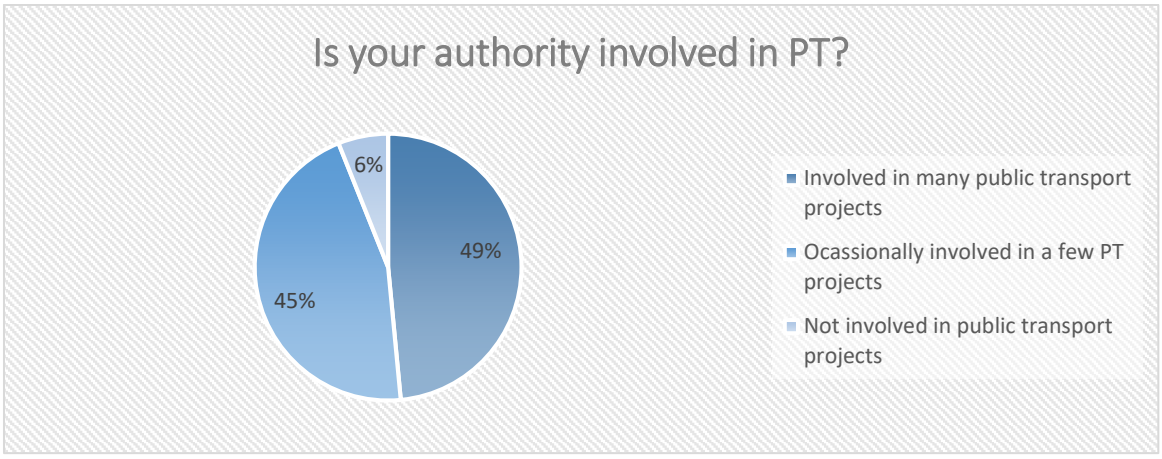
The questionnaire was filled in by mainly national road authorities (40%), followed by local road authorities (36%). Regional authorities account for 21% of the respondents. The smallest part is 3% for other levels of authorities, which has to do with the organization Trafikverket in Sweden (both national and regional). In order to use their answers still for the outcomes (and on behalf of their National Road Authority role in CEDR), they are considered as national authority.

The image below shows the spread of reactions across European countries. Not all authorities were able to answer the questionnaire. One local road authority in a south-eastern country was not able to answer the questionnaire because questions were not asked in their preferred language. Another local road authority was not able to fill in the questionnaire because the used online form was blocked by their local government. They received a questionnaire on paper.



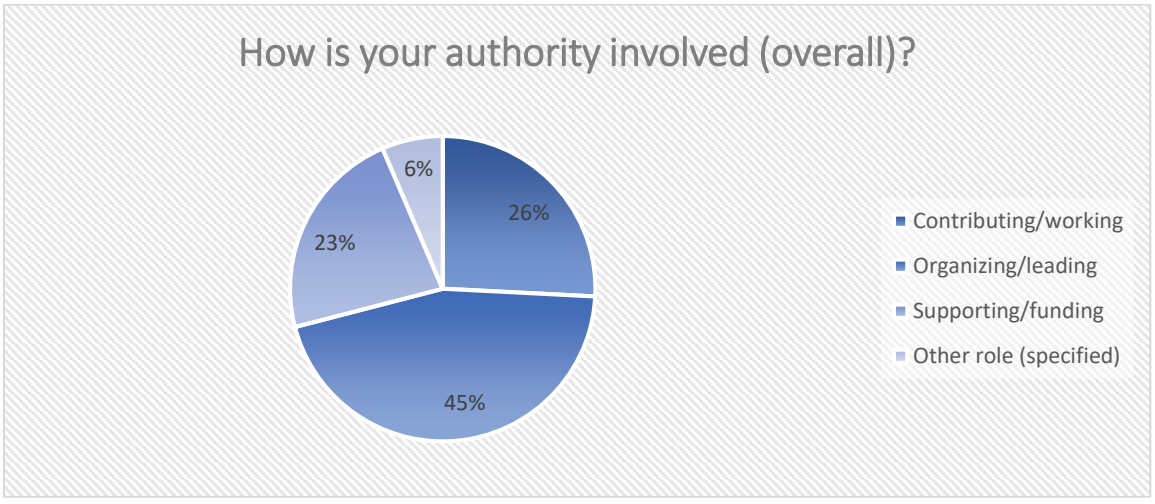
Involvement in public transport

Most road authorities say they are involved in public transport related projects. 16 road authorities are involved in many public transport projects, while 15 authorities are only occasionally involved in a few projects. Only two authorities, including Latvian State Roads (Latvia, national) and Regio Arnhem Nijmegen (Netherlands, regional), say they are not involved in public transport.

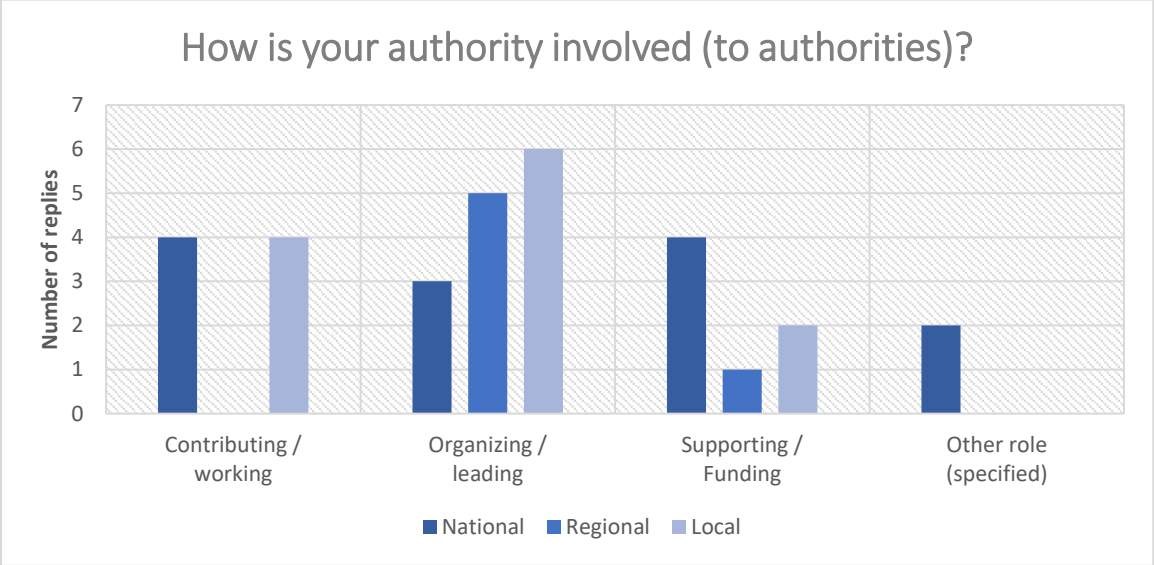


The two not involved authorities were not included in the results of involvements, because they are not involved in public transport. If we look at the overall involvement of road authorities, they are mostly involved in the organizing/leading parts. Almost a quarter of road authorities are responsible for contributing/working parts, and around another quarter of road authorities are responsible for supporting/funding public transport.

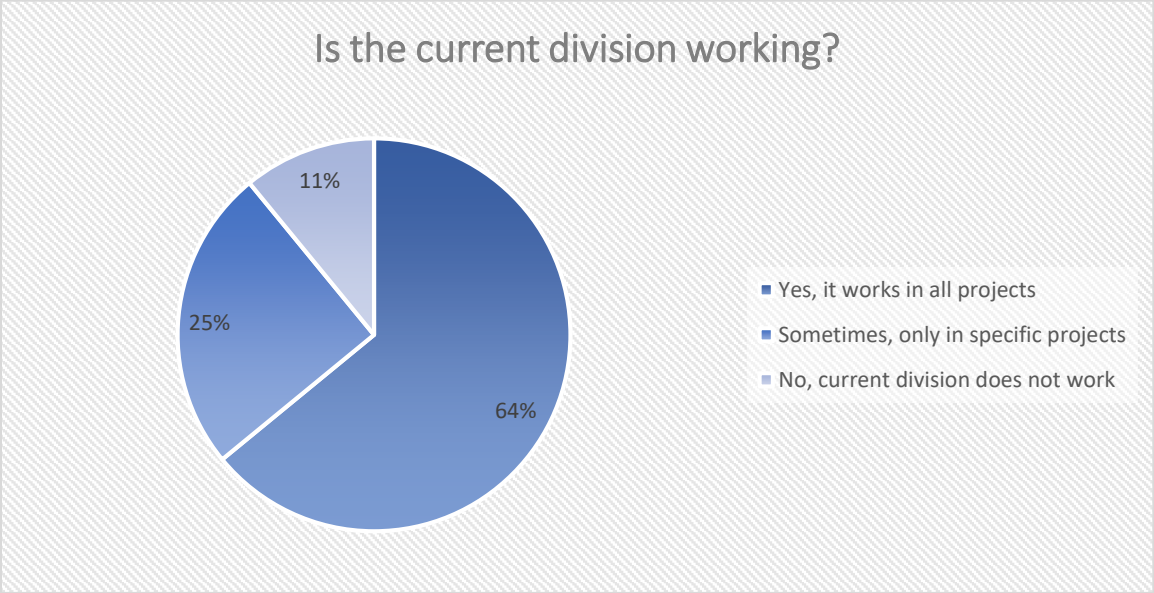
6% has another role, which refers to the Trafikverket in Sweden and the Transport Authority in Malta. Based on these results, an interview was set up with Trafikverket in Sweden to discover their role divisions. Also, in the interview with AER the Swedish role division was an important topic. There was no opportunity to set up an interview with the Maltese Transport Authority, because they were not open to further contact regarding their answers.



However, it would be more interesting to place the roles in the context of levels. Literature research has shown that countries have different role divisions for (levels of) road authorities. Questionnaire results show there is no standard role division in public transport depending on road authority levels. According to the results both national, regional and local authorities are involved in different public transport parts in contributing, organizing and supporting activities.

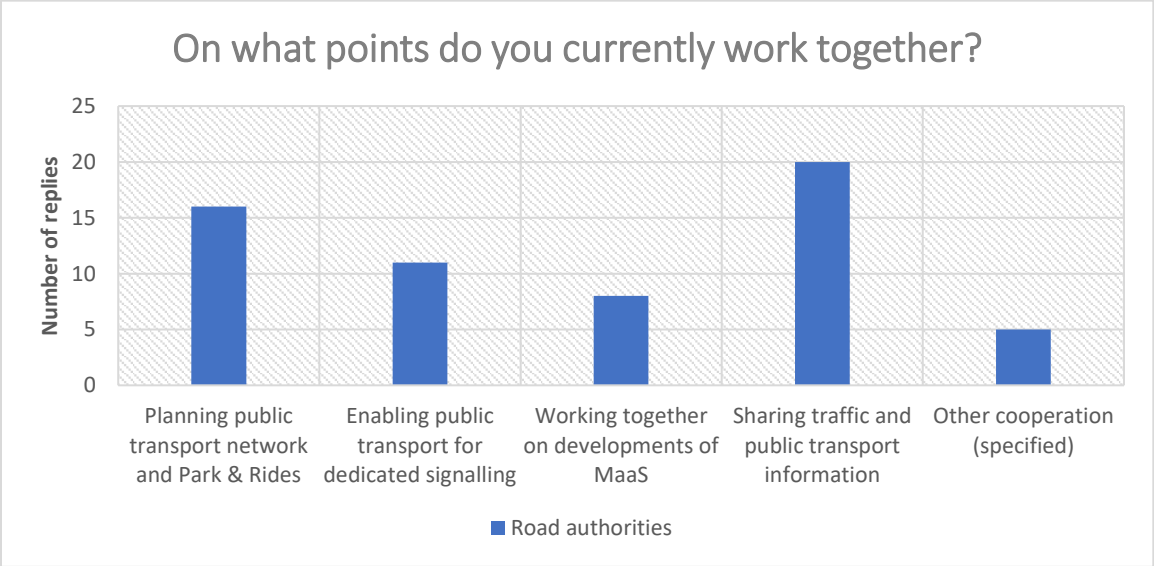


Besides their role, road authorities have been asked about whether the current role division is optimal for public transport. Most road authorities indicate that the current division is optimal in all project. A quarter indicates that the division is only working in specific projects, and just over 10 percent of the authorities say the current division does not work at all. Under road authorities are regional authorities least satisfied with role division, followed by local and national road authorities.



Cooperation

Road authorities are collaborating in public transport on different aspects. Most road authorities are cooperating with public transport partners in sharing traffic and public transport information. Another much mentioned cooperation is planning public transport network and Park & Rides. This also applies for enabling public transport for dedicated signalling. Cooperation on developments of MaaS is less mentioned by road authorities. This also applies for the latest option; 'other'.



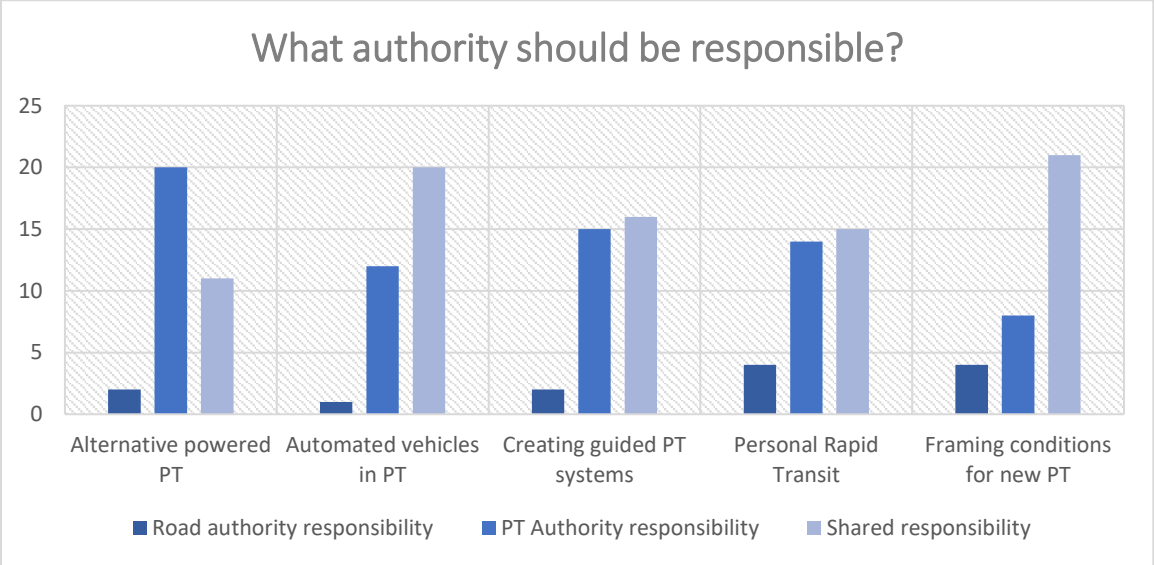
By the latest option, five other collaborations were mentioned. Agentschap Wegen & Verkeer in Flanders is realizing bus lanes, Stad Gent (also Flanders) helps PT by providing a good traffic flow and offering free shuttle services to the city centre, the Government of Aland in Finland is not working together with public transport authorities or operators and Generalitat de Catalunya in Spain has no role division (they are the same department). One authority selected 'other' but gave no answer.

N	Name of organization	Specified answer
1	General Directorate for National Roads and Motorways, Poland	Other (no information was given)
2	Agentschap Wegen & Verkeer, Belgium (region Flanders)	Other
3	Stad Gent, Belgium (region Flanders)	Other (helping PT by providing a good traffic flow and offering free shuttle services to the city centre)
4	Government of Aland, Office of Infrastructure, Finland	Other (no cooperation)
5	Territory & Land Department, Generalitat de Catalunya, Spain	Other (there is no division in department, road and public transport are inside the same department)

Responsibilities

Another question which has been asked to road authorities has to do with responsibilities. Which authority should be responsible for specific project examples? Based on the reactions, the authorities who should be responsible depend on the specific projects. Therefore, it is difficult to draw general conclusions about the thoughts of road authorities. However, we can still draw conclusions based on factual outcomes. Road authorities see themselves not solely responsible for public transport.

For alternative powered public transport, the public transport authority should be responsible. For automated vehicles, a shared responsibility is under road authorities seen as the best solution. Guided PT systems can be established by public transport authorities or must be established within a cooperation between road authorities and public transport authorities. This does also apply for PRT systems. Framing conditions for new public transport is mostly seen as a shared responsibility.



Latest part of questionnaire

The latest two questions were required and have therefore been answered by all respondents. From all respondents, 19 want to receive a copy of the results (including 10 national, 4 regional and 5 local authorities). 18 allowed to undertake additional contact based on their given answers (including 9 national, 5 regional and 4 local authorities). In the end, 24 respondents provided their e-mail address (including 10 national, 5 regional and 9 local authorities).

Questionnaire additions

In some cases, the answers on the questionnaire were not sufficiently adequate. Therefore, some extra questions have been asked by e-mail about the specific role division in the different countries. This has delivered the following reactions;

Country	Additional information
Andorra	Area de Mobilitat is responsible for both roads and PT. The organization consists of specific departments for road and public transport. These departments do collaborate in some project, but not in day-to-day tasks.
Denmark	National road authority (Vejdirektoratet) is only responsible for national motorways. There are different authorities for metro, buses, local trains and national trains. The responsibility of buses is then again split in the regions and municipalities. It is the same in all regions, but most relevant in the capital area where responsibilities are quite complex. Sensible solutions are found through dialogue, but it takes time and it is often more difficult than it could have been.
Estonia	Estonian Road administration (ERA) is competent for managing state-subsidised public transport. Managing subsidised PT is devolved to public transport authorities (PTAs). Projects serving local people are carried out by PTAs. If projects involve different counties, ERA is leading partner.
Hungary	Kozut is responsible for operation of PT network in extra urban areas, for interurban regions there are other 'Kozut'. Collaboration with companies in PT are situated at contact points of urban and extra-urban sections and sections affecting urban traffic. Examples of collaboration are consultations on VMSs and designation of bus stops.
Iceland	The road administration allocates subsidies that the state provides for bus transport, ferries and some air routes. We arrange also bus rides in the country, while municipalities do that in cities/towns. There are no subsidies for buses to the airport.
Italy	Programming, regulation and financing local PT (bus/tram/metro) are the responsibility of municipalities and provinces which in some cases use their own local authorities. Regions are responsible for regional road services. Some province and municipalities have also divisions that are interested in provincial road network. Collaboration examples in here could be the implementation of BRT projects.

Appendix III – Elaboration of interviews

Interview POLIS (Ivo Cré)

Polis (also 'Cities and regions for transport innovation') is a network of cities and regions in Europe, working together to develop innovative solutions contributing to sustainable mobility. This is being done with facilitating exchange of knowledge between cities, regions and stakeholders operating in the private sector on urban transport policy and innovation. Besides, Polis helps their local members with gaining access to European initiatives, projects, funding and research. It is the transport voice of cities and regions to the European institutions.

What is your specific role within POLIS?

"Polis works with five thematic pillars based on local transport; environment & health in transport (1), traffic efficiency (2), access (3), road safety & security (4) and governance (5). I'm working within the 'access' pillar, which is about all topics dealing with accessibility. This pillar consists of different topics, varying from public transport accessibility (for example innovations at stops or vehicles) to accessibility for cars and freight transport (for example with delivery windows, toll and parking)."

"Currently, I am working on projects designing and dynamic managing of arterial roads, also on the ERTRAC agenda. Parking places and bus lanes which are not used during nights could, for instance, be used for logistics or deliveries at shops. Or they could be closed in advance in case of an event. Of course, it is also necessary to organize this future proof, regarding to new automation innovations. Autonomous freight deliveries can be easily adopted to freight delivery windows."

What problems are cities facing on public transport infrastructure?

"One important problem appears with the grow of modality. Some municipalities are faced with too much buses causing less room for other functions in public space of inner cities, but they need these buses to organise mass transit. Another interesting but more abstract problem has to do with so-called geographic polarisation; the value of an area represented by the spatial planning character. Inner city districts have a higher value because they have more closer facilities. Sometimes cities also have an important value for the surrounding (interurban or rural) area."

What will change for cities and regions concerning transport?

"We expect more involvement of local and regional road authorities in transport because of the development and implementation of MaaS (Mobility as a Service). With the SMARTA (Smart Rural Transport Areas) project, we are aiming on understanding the current relevance and potential for future of on-demand and shared mobility services integrated with public transport. This project is mainly focused on the more rural areas, because it will be harder to implement in cities."

"Besides, I expect that local and regional policy (especially in urban and interurban regions) will be focused more and more on environment. Cities are already working on so-called SUMPs (Sustainable Urban Mobility Plans), containing concrete measures or projects to decrease air pollution and noise caused by traffic, and to improve life quality. I believe these plans for sustainability can be aimed on corridor-throughput in the future too."

What are local road authorities' works in the field of transport?

"Their involvements can be divided into three different forms; strategical, tactical and operational. On the strategic level, they are working on SUMPs, transport policy, economic development, life quality, etc. Most important on this level is that using space for car parking is not always efficient in inner city districts, so we need to find other ways. On the tactical level, local authorities are looking on network efficiency for intermodal trips. One of the examples in here could be the improvement of operation speed of public transport. On local level, road authorities work on individual changes in physical space. Think of traffic light optimisation of the improvement of bus stops and stations."

How could this be organized better?

"First of all, we need to organize a better flow of traffic in cities. This could be easily done with for example with cost-benefit analysis or using specific models. Secondly, we must look at timelines and timings of infrastructure budgets. Small works on a specific bus stop becomes less necessary if we can organize the works on bus stops together with big works on the whole street (for example when sewerage must be replaced). By having local authorities working together properly, the works on different roads along the bus route could be done simultaneously."

"Thirdly, we need a long-term vision on specifically bus networks. It must become clearer what the role of buses in the transport network is. An outcome of long-term bus network visions could, for instance, be organizing more charging places or charging buses with tram infrastructure. However, this is also coming with a political discussion about the responsibility. Some parties believe public transport should be more anchored in local policy."

What should change in role division?

"Road and public transport have many common interfaces. Therefore, their roles should not be strictly separated. Today the benefits of infrastructure improvements are going to higher authorities which are organising public transport, while local road authorities need to establish improvements and pay the bill. This will also make it easier to come to opportunities like carsharing or uniform policy about bus rapid transit the same way as it is organised in South America."

"There are already examples about how this could be better organized, for example in organizations like Ile de France Mobilité, Transport for London, BKK and CRTM in Madrid. In these cases, one single organization is responsible for both transport and roads. Modular concepts for buses and roads could be a good alternative, especially when the outcomes are unsure during the start project."

"Apart from role division, I think there is one latest important factor. Visions on public transport should be linked to spatial or city related developments. A good starting point would be, for example, to adapt parking standards on public transport stops. Locations on a longer distance from the stop will get more parking spaces and locations closer to the stop will get less parking spaces. This has been part of an EMTA research, which could be interesting too."

Interview Trafikverket (Ruben van Kersbergen)

Trafikverket is the national transport authority for Sweden. Their work contains building, operating and maintaining public roads, railways and waterways. Besides, the authority establishes long-term plans for the countries' transport system, including all modes. Trafikverket is also responsible for the administration of driving tests and licences in Sweden, from cars to public transport modes. This single authority for different modes is interesting, because it is not common in European countries. Because this concept is very new, it makes sense to discuss this in an interview.

What is your specific role within Trafikverket?

"Sweden consists, like many other countries in Europe today, of different provinces. Based on these provinces, five so-called Trafikverket regions have been set up. I work in one of these regions at the Community Planning Department, which is responsible for building and maintaining national roads. In the department, every person is responsible for one of the five Trafikverket regions. My specific responsibility is the Western Stockholm region, which consists of four different provinces."

"In Sweden, there are three different types of roads; local roads in cities (which are owned by the cities or municipalities), so-called 'landsvägar' (private property or owned by business), and national roads (where Trafikverket is the owner). National roads consist not only of highways, but also all regional roads and in some smaller cities the most important local roads. Our process of the building and maintaining roads with tendering is the same as other countries."

Why has a common authority been chosen?

"Before the creation of Trafikverket we had the same situation as other European countries. We had a separated road authority, rail authority (järnvag) and water authority. We noticed (as a transport authority) that we met a lot with the railway and waterway authority in our work for shared projects and that we did many things almost the same way. For example, think of building bridges or foundations and infrastructure, which are built by both road authority and railway authority in this country. In many projects for transport we were already collaborating at that time.

Creating a new authority where all transport comes together has many advantages. First, these have an organisational aspect. Three different authorities will need three different HR departments. With one organisation, only one HR department is needed. Secondly, we need technical knowledge for three organisations, which can be shared easier in a common organisation. That fits with the consultative and discussing nature that is (if you ask me) a bit of the Swedish culture. Finally, we can speak with one transport voice to stakeholders, instead of different authority voices.

Besides, I think merging these authorities was an important step towards the future and sustainable thinking. We believe in an integral planning system which has attention for all modes. Silo thinking (concentrating on one specific mode) is therefore not interesting anymore. If you imagine your own trip; going by bike or walking to the bus stop or metro station, taking a train, using a taxi; your trip is already multimodal. So, it could make sense to make the authorities multimodal too.

However, the process from three authorities to one authority took a lot of time. The official start of our new organization was in 2010, but today we are seeing the first efficiency gains, answering most questions in a new multimodal way.

How is Trafikverket concerning public transport

We are involved in various projects because of our role. However, Trafikverket is not responsible for all public transport issues. Regional authorities have influence on tendering and funding operation of public transport. But from a more technical point of view, we are the public transport manager. The regional transport authority and transport operator will need Trafikverket because we are managing and maintaining the used roads. Sometimes, especially in cities, this could be different. Roads are sometimes transferred to the city authority as owner in case they have new plans for the roads.

As the responsible organization for roads and railways in Sweden, we are much involved in physical public transport infrastructure projects. The most important current project is the new High-Speed Line connection, which is built between Stockholm, Malmo and Gothenburg. In this case the common organization simplifies the project progress, because we now need to talk with only one responsible person instead of two different persons from separated organizations.

Does a common authority make transport more efficient?

I would say yes. Although it took much time to organize Trafikverket, it certainly was a good step to merge the three organisations into one. The opportunities to share information with the other authorities have been increased and we can collaborate more efficient. Important to realise is that the feasibility of a shared organization depends also on the current (the strategic) role division in the country. For example, in the Netherlands, Belgium and Germany, the ministry is on the organizational level involved in road or public transport. They are managing tenders for main railway networks. In Sweden this task belongs to Trafikverket, which creates also main policy and maintains the networks. The ministry is in this case only involved for huge projects like the mentioned HSL.

Interview UITP (Caroline Fabianski)

UITP, which stands for the International Association of Public Transport, is a worldwide network bringing stakeholders in public transport and sustainable transport modes together. UITP has been set up in 1885 by European Tramway operators, but in the years the focus has broaden to all parts of public transport and members consists of industry, transport operators and authorities. Because UITP represents both the authorities and operators of public transport, it makes sense to get their thoughts about role divisions and projects regarding public transport infrastructure.

What is your specific role in UITP?

“My specific function in the association is ‘Senior Manager PhD’. This means I am managing current UITP research projects and assessing the possibilities for new research projects. Besides, I am also responsible for the processes of projects and the presentation of results to authorities and operators within our organization.

Where do road and transport authorities 'meet' each other?

"First of all, they meet each other in the general content of public space. Currently much space is needed for car dependency, but this is not sustainable with our current climate changing problem and increasing city populations. Roads are currently on the max demand; this provides a good opportunity for public transport modes, because they need less public space and are available to transport more people at the same time (especially in case of mass transit)."

"Besides, they will meet each other more and more in integration issues. Some projects, for example development of park and rides, are interfering between road authority and public transport. The border between the two authorities seems to fade a bit in there. It is interesting to see what tasks of road and transport authority are and how they work together in that area."

What problems are public transport operators and authorities facing in infrastructure?

"The most important problems are related to funding. We need to find a good funding balance in road and transport, between for example parking and public transport. This can be done in different ways, but I think the most important solution is to see the urban mobility as one integral topic rather than separate topics related to the different transport modes."

"Another problem has to do with space. Especially in city regions we encounter difficulties in public space. Now huge amounts of space are used for car parking, while public transport usually needs less space. Projects are set up to solve congestion problems, but they can also have important consequences for public transport. By approaching the public space also more integrally and better suited to all different modes, this problem can also be solved."

What do public transport authorities and operators think about role division?

"We think the role division of road authority and public transport authority must be reconsidered if it provides solutions for the mentioned problems. In Sweden and London, we see already interesting changes in funding processes because of another role division (one transport authority instead of a separated road authority and public transport authority). In these places better balances can be seen between public transport budget and for example parking policy."

"Besides, it causes better efficiency due to a clear system. In the private sector, rules and procedures are clear and fit in the system. In the public sector, rules can be different for every single authority and there is no integrated way of how things work. Different authorities have different roles and budgets, so public transport operators encounter problems in finding their role in this field. I think; therefore, it is necessary to integrate transport authorities also in cities."

Interview AER (Martin Tollen)

AER is the Assembly of European Regions in Europe, which consists of around 150 members including provinces, city regions and other regional authorities. It defines itself as a knowledge sharing place for regions and the voice of regions on the European level. AER is organized on a structure containing a general assembly which contains two members from every country, and an executive board which decides the direction and projects. It has also an own research department, which consists of three different committees. Finally, every committee has different working groups.

What is your specific role in AER?

"My role is working group leader in the regional development committee. It means I am responsible for tasks like selection of research themes, invitations to guests and of course managing the group. The working group that I lead is the group on traffic and transport. We are using this group to share best regional practices regarding traffic and transport innovations between European regions. Beside my role in AER, I am also working for the region of Oster Gotland in Sweden."

How are regional authorities involved in public transport?

"This could be in different ways. In many cases regions are responsible for public transport. There are two ways of public transport; commercial financed public transport (CFPT) and public financed public transport (PFPT). Commercial financed transport can stand on their own with ticketing income, while public financed transport needs tax money because there is not enough income. Depending on the way of financing, regional authorities are responsible for transport issues."

"I do not know the specific examples of involvements in other countries, but I can tell you how we organized it in Swedish regions. In our region, Oster Gotland, the region is partly responsible for public transport. We got money from the national government to organize the transport. For every four years we have a political discussion about transport plans. Then, we start a tender for operators, but almost every time we got no applications because the revenues are too less."

How is the region involved in public transport infrastructure?

"Also, in the infrastructure we are just partly involved, let me explain it by the example of bus stops. Normally the transport authority Trafikverket is responsible for placing bus stops or in some cases the municipality. Their task is to organize all the infrastructure including these stops, and they got money for that from the national government. We are discussing the transport network with the owners of infrastructure; the municipalities or Trafikverket."

"Sometimes we are also funding modifications on the transport network. This is allowed by the 'Transportstyrelsen', the Swedish agency responsible for transport policy. For example, in relation to the former mentioned accessibility, where we want all bus stops in our region to be accessible for all type of users. At that point, Trafikverket has not enough budget to change this on their own. In this case, we decided to use parts of our tax money income so we can share the costs together."

What problem are regional authorities facing in public transport?

“We see different problems. On the European level, I think most problems have to do with funding and ownership. New innovations must provide an answer for the European question ‘How can we make it possible to organize trips which consists of different modes?’. In my own organization in Sweden, problems are more related to accessibility. Therefore, we decided that all public transport stops in our region must be accessible for every type of user.”

“But the most usually problems we see are the problems of transport users, which has obviously to do with public-private relations. For example; as a traveller you want to be on time, and it doesn’t matter to you what operator brings you to your destination. Nowadays you will buy the ticket and take the train of the operator. Most European travellers see the operators as responsible ones for the train systems. However, in many situations the operator is not the owner of the network.”

“If your train is delayed because of track problems, technically the transport authority (for example Trafikverket) is responsible. But Trafikverket has sourced out the rail managing process, so a private company is responsible. Therefore, there is some criticism in Sweden about Trafikverket is despite of the new organization still subdivided into a different rail and road part. Personally, I think it will be a matter of time before these changes. This will change if new people start working.”

How could roles be organized better?

“The new system in Sweden with a transport authority which is responsible for all infrastructure, makes regional authorities less responsible for the infrastructure part of public transport works. Therefore, it could be a good way to organize transport division in other European countries. But we need to keep in mind that also the Swedish system has points which can be organized better.”

“Most interesting example is for instance the ‘national’ trains which are superior to ‘regional’ trains. This is done this way because the national trains have more paying travellers, and they can cover their costs with incomes, while regional trains must be set up with tax income. But on the other hand, you can see these regional trains also as more important because they are clearly so important for us that we set them up with tax income.”

Interview UITP (Arno Kerkhof)

UITP, which stands for the International Association of Public Transport, is a worldwide network bringing stakeholders in public transport and sustainable transport modes together. UITP has been set up in 1885 by European Tramway operators, but in the years the focus has broaden to all parts of public transport and members consists of industry, transport operators and authorities. Because UITP represents both the authorities and operators of public transport, it makes sense to get their thoughts about role divisions and projects regarding public transport infrastructure.

This second UITP interview with Arno Kerkhof has been set up to provide more information about the role divisions, especially related to buses and bus infrastructure.

What is your specific role in UITP?

"I am the coordinator for buses, which means I am responsible for all UITP activities related to public transport buses. Buses are an interesting theme, because we have more and more interesting things to deal with (new energy sources, networks, software integrations, etc). Within our international organization I bring public transport operators, authorities and manufacturers of buses together. Our goal is to promote the benefits of public transport and to establish sharing of knowledge and contact between public transport related organizations. We do this with among others transport companies, provinces and city regions."

How do UITP members see the role division?

"Road authorities are secondarily involved in the bus segment, and the buses itself (together with other public transport vehicles) are owned by the transport operators of authorities. First, there is an interesting division between authorities and operators. Authorities are organizing tenders, while road authorities are applying on these tenders. This system is used in many European countries, but tenders are also usual in other parts of the world."

"Europe is one political area, but even within the member states the role and task division is different. We can see similarities in European regions (for example in Scandinavia), but there is no 'one-way' how the role division is organized. Spain and Italy, both countries in the south part of Europe, have the same roles, while the eastern countries of Europe have a very different structure. There, organizations are more based in a traditional (public company) related way. Looking at our members, role division in public transport could also be organized based on tradition. For example, in London, the transport organization (Transport for London) has created a very open market for the rural areas outside the city. This fits the culture of 'let the market do the work'. The qualifications of operators are checked, but after that the market can do what it wants."

Is the role division causing difficulties?

"I do not think role division is currently a problem. The transport market or operators in this market are solving the problems of role division by themselves. They are aware about the culture and ensuing task division in countries. Besides, operators are prepared to take the risks, otherwise they will not apply for the tender. Too high risks will cause no applications on a tender, this happens mostly also because of carelessly market explorations. Good to know is that the importance of role division depends mostly about the requirements and opportunities of specific countries. The average commercial speed is a requirement which gets more and more important in here."

"However, role division is able to cause problems. Especially in case of new innovations for public transport this is causing difficulties. Let's take the electrification of buses. With creating charging points in public space, public transport needs to deal with cable owners, suppliers, road authorities and owners of loading infrastructure. In case of, for example, the concession Amstelland in the Netherlands, the authority and operator decided to place three charging points on private space at Schiphol Airport and one charging point on public space. They experienced it was more difficult to organise the one point in public space, causing the other three to be ready-to-use earlier."

What will be the most important changes in the upcoming years?

"If I speak for buses, I think the systems will be based more and more on clean bus rapid transit (BRT). Redesigning roads in order to provide BRT systems asks for political expansionist policies of the road authorities. They will have to allocate parts of their road infrastructure networks to public transport. A couple years ago, in 2003, a cost-action research has been done on this field. All countries within Europe where involved. I think it was called 'cooperation technical scientific exchange knowledge'; you should find it if you look at 'BHLS', meaning 'buses high level of service'".

"We see a current development where transport authorities are founded by different municipalities together to become a more interesting location for operators. We see that authorities impose new obligations related to things that will usually not be offered by operators. Besides, I think there will be more attention for the climate in transport policy in the future. Hydrogen and fuel cell may be an option beside electricity. However, I do not think green gas or biogas will be an option for all locations, because it is not really integrated into all countries."

Based on this, how could the role division be organized better?

"Different countries have different cultures and commons, so it may be hard to find a one-way. For example, in Brussels the local municipalities (which are quite a lot) have much influence on road management within the city. Because of this, creating a new public transport line will become very difficult. In Copenhagen, for example, the local transport operator for the city (MOVIA) is organising public transport closely together with the municipality and regional authority. Working together is good, but sometimes there are still levels. Maybe it will be interesting to create a contact point or consultative body which deals with all the mentioned partners in case of electrifications for buses."

Interview Parliamentary Research (Marketa Pape)

The Research Service for the European Parliament, also EPRS, is a European institute doing research on themes and topics the parliament want them to investigate. The mission of EPRS is providing members of the parliament with independent objective analysis and research on policy issues in the European Union. The EPRS has many products and services, made by internal experts and knowledge sources in all policy fields. It supports and promotes also parliamentary outreach to the public.

What is your specific role in the EPRS?

"I am policy analyst within the Directorate Members' Research Service. This means I am responsible for the research that we carried out and the work we share with the parliament members, but also with the wider public. I have been involved in research about TEN-T for several years, among other issues. Though I am not an expert on road transport, I know something about TEN-T policy and the financing and could be of some help there."

What does the Research Service know about role division in public transport?

"In the specific part of role division, no very specific research has been done. If you are specifically looking for information about projects and the roles in there, you should contact the regions. They can probably tell you the more practical story and their experience over there. However, I can tell you some information about the procedure and involvements so far as we know."

What problems does the Research Service see in public transport infrastructure?

"In my opinion, the problem is that authorities are not using the released EU funds. Last years, not much money was spent (there was quite some money available for EU, which could have been used for example in the eastern countries). I believe there are technically two important reasons for this in public transport infrastructure projects; project permitting and financing. Permitting problems occur because these projects cannot be followed by cities due to inconvenient procedures. Therefore, the Commission started a new discussion to establish easier procedures which can be passed easier."

"Financing problems occur because there are differences between financing schemes. EC is funding urban mobility with different kinds of budgets. For TEN-T there is an estimated budget; which means the funding will depend on the cost. For other projects with EU finance, there is a certain amount of money. Other costs need to be financed by regions themselves. This may scare them off."

How is the EU concerning public transport in cities?

"European policy paves the way for additional national policy and regional/local policy. Technically, the situation within cities has nothing to do with EU. Though there are some European issues like environmental and safety issues, on the local scale the EU is originally not involved. However, the Commission (EC) can support of fund Sustainable Urban Mobility Plans, where local policy is created or implemented to reach a better environment for citizens. The role division in here is a national issue, and therefore a national concerning of member states."

Can transport infrastructure agencies solve this problem?

"I think separate road and transport authorities or one transport authority for all modes are both a solution. However, to say this hard; role division is not famous. Possibilities for other role divisions are different in every country, and opinions are divided about these role divisions. I believe new authorities could be interesting, but only if they are adapted to specific countries. See for example other types of transport authorities, which have been set up in Vienna (Austria) and Brno (Czech Republic), making them also available to collect better funding from EU."

Interview DG MOVE (Pedro Barradas)

The European Commission is responsible for creating cross-border policy on the European level. It has several departments related to different themes. For mobility & transport, the department for Mobility & Transport (DG MOVE) has been set up. DG MOVE is divided into five directorates; policy coordination (A), investment/innovative/sustainable transport (B), land (C), waterborne (D) and aviation (E). Waterborne and aviation are separated from land modes because of different safety regulations that must be created by the commission. Because the research is most related to innovations and sustainable transport, interviews were held with the second department.

What is your specific role in the European Commission?

"I am policy officer as well as seconded national expert. Seconded national experts work for the commission, using knowledge which they bring from their own country. I was originally civil engineer, but I have been involved in projects at the national ministry and eventually in European Commission. I work in the Unit B.4, which is responsible for sustainable and intelligent transport. With intelligent, we are talking about topics around connectivity and 'smart' traffic; think about sharing accurate and historic data, but also about more concrete examples like adaptive traffic light systems, parking systems, etc. One of my current challenges are the developments around cooperative ITS vehicles."

How does the commission see role division in public transport projects?

"First of all, I have to note that authorities can be divided in different ways. Member states in Europe do all have three types of authorities. On the national level, there is the ministry. They organise the guidelines for public transport in their own country. Most ministries have their own departments or separate agencies for transport modes (road, rail and water)."

"On the regional level, we have regions where tasks can be very specific. In some member states the regional authority is also responsible for roads, while in other member states roads are no regional concerning. On the local level, authorities operate mostly contract based. They are in most countries responsible for spatial planning in cities; where do we organise the roads, where do we need public transport and which places can we build."

What points or subjects are currently changing in here?

"Examples of current public transport projects on roads are showcase situations. We know that a lot of ideas from current projects are not implemented everywhere. For example, traffic light priority for public transport is implemented in some main cities but not in all European cities. This has several reasons; authorities are less involved in innovation than others, authorities are currently not able to implement this because of another culture or policy, or they do not have enough budget. Important to notice is also that every culture is different, but transport is everywhere an important theme."

"Besides, public transport needs to 'fit' in locations. Cities must ask themselves questions about the interfaces of public transport; which way does their public transport need to operate, how far does it have to go / which areas must be connected, and how fast do the connections need to be? Back to the question, there are no points which do apply for all member states. Measures need to fit local policy, otherwise they cannot be implemented."

Could Transport Infrastructure Agencies be a solution for other countries?

"Transport Infrastructure Agencies are a modal set up by North European countries for providing better collaborations between involved transport parties. Indeed, this is a successful story for their countries because it fits in their culture. However, I do not think this structure will fit in other European countries too. Coordination of our transport is on main level done by national governments, based on national or country-group culture. We experienced it is hard to start a conversation about shared missions in public transport or authority roles."

"However, this does not apply for conversations about intelligent infrastructure systems and data sharing. European authorities do understand the need to talk about data sharing with other authorities. Data intelligence (and information) is very important for developments like Mobility as a Service. Actual train positions combined with parking information can make multimodal trips using park and rides much easier. These digital services need to be combined, so in the light of sharing information a shared authority could be very interesting."

What will the European Commission do?

"There is one very important word in our department; interoperability. With interoperable we mean digitalisation and exchange of all public transport data. European Institutions need to focus on this point and organise European rules and guidelines, so the shared data will be in the same formats. This makes it easier to provide new software & applications on the European level. With issuing new regulations in cooperation with road and transport authorities and public/private operators we can establish this further. Therefore, the normal bottom-up procedure of Europe must be used; from the council and commissions towards the parliament."

Interview DG MOVE (Martin Zeitler & Gudrun Schulz)

The European Commission is responsible for creating cross-border policy on the European level. It has several departments related to different themes. For mobility & transport, the department for Mobility & Transport (DG MOVE) has been set up. DG MOVE is divided into five directorates; policy coordination (A), investment/innovative/sustainable transport (B), land (C), waterborne (D) and aviation (E). Waterborne and aviation are separated from land modes because of different safety regulations that must be created by the commission. Because the research is most related to innovations and sustainable transport, interviews were held with the second department.

This second interview with Martin Zeitler and Gudrun Schulz was set up to collect more information about consequences of role division on European Transport Networks.

What is your specific role within the commission?

We are colleagues in the European Commissions so-called TEN-unit. This unit is primarily focusing on TEN-T developments, and it consists of one (horizontal) overall policy team and a colleague for every corridor on the core network. Our work consists mostly of creating policy and guidelines for the TEN-T corridors in Europe. Gudrun works more on the main level, where developments in all corridors are monitored and new TEN-T policy is created. Martin works within the Scandinavian – Mediterranean corridor and is monitoring corridor-specific developments.

What stakeholders are involved in TEN-T projects?

Many different authorities and companies are involved in TEN-T projects. On national, but also on local or regional level. Corridors for TEN-T are mostly playing a role on national level, so the EC is talking with member states. However, national governments do collaborate with their regional and local partners in specific projects. Generally, we can say the European Commission is within TEN-T not working on local or urban mobility issues. This are more specific issues for the member states and its specific authorities, following the agreed regulations about TEN-T with member states.

With TEN-T we are only able to finance or influence member states on this national level. Sometimes there is some overlap between authorities. For example, in Germany, where national roads through cities are still responsibility of national highway authority. Having the member state government (in this case the ministry) as responsible stakeholder makes it easier to find all partners. The national ministry has in our opinion a better overview of the needed stakeholders and project partners.

Is role division influencing (the elaboration) of TEN-T corridors?

No, not really. From our unit perspective, it doesn't matter if the corridor must deal with a national road company, a ministerial department or with a transport infrastructure agency. As the European Commission we deal with the member states; and they deal with the responsible organizations. TEN-T projects are in addition also using national budgets and procedures, which will lead to higher values of regions in the end. Our starting point is that we are building on national networks. On European level, a 'Corridor Forum' is organised for every corridor. Stakeholders take part in this forum.

However, sometimes does the role division not match other European regulations. For example, in some countries which have an 'old legacy' railway company which also owns the rail network. With a view to the common and fair market, this should be changed because rail managers can give priority to their own rail company instead of other companies.

What type of stakeholders are involved?

I should note that the corridors have to do with a lot of stakeholders in every country. Federal, local or regional road authorities are just an example. Sometimes we also see regions or municipalities involved in TEN-T projects, because they have also advantaged by project results. For example, in cases with a wish from different regions for new connections by train or road. However, TEN-T is focused on the transport network as a whole system, so we avoid urban issues. They are usually part of specific European finance programmes, for instance the Horizon 2020 connecting Europe.

What are the current developments?

Main concerning is the infrastructure, especially in Eastern Europe new roads are being build. Years earlier this has been done in southern countries like Spain and Portugal. In addition, we have other points like software and applications, where this can also be seen. East-European member states who recently joined the EU are not as far with traffic management as Western-European countries. They are currently working on more traditional topics, like the improvements for real-time traffic information, information about dangerous goods and availability of parking spaces. Western states are having experiments with CAD and traffic innovations, while newer member states need to focus first on the 'hard' infrastructure before they can use traffic management. In mainlines the network exist, but the quality and degree of network parts is different.

Another concerning is sustainability. We try to implement also more sustainable transport modes. Think of ships which use hydrogen instead of diesel, or charging points for electric, hydrogen and biogas energy sources on the corridor networks. Therefore, for example we can create guidelines about the amount of charging stations in specific distances. However, this is complex because just creating stations for new energy sources is not the right way; we need enough cars too.

Do we need to change role divisions, if we look at TEN-T?

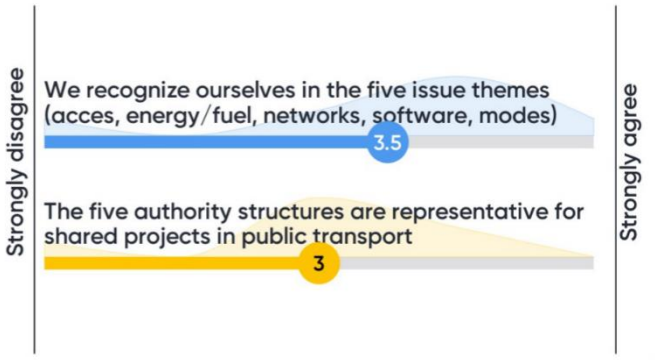
We do not believe this is necessary to develop the network. Member states have their own culture and identity, which are interwoven with their authority structures. Think for example of the German Bundesambt fur Eisenbahnen, an independent authority which focuses only on railway transport. I assume that roads, rails and transport can be combined in a smaller country, like Malta. Both types of organizations can be in line with European regulations. To compare this with corridor Scandinavian - Mediterranean, transport infrastructure agencies that work in Scandinavia do not necessarily work in Italy too. I believe we have to look more to the functional way; if a structure 'works' (optimal) in a specific country, we should keep it that way. And if the division is not optimal; they can have a look at other divisions and consider new possibilities.

Appendix IV – Elaboration expert session

In the final part of research, an expert session was set up with experts from national road authorities in Cracow, Poland. This session, which was held during a workshop of WG (Working Group) on Traffic Management, was the final step to validate important research outcomes. This was the closest WG to the research topic within the research period. Although the experts were very technical, they were also familiar with organizational structure and transport management issues in their own countries. The first day of the workshop indicated different examples of road authorities concerning traffic management. Countries presented some information about their improvements in the fields of traffic management. Various examples of software (including data warehousing) and application involvements (for road, public transport, bike and multimodal) were mentioned. Some of these examples were not known yet and have been added to the information in chapter 2.

The expert session consisted of a briefly presentation of results, followed by four theorems where experts from road authorities had to vote. Voting was done by a live and interactive system during the workshop which increased the attention. Using this system, it was possible to collect information from 14 experts at the same time with possibility to analyse results after the session. The intention was to start a discussion based on these theorems after voting. However, by asking who chose agree and disagree, no hands were raised among the experts. Therefore, I decided to ask specific experts for their chosen answers and their motivation for these answers; that brought me more additional motivations. Nevertheless, the most information was collected after the full workshop, where I had some additional conversations with some experts. During these conversations we discussed specific opinions about the specific theorems that I tried to discuss.

The expert session started with providing the research results of chapter 2. The five issue themes (accessibility, energy & fuels, network planning, software & applications and transport modes) were briefly presented to the experts. Then, the experts were asked if they recognize their selves in the five issue themes. Most experts in road authorities did strongly recognize their selves into the five themes, only one expert did not. During the conversations in the end, this expert told me that he chose the answer because the need of five issue themes could differ for every country and/or region. For example, in some cities the focus lies more on energy & fuels, while others focus more on software and applications. However, because the literature review was based on different countries over Europe, this is not causing a problem for the validity of that step.

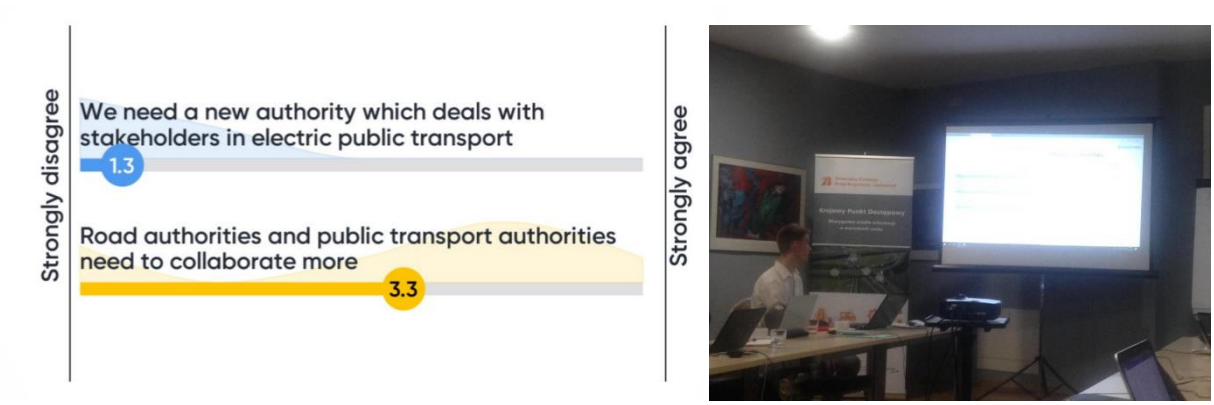


Afterwards I discussed the five identified authority structures, followed by the question if the five authority structures were representative for public transport. Although experts did less agree then with the five issue themes, most experts did still agree. One expert did not agree, because things were not always organized the same. Following this expert, it provides a general view of role divisions between authorities in countries. At national level it is often clear how things are regulated, so therefore the authority structures are very representative. However, in local public transport projects the responsibilities are not always the same as theory. Responsibilities that are in theory part of a regional transport authority, are in practice sometimes part of a local road authority. In addition, a transport infrastructure agency (the highest score) can still consist of departments which have the own responsibility and so experience in only the same field.

After we shortly spoke about the first two theorems, two other theorems were presented. The third theorem was based on one of the former conclusions. This conclusion, based on interviews with public transport stakeholders in UITP, states that a new authority or organization must be set up to deal with the involved partners of electric public transport. Most experts did strongly disagree or disagree with this conclusion, because they do not see a need for this new organization. This is an interesting outcome, because it puts the motivation of public transport and road authorities opposite each other while they are involved in the same situation in the end. An important motivation for this is that national road authorities are not always responsible for local transport issues and could therefore not always estimate the need of local road authorities.

The last theorem was related to an estimation of the European Commission and a discussed point during the workshop; both underlined the field of sharing data and involvement of partners, because there is currently less exchange of information. Especially on the field of sharing data, there is currently less or no cooperation. To develop systems like MaaS, it will be necessary to collaborate more and share data and information with each other. Most experts did strongly agree, because they see not enough collaboration at the moment. Only two experts did not agree, including one expert who indicated the wrong answer. The other expert disagreed because the road authority was already widely collaborating with the public transport authority; as a successful example, one created a platform where information of different transport modes (car, public transport, bike) is combined.

The information in this expert session has underlined and refuted different conclusions from earlier research steps. However, this session has also shown that road authorities have not always the same thoughts on different issues. Therefore, an important recommendation for further research on roles and interests of road authorities on interfaces with other authorities should be implemented.



Appendix V – Overview of involvements

This overview and table establish an overview with the involvements in public transport, based on the used projects. On the left side five themes (elaborated in chapter 2) describe the involvement topic, followed by the underlying concerning areas. Projects where road authorities are involved are indicated with 'X'. On the right the involvement, whether or not present, is explained.

Please mind that the general information in the table below is based on current project results from the projects collected in this research. Although the overview is compiled with utmost care and discussed with all interview respondents, the given information could still be incomplete. Please bear this in mind if you are about to use this information for new studies or research.

Road authorities are involved in the following themes:

A Designing / maintenance public transport stops in public space, Designing / maintenance innovative public transport stops like overcutting stops and inside stops, Designing vehicles relation to compatible infrastructure, Other accessibility like requirements on platforms for disabled people, etc.

B Energy savings in case of gained power from driving is going back to infrastructure network, New energy sources in case of electricity / hydrogen / biogas / HVO must be charged or fuelled in public space

C Designing routes if dedicated routes for public transport are implemented in public space, if roads are passed or crossed by rail transport vehicles (tram/train), Situating stops if the road authority is public space owner, Multimodal networks in case public transport and car are combined (P+R)

D Software & applications in case of solo road or multimodal applications, flowing public transport in case of public transport priority at traffic lights, other examples like opening bridges or lanes based on public transport schedules if road traffic is affected, Combined systems if new multimodal trips must be set up

E Personal rapid transit and infrastructure designing regarding these vehicles, on demand vehicles collaboration with public transport authority, new transport questions and discussions (priority, etc), guided systems in case of guided buses

A. Accessibility	A1. Designing / maintenance public transport stops X	In *public space* this is an issue for road authorities (stops in public property)
		In *private space* this is an issue for transport operator or business (private property stops)
		Regulations for public transport stops are set up on national / regional level (guidelines)
	X	*Innovative bus stops* like road overcutting stops and inside bus stops need collaboration

	A2. Designing public transport vehicles	*Regulations on EU level* about safety and passenger rights; only involved in discussions
		Capacity and demand are usually an issue for the transport operator (modular vehicles)
		Both transport authority and operator can be *owner of vehicles*, road authority usually not
	X	*Compatibility of vehicles with infrastructure* is a shared issue of transport and road authority
	A3. Other accessibility issues	*Additional passenger services* (help service with boarding, etc), no involvement
		Interoperability vehicles with online database (connections of vehicles), no involvement
	X	*Requirements on platforms / vehicles* for disabled people, road authorities build this
B. Energy & fuels	B1. Energy savings	*Reducing energy usage* of auxiliaries is profit and issue for transport authority/operator
	X	Road authority is involved in *gaining power from driving* if energy goes back to network
		Changing driving styles of drivers for ecologic or economic reasons, only operator involved
	B2. New energy sources X	*New source: electricity* (developed in almost all PT, involved in case of public space)
	X	*New source: hydrogen* (developed for mostly bus, involved in case of public space)
	X	*New source: HVO/biogas* (developed for mostly bus, involved in case of public space)
	B3. Charging and fuelling	Different *charging/fuelling times* depending on current energy source needs, not involved
		Fuelling (charging) in depot: road authority completely not involved
	X	*Fuelling (charging) in public space*: road authority is involved as public space owner
C. Network planning	C1. Designing routes	Road authorities are only involved designing routes *regarding physical infrastructure*
	X	*Dedicated routes*, roads and/or infrastructure for public transport modes (bus lanes, etc)
	X	*Passing or crossing roads*; road authority involved (for example trains or trams)
	C2. Situating stops	*City planning / town planning*: organizing the locations for bus stops (bus stop locations)
		Mostly *municipal departments* (cooperation with public transport and citizens/business)
	X	Road authority is involved in situating bus stops only as *the public space owner*
	C3. Multimodal networks (P+R) X	*Combining cars & public transport* > park & ride means collaboration local road authority
		Physical and digital cooperation (departure times, communication), not involved
		Three usual partners: road authority, public transport authority, town planner involved

D. Software & applications	D1. Smartphone applications	*Solo public transport* applications (times, schedules, services), not involved
	X	*Solo road transport* applications (routing, parking, advising), road authority involved
	X	*Multimodal applications* (not based on one transport mode); collaboration road authority
	D2. Flowing public transport X	*Priority at important crossings* equipped with traffic lights; road authority organises this
		Digital vs physical blockings and registrations of vehicles; road authority partly involved
	X	Other examples (*opening bridges, lanes based on schedules, etc*), road authority involved
	D3. Combined systems X	Options of *new multimodal trips* (combination with P+R or K+R), road authority involved
		Feasibility of *data combinations in software and practice*; currently transport operator
		Data using through authorities and privacy issues; in public transport only for operator
E. Transport modes	E1. Personal rapid transit	*Personal Rapid Transit vs Group Rapid Transit or Bus Rapid Transit*, transport authority
	X	PRT Vehicles and *Infrastructure Designing regarding these vehicles*, road authorities
		Other *Personal Rapid Transit related issues* (costs, efficiency), transport authority
	E2. On demand vehicles	Closed with *own infrastructure or mixed with other* traffic, road authority could be involved
		On demand vehicles *instead of scheduled, app/based, demand*; transport authority
	X	*Cooperations of road and transport authorities*, both authorities involved
	E3. Cybernatic transport systems	Using *CTS for door-to-door trips* in urban regions; transport authority/operator
		People *or also freight delivery* (transport authority as involved partner)
	X	New *transport questions and discussions* (who gets priority, etc), road authority involved
	E4. Guided systems X	*Guided buses* (less public space is needed), road authority is involved in public space
		Possibilities *buses on tram rails* (charging for trolleys), road authority could be involved
		Interference *other guided systems* or closed systems; which/why, only transport authority