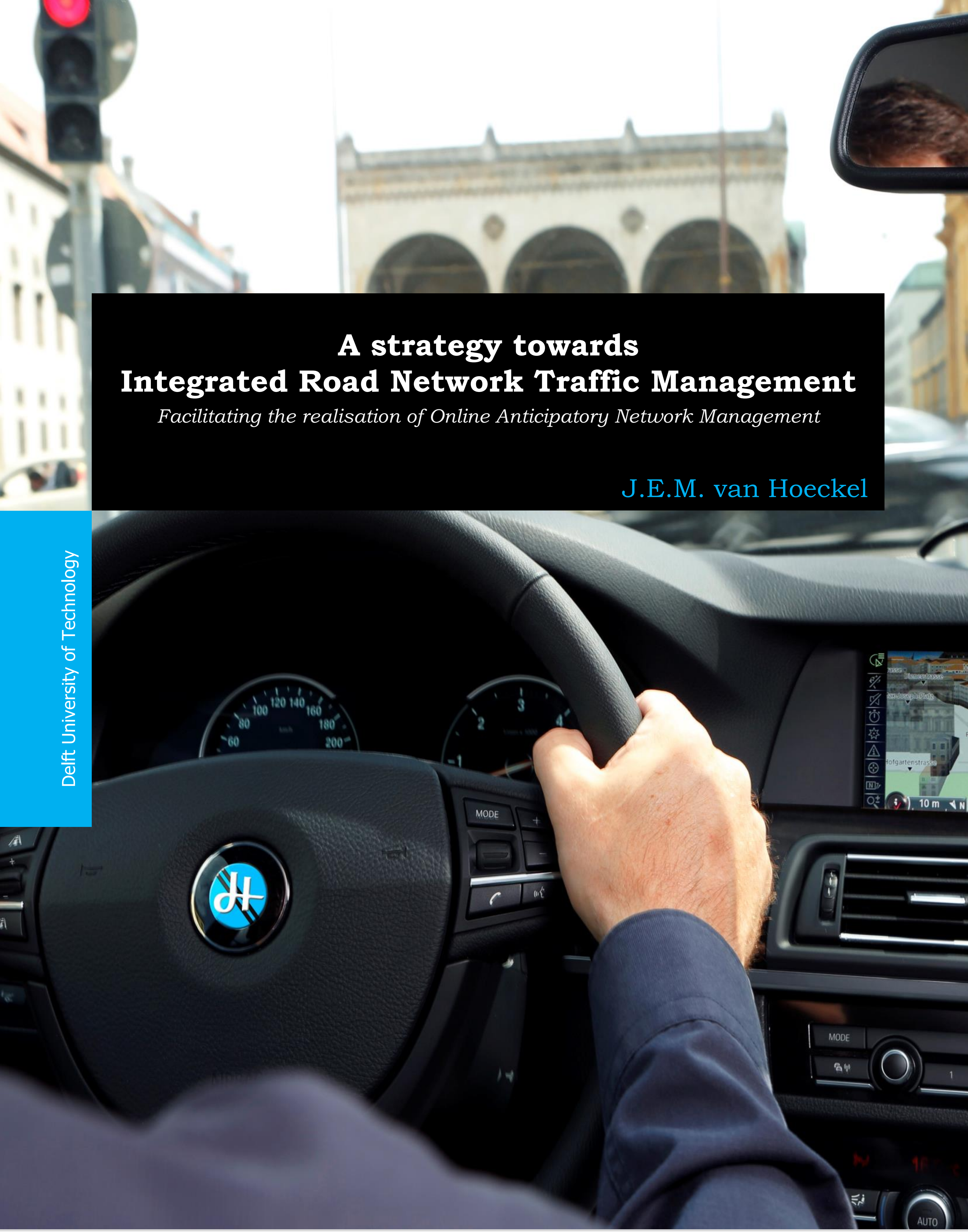

A strategy towards Integrated Road Network Traffic Management

Facilitating the realisation of Online Anticipatory Network Management

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SWECO

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Facilitating the realisation of Online Anticipatory Network Management

By

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in partial fulfilment of the requirements for the degree of

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Preface

This thesis concludes my master degree in Construction Management and Engineering at the Delft University of Technology, which I have completed during my internship at Sweco in 2017.

My starting point was my previous graduation thesis. Here, I investigated Online Anticipatory Network Management. This is a rather conceptual traffic management approach far from implementation and rather complex and thus difficult to explain to people that you want to involve. In this research I wanted to investigate its implementation because I felt that this would have all kinds of hinder in reality. Pretty soon I knew that I wanted to look beyond the technology and since my previous research was still in a conceptual state, my research gained a strategic time frame (that included development, implementation and operation). This led me to the TIP approach (Technological, Institutional and Process) and policy analysis which reached beyond my education. Furthermore, I knew that the approach I previously investigated is just one of many possible approaches. Therefore, I wanted to create a research that was a bit broader and could still be applied if the development of traffic management or the demand of the government went in a different direction. So once again my research expanded in size and in its degree of difficulty. Therefore, I did what anyone would do, and I found out that this topic also had some great economical features to dive in….

So it was an ambitious topic. One of the moments I was confronted with this was in my introduction conversation with my (then future) Sweco supervisor Gerbrand Klijn. He told me that I've been describing a problem that he recognised. Then he asked me if I was really so ambitious to solve a problem that had been around for over a decade, in just a couple of months. But I took on the challenge. By sparring with Gerbrand in the minutes between his appointments and following various online courses of Faculty of Technology, Policy and Management I gained valuable insights in how to structure the problem and apply theory on it.

During my research I was also affected by various obstacles. First, I found it very difficult to choose a subject where I could achieve some synergy between the two graduation theses. Second, I was greatly affected by the ambiguousness of the rules (ironically "institutions") regarding this double graduation. Third, I had the discomfort of needing to switch of graduation company during my research because there was a disagreement with the direction of the research. Luckily, Gerbrand and Sweco have provided me with a more than suitable alternative. Here, I was given the opportunity to talk and learn from a lot of people experienced in the field of traffic management and invited to a smart traffic event. In the end, my research may be a bit abstract, but I think it offers valuable insights and a good methodology. So, I'm content with the result and what I've learned.

Of course, I've had quite some help in achieving this. So, I would like to thank my supervisors: Bert for his keen analytical supervision, John for guiding me through the process, Henk for the technical assistance and supervision and Gerbrand for sharing his experience and expertise. I would also like to thank the interview respondents: Bas van der Bijl, Jeroen Brouwer, Lieke Berghout and Willem Hartman for their valuable insights. The people close to me have helped me through another tough period. So, I would like to thank my girlfriend Marloes, my family, my housemates, my study buddies, my colleagues and all other friends for helping me through it. Finally, many thanks to Bram Peerlings for his final check.

Jim van Hoeckel
Delft, May 2017

Summary

Traffic is a vital element of our society. Managing this traffic on a network level has become an increasingly complex task, due to an increase of traffic density and variety of involved actors and (often incompatible) approaches. There are technological opportunities to develop, implement and operate integrated approaches that are expected to increase road network performance. However, these approaches are hindered by problems and uncertainties caused by a multi-actor environment of public and private parties and technological complexity and uncertainties. Therefore, this research creates a strategy for the national government of the Netherlands to cope with the strategic behaviour of actors and uncertainties associated with Integrated Network Traffic Management (INTM), to stimulate its development, implementation and operation. It considers INTM to be a socio-technological system that is affected by technological, institutional (i.e., rules that constrain human behaviour) and process elements. The strategy created in this research must therefore incorporate all of these elements.

Historically, the governance of the public road infrastructure in the Netherlands is done by a geographical patchwork of more than 400 road authorities. Nowadays, an increasing number of them continuously steer traffic conditions using traffic control and traffic information. Meanwhile, the developments in traffic management and the advent of private traffic information parties gave way to numerous parties and approaches that are steering traffic dynamically but often without cooperation. This results in a complex system where traffic across the network is managed by various parties and approaches, often simultaneously.

This complex system has problems that lie beyond the operation and are caused by (and possibly resolved with) technological development and its implementation. Herein, the operation is affected by the previous mentioned parties that have different interests, geographical boundaries and means of optimising their traffic management, causing for road network inefficiencies and unpredictable traffic behaviour. The implementation of the NTM approaches on the road bound infrastructure is affected by case-by-case decision-making of many authorities that limits economy of scales, limits interoperability and induces procurement inefficiencies. The development is characterised as a market of supply and demand of technological complex products between private firms and road authorities. The complexity of its products increases the information asymmetry and the risk of the supply while the previous mentioned case-by-case decision-making of numerous road authorities causes a variety and uncertainty in the, by resources limited, demand. The entire system is affected by a limited incentive for actors because the quality of traffic management is often not specified and measured. Thus the system is characterised by various problems and uncertainties between various actors. Resolving these can only be a collaborative effort. Essential in the collaboration is a shared problem perception. Therefore, the identified problems are aligned with the perceptions of diverse actors by conducting interviews with them.

The future of the system is characterised by uncertainty because the system is constantly evolving. In this uncertainty, it is suggested to steer toward a specific desired future (prescribed future). Here, it is proposed to realise a specific INTM approach: Online Anticipatory Network Management (OANM). This approach, investigated by van Hoeckel (2016), is expected to improve road network distribution by optimally steering route choice behaviour with traffic control and traffic information. Furthermore, it allows road authorities to regain partial steering control over the network that they have lost with the advent of private traffic information providers. A trend and scenario analysis show that this prescribed future is possible. However, its realisation requires a collaboration of a range of actors, the involvement of the national government and is hindered by the aforementioned problems.

Cooperation between a range of actors must be achieved in order to realise the previous prescribed future and to mitigate the identified problems. Among the range of actors, the resources required to realise or to block the prescribed future are scattered and the decision-making takes place between many different actor groups. Stakeholder analysis shows that the majority of actor groups and their subsequent interest and power allocation are predicted to be in favour of the prescribed future. Within this future, several issues between actors and potential coalitions that may affect progress are found. However, the changes and issues regarding the prescribed future can be incomplete due to the technological uncertainty. Furthermore, the network strategic interests and perceptions can change over time. This may cause yet unforeseen strategic problems and uncertainties that can hinder the realisation of the prescribed future and will require constant monitoring and a strategy that can cope with this.

Institutions and its reforms may cause and reduce the aforementioned strategic and technological problems and uncertainties. To make an assessment of this, an institutional framework for road-bound traffic management (based on frameworks presented in the literature) is created. Subsequently, problems that could hinder the prescribed future are inducted from this framework. To reduce these and previously found problems institutional reforms are proposed and investigated. These reforms are mainly focused on the resources and organisation of the government, because there exist strong limitations and concerns to institutional reform in a multi-actor environment. This leads to the selection of three institutional directions: 1) stimulation of timely data exchange; 2) performance goals and their measurement; 3) central coordination of traffic management. These directions are further specified in a number of dimensions, evaluated through interviews and used in the final strategy.

To conclude the various problems and uncertainties (technological, strategic and institutional) and the large numbers of interdependent actors (as described before) lead to complex interaction processes. These require a combination of an institutional strategy and a process strategy because of the differences and complementarities between them. The institutional strategy prescribes a list of performance factors (possibly with weights and target values) and their measurement approach that should be applied on a national level. Furthermore, it prescribes a covering grid of interconnected traffic management zones with boundaries in non-urban areas for the Netherlands, where coordination exists with the road authorities that make up this traffic authority and between traffic authorities. In addition, it is advised to investigate the possibility of national benchmarking. Finally, it is advised to investigate the ownership and potential value of (dynamically changing) traffic control data and the impact of future vehicle-infrastructure communication on the latter. The process strategy prescribes a process management and design to facilitate the process of cooperation. Starting from the shared problem perception and desired future, many separate dilemmas can be identified. Eventually, a package deal of all these dilemmas can be made. This should allow actors to give and take on individual issues that could otherwise hinder progress. The proposition of realising OANM increases the complexity of this research, but it also increases the benefit for both public and private parties to join the process. To guide the process, it is advised that the national government should compose the role of process manager.

Hereto, it is recommended that the government of the Netherlands adopts both strategies. Although their application will not be an easy task, more efficient development, implementation and operation of INTM and the realisation of OANM can be achieved. This is expected to reduce road congestion and its impact, reduce government spending and increase liveability and could contribute in sustaining and improving the leading role for the Netherlands in traffic management.

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Glossary

Term	Definition
Actor	'A social entity, person or organisation that has a certain interest in the system and/or is able to influence the system directly or indirectly' (Enserink et al., 2010).
Arena	The place where a specific group of actors make choices on the basis of their perceptions of problems, solutions and each others' strategies (Cohen, March, & Olsen, 1976, p. 25).
Game	A series of interactions that occurs around an issue (Scharpf, 1997).
Institutional uncertainty	Uncertainty that is caused when actors from different institutional perspectives interact (Koppenjan & Klijn, 2004).
Institutions	'A set of rules that regulate the interaction between parties involved in the functioning of a (technological) system' (Koppenjan & Groenewegen, 2005, p. 244).
Networks	'More or less stable patterns of social relations between interdependent actors, which take shape around policy problems and/or policy programmes' (E. H. Klijn, 1997, p. 30).
Perceptions	The image that actors have of the other actors and the networks and the substantive characteristics of a policy problem (Bots, van Twist, & van Duin, 2000; Scharpf, 1997).
Resources	'The practical means or instruments that actors have to realise their objectives' (Hermans & Thissen, 2009, p. 809)
Strategic uncertainty	Uncertainty that arises with strategic choices of actors in complex problems (Koppenjan & Klijn, 2004).
Substantive uncertainty	Uncertainty caused because the necessary information is not available (in time) (Koppenjan & Klijn, 2004).
Values	'These provide the directions in which actors would like to move; they describe the internal motivations of actors' (Hermans & Thissen, 2009, p. 809)

List of acronyms

Acronym	Definition
FCD	Floating Car Data
GNSS	Global Navigation Satellite Systems
INTM	Integrated Network Traffic Management
NTM	Network Traffic Management
OANM	Online Anticipatory Network Management

1 Introduction

In this research, Integrated road Network Traffic Management (to be called INTM) is investigated. This chapter will introduce this topic by explaining the motivation behind it and presenting its goal, scope, context and methodology. Finally, the structure of this report is presented.

1.1 Research motivation

Transporting people and goods and the resulting traffic is and has been of vital essence to our way of living. As long as the traffic is able to move around unhindered, no intervention is required. However, due to an increase of demand on roads over the past decades, congestion occurs on a daily basis. When this congestion forms, efficiency, safety and environment are negatively affected, posing a strain on society.

Various measures exist to combat congestion. Traditionally, the construction of large infrastructures is undertaken to increase capacity and thus decrease the pressure on the road network. However, this is a costly solution that is often accompanied by time-consuming political procedures that concern financial, environmental or land-use issues. Thus, simply investing more in new infrastructures does not seem preferable. Therefore, the government of the Netherlands aims to better utilise their road infrastructure (Schultz van Haegen, 2013), like many other countries. Traffic management is one of the possibilities to do so and has been proven to be successful in the past decades (Kennisinstituut voor Mobiliteitsbeleid, 2014).

Traffic management is the intentional informing, guiding and steering of traffic flows on the basis of traffic data and timely site-specific traffic conditions (Ministerie van Verkeer en Waterstaat, 1995). Its goal is to manage traffic flows to improve or preserve road efficiency, road safety and the environment. Traffic management can be differentiated in different approaches according its optimisation domain, namely local (single intersection), zonal (usually an artery of intersections) and regional (a network of intersections). The latter, managing traffic flows on a network level, is called Network Traffic Management. It has the challenging task to combat the disruptive network characteristics. One of them is that the throughput can decrease steeply when the number of vehicles on the road surpasses a critical point. This causes spillback and can increase pressure on alternative routes, which can in turn also reach this critical point. Thus, it causes the network to degrade under pressure, possibly causing gridlock. As the road network is used more intensively, the spreading of congestion as network characteristic becomes more evident and cause congestion to propagate trough the network like an oil spill.

In order to cope with the unequal network distribution, all sorts of network traffic management approaches have been and still are being developed, implemented and operated. In the 1990s most network traffic management was performed by governmental agencies that used road-bound installations (traffic control installations and traffic information panels at the side or above the road). At the beginning of this century a combination of developments in telecom, electronica and Global Navigation Satellite Systems (GNSS) gave drivers the ability to acquire (real-time) traffic information to support the traffic routing decision-making (van Hoeckel, 2016). This gave private companies the ability to steer (and thus manage) traffic with traffic information and collect traffic data with in-car (or mobile) equipment. This led to a differentiation of tracks within network traffic management, namely 'road-bound' and 'in-car' and partially shifted the task of network traffic management in private hands. Although it supplied drivers with more traffic information it did not necessarily improve network performance because private traffic information is usually more focused on the individual travel time gain rather than overall system performance. Furthermore, it causes traffic to be steered by multiple actors that steer with different goals and on different scales and using different measured data that may prevent accurate traffic control optimisation and traffic information. Although, it is evident that private traffic information services offer valuable services, the current situation leads to a road network distribution that is undesirable from a societal perspective.

There are technological opportunities that reduce congestion and traffic management suboptimalities. A traffic management approach that combines both traffic information and traffic control called Integrated Network Traffic Management (INTM). A specific INTM approach, called Online Anticipatory Network Management (as conceptualised by van Hoeckel, 2016), is currently a conceptual approach that brings the additional opportunity to improve network distribution from a societal perspective. It offers a possibility to utilise the integrated potential of road-bound and in-car traffic management that allows governments to steer traffic (for the common goal) while utilising a range of private traffic information services (described in more detail in Subsection 2.3.4). It proposes to change the perceived travel costs (e.g. travel time) by determining and applying traffic control (e.g. traffic signals) settings that optimally affect network-wide travel costs, route choices and thus network distribution, while informing drivers about the modified travel times and anticipating their reaction to the perceived travel costs. However, the realisation of INTM and OANM in specific will not be self-evident, especially because they are not just a technological challenges.

1.2 Problem formulation

The challenges originate from developments in traffic management technology that gave way to a wide range of traffic management approaches developed, owned and operated various public and private parties. The used traffic management approaches operationally have different goals, means and different areas of influence that often overlap, while many more are being developed and offered in a market of demand and supply. This makes the traffic management system more interdependent than ever. It results in a system: 1) that transcends the boundaries of one organisation; 2) involves both private and public parties; 3) the development and functioning of this system is affected by the technology but also by the behaviour and decisions of actors; 4) that can be influenced by market forces and government regulation. These are all specific characteristics of a complex socio-technological system (according to Koppenjan & Groenewegen, 2005). Here, strategic behaviour and uncertainties cause for societal suboptimal road network performance and impose transaction costs that are able to hinder efficient realisation (decomposed into development and implementation) and operation. While individual actors may stand to gain from this uncertain situation, it makes setting policy difficult, which in turn hinders governments to intervene adequately, resulting in a prolonged societal suboptimal situation of muddling through (incremental process of decision-making). Therefore, this research considers the following problem statement:

> Problem statement
>
> Strategic behaviour and uncertainties hinder development, implementation and operation in the complex socio-technological environment of Integrated Network Traffic Management from a societal perspective.

The number of actors involved with this problem is huge. However, their level of interest in solving the problem as well as their ability to do so is different. It is assumed that having a problem owner that is able and willing to (partially) resolve this problem is more effective. This problem affects society as a whole but is assumed to be unlikely to be resolved efficiently by the directly involved actors. Therefore, a problem owner is chosen that has the geographical scale and resources available to intervene and has sufficient interest in the mitigation of this problem. This leads to the following problem owner:

Problem owner

The national government of the Netherlands.

1.3 Goal of research

Since we depend on secure and reliable transportation to ensure our way of living and a strong economy, just 'wait and see' and allowing for 'trial and error' is not acceptable and can be very costly. Therefore, the aforementioned problem requires a strategy to cope with the strategic behaviour of actors and uncertainties. However, determining policy regarding a complex socio-technological system is a non-trivial task. This research will assist the problem owner in determining their course of action regarding the development, implementation and operation of INTM. The result should be a strategy that should give direction to the organisation and agreements that shape the activities and the division of roles between public and private parties with regard to INTM in the Netherlands. Additionally, it could be used by the involved parties to assist them with strategic choices and could help contribute in creating (and sustaining, according to Soekroella, Hoogendoorn, & van Lint, 2014) in a leading role for the Netherlands in traffic management. To summarise this, the goal of this research is listed as:

Goal

Create a strategy for the national government of the Netherlands that copes with strategic behaviour of actors and uncertainties in the socio-technological environment of Integrated Network Traffic Management to stimulate its development, implementation and operation, taking Online Anticipatory Network Management as case study.

The design of the strategy in this goal is still unknown and requires investigation. Therefore, this research will attempt to answer the following research question:

Research question

How should the national government of the Netherlands cope with the strategic behaviour and uncertainties in the socio-technological environment of Integrated Network Traffic Management to stimulate its development, implementation and operation, taking Online Anticipatory Network Management as case study?

To answer this complex question, it is decomposed into several sub-questions. The rationale behind this decomposition originates from the research approach to be presented in Section 1.5. These sub questions will form the basis of the chapter structure that will be presented in Section 1.6, where this decomposition is discussed. The considered sub-questions are:

Sub-questions

1) *How do the governance of the road infrastructure and network traffic management in the Netherlands function and how did these evolve?*
2) *What are the problems and uncertainties of current network traffic management system that hinder its development, implementation and operation?*
3) *In what direction is network traffic management and its governance expected to go and how can this direction be realistically shaped for the benefit of society?*
4) *Who are the actors involved and how will they perceive, respond to and interact regarding to the prescribed future?*
5) *How do institutions play a role in current problems and how can they contribute in resolving the problems?*
6) *How could the national government cope with complex interaction processes?*

1.4 Scope

This research only investigates the Netherlands with a time scope of twenty years. Within this time scope and given the previous described uncertainty, a lot can change. Therefore, it will require a flexible strategy, especially for when time progresses. Furthermore, it investigates realisation of INTM (and OANM). This does not include a cradle (end of cycle) phase because the conceptual technical design limits its analysis, the uncertain life expectancy in a continuous evolving system and the current variety infrastructure and traffic management prohibit an accurate analysis of this stage. Finally, the realisation of INTM (and OANM) is only investigated for motorised vehicles. While the concept could be applied on other modes, the majority of congestion and thus possible benefits are expected to be for motorized vehicles.

1.4.1 Assumptions

In this research a number of assumptions will be made, which are listed below:

- OANM has some technical hurdles. It will involve a very computational demanding process and traffic estimation in high dense urban areas. This research assumes that this is a technical problem which can be overcome with additional traffic data, new theoretical insights and IT developments.
- OANM requires drivers that have and use connected navigation devices to inform drivers of the effects of changed traffic control settings. Although not all drivers have such a device, de Mooij (2013) predicts that sixty per cent of all drivers in the Netherlands will have the online traffic information ability within ten years and all of the drivers between fifteen to twenty years. Thus, it is assumed that this will not pose a restriction for OANM.
- OANM is assumed to have a positive cost-benefit ratio. This is done because it is too soon to estimate costs because of the conceptual stage and the variability of its socio-technological environment. Thus the cost of collaboration may change because of this research and because the benefits can be highly dependent on the network, technical characteristics, external factors et cetera. Even if the approach does not prove to give adequate return on investment, this research is still valuable as methodology and investigation towards INTM, similar concepts and for the general traffic management development.
- The OANM-approach can theoretically be developed, implemented and operated by the government or parties that are funded by the government (along with the resources required). But, it is assumed that such a go-alone strategy is not the way to efficiently stimulate development, implementation and operation of Integrated Network Traffic Management, because it is costly solution that does not solve the underlying problems for the realisation of traffic management.
- The actors involved are implicitly assumed to behave according to individual (long or short term) utility maximisation that involves the minimisation of perceived costs.
- It is assumed that cooperation does not to emerge without facilitation because of the number of actors, the variety of interests and objectives, the resulting conflicts of problems and solutions.
- The total outcome of improving the INTM system and realising OANM in a collaboration is assumed to be higher than the cost of collaboration.

1.4.2 Focus

This research will have a couple dimensions in which it will focus. First, this research will engage in policy analysis. This can have six goals according to Mayer, van Daalen & Bots (2013, p. 43). In this context, this research will focus on providing strategic advice, but the other dimensions will also be covered (i.e. ´research and analyse´, ´design and recommend´, ‘clarifying arguments and values’, 'democratising' and 'mediating'). Second, as previously introduced, OANM will be used as a case study for INTM. The technical complexity of this approach will invoke a strong technical orientation and potential other INTM approaches will be neglected. Third, the national government as problem owner will result in a focus on road-bound infrastructure and its interaction with in-car traffic information, since the government has more influence in this area. This means that in-car traffic information system and market will not be fully assessed. Finally, there is a wide range traffic management approaches and developments that do not operate on a network level. Although they may affect INTM, their direct inclusion would make this research to vast for the set research timeframe. Thus, it is partially neglected and the same goes for vehicle development.

1.4.3 Applicable domain

The domain of this research is divided in the intended domain and the reached domain. The first is the domain where the actual research takes place and the second to which the research can be applicable. The intended domain is 'INTM in the Netherlands'. This domain is chosen because, the Netherlands has a dense meshed road network that is equipped with high quality measuring devices from international perspective (Wilmink et al., 2016, p. 38) and has relatively good mobile connectivity (GSMA, 2016; The World Bank, 2015). Furthermore, there are obvious practical research advantages (no language barrier etc.). This makes it ideally suited for the OANM approach that requires route alternatives, accurate traffic data and the possibility to inform drivers real-time. Eventually this research can be applied (with adjustments) to urban areas of all developed countries and influence traffic management in general (reached domain).

1.5 Research approach

Since Integrated Network Traffic Management was argued to be a complex socio-technological system (Section 1.2), this research will engage in policy analysis to create a strategy for a complex socio-technological system. Such systems consist of more than a technological dimension and pre-suppose that coordination of the behaviour of parties is required to achieve a functional system (Koppenjan & Groenewegen, 2005). To analyse this, Bots (2007) states that socio-technological systems design requires an interrelated design of the technological system, the institutions (i.e., rules that constrain human behaviour) and the decision-making processes. This research will therefore suggest an interrelated TIP (Technological, Institutional and Process) approach to acquire this design (illustrated in Figure 1). Specifically, it will attempt to resolve the T problems with I and P.

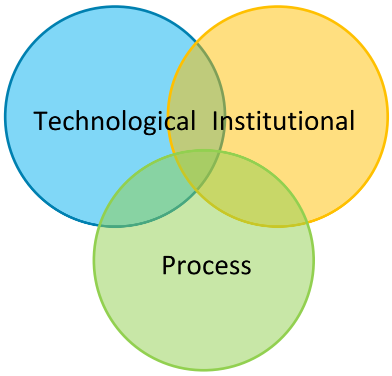


Figure 1 - Research framework

1.5.1 Research origin

The origin of this research lies in a previous research of the same author. In that research (van Hoeckel, 2016) the OANM approach was investigated. Although promising results were found, the researcher also found indications that the approach was not likely to be realised unless its realisation process was managed and stimulated. Given the potential social benefits, this current research is therefore undertaken. This has added advantage that some specific technological insights are already acquired (these are presented in Subsection 2.3) and leads to a policy analysis approach that is able to further into technical details if necessary.

1.5.2 Research position

This research will hold a certain position in regard to the scientific literature and applied research. Its position is important to identify, assess and position potential research contributions.

The scientific literature shows an increasing interest in the co-evolution of technology and governance in various disciplines and perspectives (e.g. new institutional economics, new public management etc.). The current research employs this, but starts from a technological perspective and conducts policy analysis that draws from and integrates elements of many scientific disciplines such as mathematics, economics, political science, sociology and psychology. This multidisciplinary view will be applied using the TIP framework to Integrated Network Traffic Management. Although some applications of this framework can be found in the literature (e.g. Herder, Stikkelman, Dijkema, & Correljé, 2008; Künneke, 2008), a similar approach or topic was not found in the literature database (searched for 'institutional process technological design', articles that referred to 'Koppenjan & Groenewegen, 2005' and 'institutional design traffic management' etc.). Furthermore, the proposed research is no intellectual design process because it does not have a single decision-maker (as precribed for complex societal problems by Koppenjan & Klijn, 2004, p. 45).

There has been applied research (governmental and consultant reports) regarding elements of this research that detected problems and proposed visions of the future. These are listed in Appendix E. However, in this applied research no strategy has been proposed that facilitates the realisation of (integrated network) traffic management with respect to the multi-actor environment.

1.5.3 Research complexity

The complexity of this research lies in the entanglement of the socio-technological system and in its problems and uncertainties. This research expects that these originate form:

1) a socio-technological system evolves fast and the chosen timeframe is long;
2) the socio-technological system includes the merger of two previously separate subsystems (traffic information and traffic control) and involves multiple stages (development, implementation and operation) that operate at a different pace (in time);
3) the complexity (dynamic, non-linear, etc.) of the traffic interaction;
4) multi actor dependencies, dynamic positions, diverging perceptions and strategic behaviour of the actors involved;
5) a range of geographical boundaries and the interactions between them;
6) the vitality of the traffic management systems and its invested capital limit physical change; and
7) the information available for analysis regarding the previous complexities.

Thus, this research states that the problem is technological complex, exists in a multi actor environment and has limited social consensus. Therefore, the literature describes problems with these characteristics as 'unstructured', 'untamed', 'intractable' and 'wicked' (Hisschemöller & Hoppe, 1995; Mason & Mitroff, 1981; Radford, 1977) and therefore attention should be paid to the decision-making process and the way information is handled (de Bruijn, ten Heuvelhof, & in 't Veld, 2010). A topic of special interest herein is how to cope with the uncertainty that is involved with this complexity. This will be discussed in the next subsection.

1.5.4 Research uncertainty

The application of new technologies and new scientific findings not only introduces new ways for problem solving and the pursuit of prosperity, but also leads to new problems, new risks and new uncertainties (Beck, 1992). Not only the problems but also the risk and uncertainties are important when conducting policy analysis. Therefore, a large part of this research will try to deal with these.

Complex societal problems in a network setting have three manifestations of uncertainties according to Koppenjan & Klijn (2004), being substantive (or technological), strategic and institutional uncertainty. Van Geenhuizen et al. (2002, p. 7) describe different strategies to deal with uncertainty, where some of them are complementary and depend on each other, as cited below:

- 'To ignore uncertainty, take policy measures and see what will happen. In fact, this means accepting the risk of great uncertainty in policy outcomes and serious policy failures by the wrong (or incomplete) selection of measures.'
- 'To identify and, if possible, specify uncertainty. This enables the policy maker to act consciously in the presence of uncertainty, mainly uncertainty about future external factors and system performance response to these factors.'
- 'To reduce uncertainty. Like the previous strategy, this mainly applies to uncertainty from external factors and related system performance responses. First, a reduction of uncertainty can be achieved by additional research and/or a better integration of existing knowledge. Also, uncertainty about external factors and system performance may be reduced by negotiating with stakeholders whose behaviour is uncertain.'
- 'To accept uncertainty and act consciously in its presence. Here, too, different strategies are possible, and these can be applied to all major classes of uncertainty. A robust policy may be selected, that is, a policy expected to do well in most possible future circumstances. Or, a flexible or adaptive policy can be designed.'
- 'To see uncertainty as an opportunity to creatively shape the future. This strategy holds mainly for the overall uncertainty in making the right policy choices. Rather than emphasizing a choice for a presently available policy option, this approach calls for the development of a broad vision that provides the guiding principles for present and future action, allowing for experimentation and small-step learning.'

These strategies will be used throughout the research to describe what approach to cope with the uncertainty is chosen.

1.5.5 Research methodologies

To cope with the previous complexity a wide range of methodologies are used. The table below presents an overview of the methodologies used to answer each sub-question. The rationale for the specific methodology is presented when employed in the research.

Table 1 – Methodologies per sub-question

Sub-question	**Main methodology**
1) How do the governance of the road infrastructure and network traffic management in the Netherlands function and how did these evolve?	Literature analysis of governmental sources regarding road authorities, traffic management governance and analysis of scientific traffic management literature.
2) What are the problems and uncertainties of current network traffic management system that hinder its development, implementation and operation?	Identify problems based on the literature and induction, structure these according to systems analysis, supplement these with the use of traffic management and control theory, and supplement, verify and rank these by interviewing actors involved.
3) In what direction is network traffic management and its governance expected to go and how can this direction be realistically shaped for the benefit of society?	Trend analysis and scenario analysis, whereafter its result will be compared with the proposed technological future (OANM) and its market application will be evaluated in a causal

Sub-question	Main methodology
	diagram. Finally, a general strategy is proposed on the basis of a SWOT & TOWS analysis.
4) Who are the actors involved and how will they perceive, respond to and interact regarding to the prescribed future?	Stakeholder analysis with some adjustments for policy analysis and an expansion to identify actor network attributes. Some interview elements are used as input for the stakeholder analysis.
5) How do institutions play a role in current problems and how can they contribute in resolving the problems?	Analysis with a proposed socio-technical institutional framework (on the basis of diverse other frameworks), whereafter varies institutional directions are decomposed and evaluated by induction and evaluated with interviews.
6) How could the national government cope with complex interaction processes	The network constitution approach and the process management approach

1.6 Structure

The structure of the report is presented in Figure 2. In this figure, each rectangle represents a chapter. To present the previously described complexity in a structured way, the technological, the institutional and the process elements will be discussed separately. So, each rectangle is marked in a colour that represents its main orientation (blue for technological; orange for institutional, green for process and grey for general). It has to be noted however, that complete unentanglement of the TIP elements is not possible. The arrows between the boxes in the figure represent output/input relations.

This report starts by generating a background in Chapter 2. It will consist of the functioning and evolution of road infrastructure governance and traffic management in the Netherlands (answering sub-question 1). Exploring this can assist in explaining why it functions like this today and may function in the future. Here, the ITNM and OANM will also be described in more detail.

Hereafter, the NTM will be analysed as a system from a technological point of view in Chapter 3 to identify and structure diverse problems (answering sub-question 2). Because this research will show that cooperation will be required, Chapter 3 will strive for negotiated knowledge by including multiple disciplines and researches and validating it with actor interviews in order to facilitate cooperation.

Then, in Chapter 4, the technological future of the system is analysed with trend and scenario analysis in an attempt to predict how the system and its governance will change. Subsequently the application of the OANM approach (a promising INTM approach described in Chapter 2) is evaluated in regard to this future (answering sub question 3).

Then, in Chapter 5, the actors and their network are analysed to evaluate how they perceive the prescribed future (suggested in Chapter 4) in comparison to the current situation and its problems (described in Chapter 3). In this chapter, the actors hold a certain position and have a certain perception that is affected by the past (partially described in Chapter 2). Subsequently, this will affect the role that they will fulfil in the prescribed future and in the decision-making leading towards that (answering sub-question 4).

Chapter 6 will evaluate how the behaviour of actors in relation to the technological and strategic problems and uncertainties can originate from and be influenced with institutional arrangements. Subsequently, institutional propositions are made and evaluated from a theoretical point of view and with interviews to assess their preferred design (answering sub-question 5).

Finally, in Chapter 7, a strategy is proposed consisting of an institutional component (originating from Chapter 6) and a process component (based on Chapter 5) to stimulate cooperation that proposes the OANM approach (evaluated in Chapter 4) in a response to the (negotiated) problems and uncertainties from Chapter 3 (answering sub-question 6).

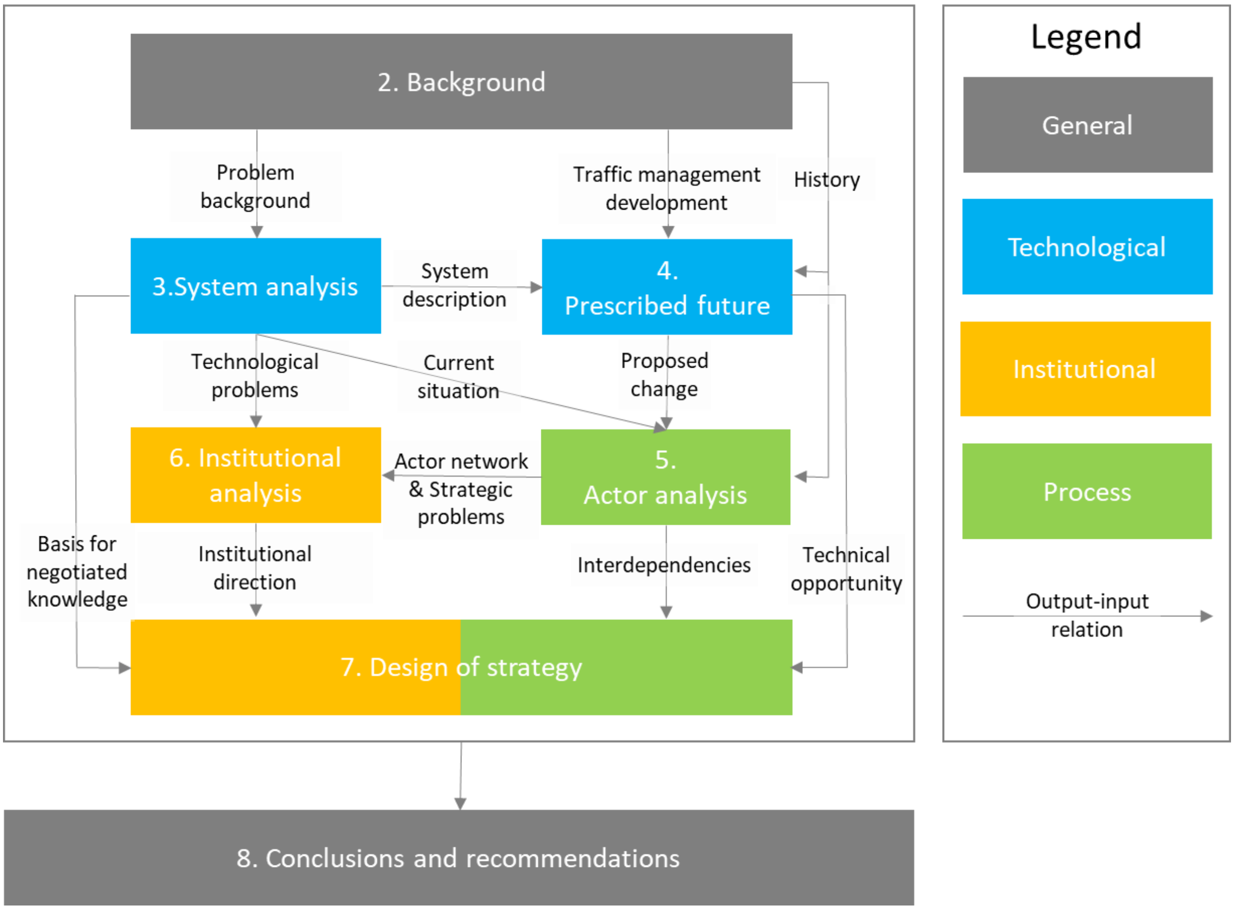


Figure 2 - Structure of report

2 Background of road infrastructure governance and traffic management in the Netherlands

This chapter will provide background of the road infrastructure governance and traffic management in the Netherlands. Its goal is to answer the following research question: *'How do the governance of the road infrastructure and network traffic management in the Netherlands function and how did these evolve?'.* To answer this, a literature study consisting of mostly governmental and scientific sources will be conducted.

It will start with describing how governance of the public road infrastructure in the Netherlands is divided over many road authorities. Then it will describe how the role of these road authorities has evolved. This is followed by a description of traffic management and its development, as this has changed and will continue to change the role of road authorities. Finally, national network traffic management is discussed because it stretches over the zones of road authorities.

2.1 Road authorities in the Netherlands

The governance of the public road infrastructure in the Netherlands is geographically divided over many different authorities, called road authorities. The majority of the public road infrastructure of the Netherlands is owned and managed by public road authorities. In 2016 the Netherlands has more than 400 different these public road authorities (Rijkswaterstaat, 2016a). This includes Rijkswaterstaat (Waterways and Public Works Agency) with 16 districts, provinces, municipalities, water boards and private road authorities (Rijkswaterstaat, 2016a). In this differentiation Rijkswaterstaat is acting manager for the Ministry of Infrastructure and the Environment.

Each of the road authorities operate in their own zone. These zones partially resulted from a differentiation of land ownership. A Water board, for example, owns and operates the traffic control on a bridge (because it runs over water), but a province or municipality owns and operates the traffic control installation downstream of that bridge. Another reason for this differentiation is the type of road they own and manage. In the Netherlands the following three main types of roads can be distinguished (they have been reduced to three for safety and driver experience) (SWOV, 2012):

- Access roads (erftoegangswegen): provide access to destinations. On this road, motorized traffic merges with vulnerable road users such as pedestrians and cyclists. To preserve safety of the road, motorised traffic is considered to be a guest and has to adapt to the vulnerable road users.
- Distributor roads (gebiedsontsluitingswegen): connects flow roads with access roads
- Flow roads (stroomwegen): allow for maximal traffic "flow" and are configured so that traffic safety at high speeds can be preserved. These include motorways and fast provincial roads.

It can be said that most access roads are owned by municipalities and most flow roads by the national government (and thus maintained by Rijkswaterstaat). This separation often results in a geographical patchwork zones (see for example Figure 3).

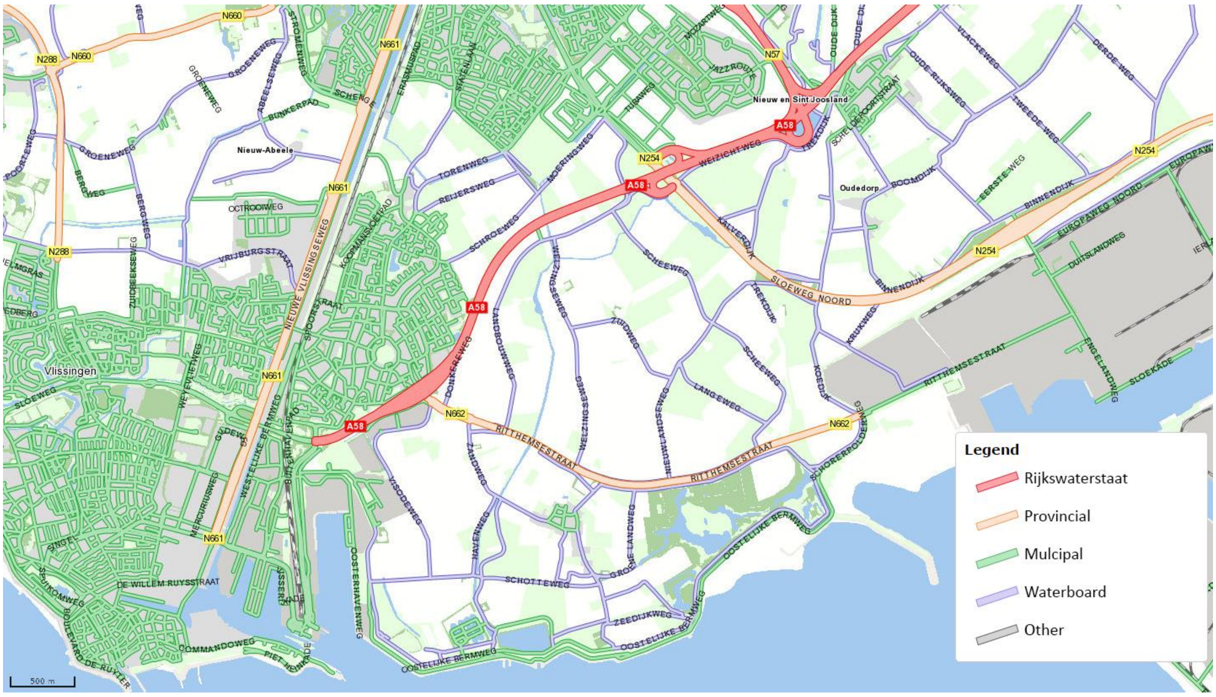


Figure 3 - Geographical distribution of road authorities in Vlissingen (map by OpenStreetMap, 2016; overlay by Rijkswaterstaat, 2016b)

The number of roads forming the patchwork stretching over the Netherlands is not equally distributed among road authorities. Using the categorisation on the road length data from CBS (2016), it is evident that the municipalities manage most of the 139.124 kilometres of road in 2016 (see Figure 4). Exceptions for this are the national roads (managed by the province and Rijkswaterstaat), motorways (managed by Rijkswaterstaat) and access roads and dike roads in Zeeland, Zuid-Holland and Noord-Holland (managed by water boards) (Ministerie van Verkeer en Waterstaat, 2007b, p. 20).

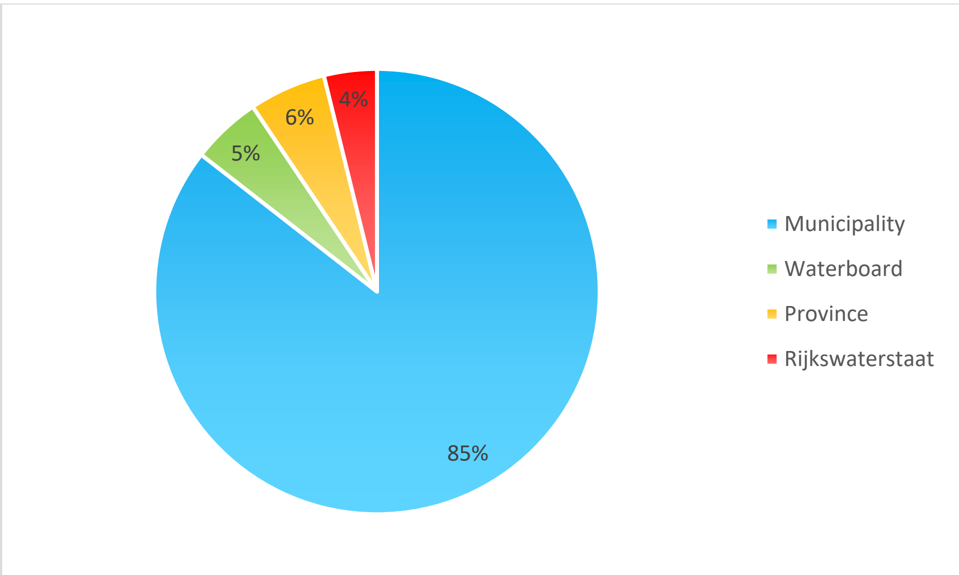


Figure 4 - Percentage of public road length per road authority in the Netherlands (data from CBS, 2016)

Because the types of roads are not equally distributed among the different types of road authorities, the usage per kilometre road and even per lane may be very different. If the Figure 4 were to show driven vehicle kilometres per year, the percentage of the Rijkswaterstaat would probably increase drastically. However, such data were not available for this research.

Another differentiation between road authorities is the traffic signal control that they own and operate. Currently around 5600 traffic signal control installations exist in the Netherlands. Based on a survey held in 1998 (A. Wilson, 1999), where water boards were not included, 81% is operated by municipalities, 15% by provinces and 4% by Rijkswaterstaat. Notable about this is that there were 17 municipalities that operated more than 50 installations, while there were 175 municipalities that owned 5 or less installations. Furthermore, this does not include ramp metering installations. Rijkswaterstaat had 99 of those in 2010 (Connekt, 2011).

The size of a road network, its types of roads, the installations on it and its usage, all have an impact on the way a road is and should be governed. Since the road network has evolved over time, so have the tasks of the road authorities. This will be discussed in the next section.

2.2 The role of road authorities

In the post World War II era, high economic growth and intensive product development has led to a huge growth of roads and road usage. Because of this, the task of road authorities gained more operational activities. Although traffic data from that time and for non-motorways is not available, it is a trend that has still continued in the past decades on motorways as shown in the image below. In the figure, dark green represents vehicle kilometres travelled on the main roads index (1995), blue represents main road kilometre lane length index and light green represents vehicle kilometre per lane kilometre index. Thus, the average density on the road has increased past decades.

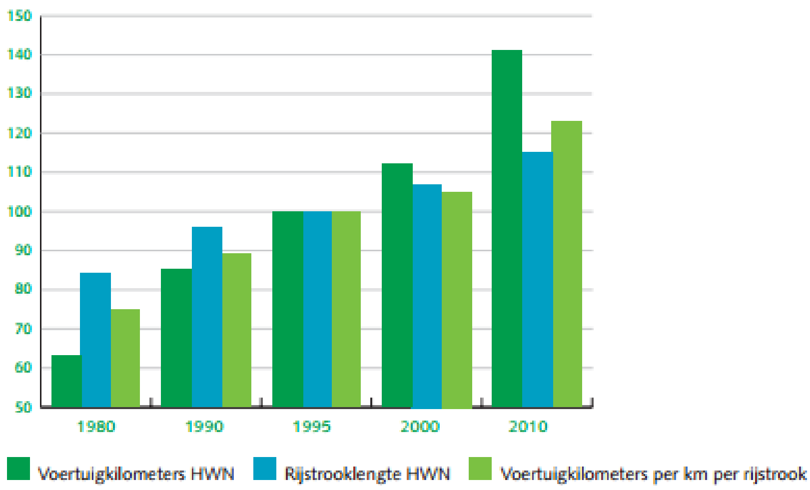


Figure 5 - Growth of roads and road usage (Ministerie van Verkeer en Waterstaat / Adviesdienst Verkeer en Vervoer, 2003)

Road law (articles 15, 16 and 17) of the Netherlands (Reymer, 1930), which originates from the pre-WWII era, defines that the road authority has to maintain the roads in good order. However, the growth of road usage demanded a different type of management of the road infrastructure. Thus, besides maintenance and development planning, the road authority is now expected to conduct a wide range of activities. According to the involved ministry (Ministerie van Verkeer en Waterstaat, 2007b, p. 11) this task includes "all activities that are focused on the development, maintenance and managing all functions of the Dutch road network in service of the users". To illustrate the wide range of tasks that may belong to the road authority a decomposition of tasks is listed (based on Ministerie van Verkeer en Waterstaat, 2007b, p. 12):

- Road & traffic management (operational)
    - Incident management
    - Traffic and route information
    - Network traffic management
    - Incidental (urgent) road repair
- Road maintenance & construction (tactical)
    - Road
    - Safety features
    - Lighting
    - Signage
    - Plantation
    - Vehicle permits
- Road development (strategic)
    - Development planning
    - Policy setting
    - Financing
    - Contracting

It has to be noted that not all tasks are performed by all road authorities. Some road authorities may have focus on planning, while others have focus on e.g. operational aspects. This is likely to be caused by (local) political visions and the type of network involved.

Throughout the years, this list has grown and especially on the operational tasks to facilitate the increasing traffic. This was enabled by the ICT development which gave way to the existence of a traffic control centre. Originally, the purpose of this centre was safeguarded bridges and tunnels. But from the 90's on, its function was expanded drastically. Now, this centre can change traffic control settings, dispatch traffic information and possibly order incidental (urgent) road repair, to steer traffic conditions and to preserve the throughput of the road. It is operated by a traffic manager that is appointed by or part of a road authority. This leads to a possible composition of tasks that includes three roles: a strategic development planner, an infrastructure manager and a traffic manager. The latter uses the concept of traffic management to improve road and traffic conditions.

The execution of these roles has changed over the years. For years now, the design, construction, maintenance and management of roads has been done in collaboration with diverse private parties. In this process, the government is usually the client that has to represent the wishes of the public and the private parties are usually the contractor. In more recent years, more responsibilities regarding construction, maintenance and management have been placed more and more with private parties with for example Design, Build, Finance and Maintain (DBFM) contracts. This is also starting to occur for traffic management because it has become a specialist environment where the role of private parties is increasing. This will be explained in the next section.

2.3 Traffic management and its development

This section is composed (with small alterations and additions) from an earlier publication of the same author (van Hoeckel, 2016).

Traffic management is the intentional informing, guiding and steering of traffic flows on the basis of recent and site-specific traffic conditions and traffic data (Ministerie van Verkeer en Waterstaat, 1995). Its goal is to manage traffic flows in order to preserve or improve efficiency, safety and environment. Managing traffic flows has the difficult characteristic that the throughput of traffic networks degrades under pressure. If the number of vehicles in a network surpasses a critical point, the throughput decreases steeply, which can cause total gridlock. This is different from for example water through a pipe, where a higher pressure (demand) implies more throughput. International research has shown that there are four intertwined reasons for this decrease in performance of congested networks (van Lint et al., 2013):

- There is a significant (up to 30%) drop in (local) capacity on motorways once the level of congestion is reached.
- Queue spillback can cause blockages upstream of bottleneck, which can further accelerate congestion build up.
- Unequal spread of traffic over the network can cause local problems, which can then further propagate throughout the network.
- Individual route choice (based on the maximisation of individual gain) in congested traffic is up to 30% less effective than system optimal route choice. This is even the case when the user's route choice is based on accurate real-time information.

Because the network is used more intensively than in the past, roads in the network are closer to their congestion point. This results in more frequent traffic jams and faster spreading of these jams (Raad voor Verkeer en Waterstaat, 2007). To combat the previous reasons of degradation of a network, two types of traffic management are applied. These are traffic information and traffic (signal) control.

2.3.1 Traffic information

In order to prevent drivers from having the discomfort of traffic jams while simultaneously reducing its effects, road authorities started to inform drivers about the existence of the jam such that they could avoid it. This started in the late 1980s with congestion information on a FM radio broadcast based on new monitoring equipment of the national road operator Rijkswaterstaat (Ministry of Infrastructure and the Environment & Connekt, 2012). In addition to this, Dynamic Route Information Panels (DRIPs) were placed along the motorways since the 1990s, (Rood, Hillen, Remeijn, & van de Laak, 2013).

During this time, commercial parties also started to offer traffic information, which was later dispatched via (on-board) navigation devices. These navigation devices became possible when precision Global Navigation Satellite Systems (GNSS) became open to the public. The first GNSS (called GPS) became available after discontinuing the policy of intentional degradation of public signals at the direction of President Clinton in May 2000 (National Coordination Office for Space-Based Positioning, 2013). Since then multiple other GNSS systems are being developed, like the Russian GLONASS and European Union's Galileo.

Simultaneously new communication possibilities such as the World Wide Web (1989) (World Wide Web Consortium, 2016) and mobile telecom were developed, which included the development of 1G (1st generation) and 2G in the 1980s and the 1990s (Haas, 2006) and later 3G, 4G and some variants of these. The combination of communicational and traffic information developments gave drivers the ability to acquire real-time traffic information to support the traffic routing decision-making. These systems were later further developed to include traffic forecasts (e.g. Tomtom HD Traffic (Tomtom, 2010)) with the use of traffic models and/or historic patterns. With the arrival of connected navigation devices the routing of drivers has become more user-centred (Deloitte, 2015). Private parties provide personalised traffic information services to the road users that cause them to (partially) neglect the route advice given by governmental services.

The developments in mobile telecom, satellite navigation and digital storage also gave way to a new traffic data source called Floating Car Data (FCD). FCD is generated at a vehicle level (which floats through the traffic) rather than at the side of the road. This new data source, which can be extracted from GPS devices or mobile phones, offers the potential to monitor traffic on theoretically all roads, without making infrastructural changes to the road network. (Partially) automated vehicles may also be a source for floating car data with the added advantage of more precision (e.g. it may include the lane on the road) and not having to determine ones' mode choice. Since the amount of (partially) automated vehicles will increase and the increased precision of European Union's Galileo (European Commission, 2016b) is expected to improve the quality of the data (Klunder, Hoogendoorn, Kester, & Taale, 2013). Hoogendoorn et al. (2016) state that FCD is a very cost efficient additional source of data for traffic managers and that it offers great chances for road authorities and cities. Interview respondents (Appendix D) state that it is likely that FCD will become an important if not the main source of traffic data for road authorities.

The rise in new traffic data sources and traffic service also led to market for traffic data. According to one of the interview respondents this takes place in three ways. First there is B2G for FCD and some instances of road bound data (cameras, bluetooth etc.). Then there is G2B for road bound data gained from public infrastructures and emergency data. This is currently offered for free (according to their open data policy) and it is unclear if companies would be willing to pay for this data. Finally, there is B2C, where consumers pay for a subscription (like TomTom does) or pay indirectly via for example advertisements.

2.3.2 Traffic (signal) control

Traffic signal control (also named traffic light/signal) is an important subset of traffic control and a way to control and steer (intersecting) traffic such that safety, throughput and/or environmental standards are ensured with the use of signals.

This type of traffic management started with the invention of first traffic light in 1868, which worked with waving semaphore arms and red-green lamps, operated by gas (Guardian News and Media Limited, 2015). The first (temporary) electrical traffic signal appeared in Salt Lake City in 1912 (history.com, 2009) followed by the arrival of automatic signals in 1922. Since then, automatic signals became widely used and accepted among the general public.

Originally, automatic signals made use of fixed signal times. Webster (1958) was the first to create a method to seek optimal signal timings for (single) traffic light controlled intersections. In the years after Webster, researchers realised that separated intersections can affect each other and stated the significance of this (Wallace, Courage, Reaves, Schoene, & Euler, 1984). This realisation, together with the increase in computational possibilities, lead towards the development of network optimisation of control (e.g. TRANSYT of Robertson, 1969; Smiths P0 of Smith, 1987) and coordinated traffic control (MAXBAND of Gartner, Little, & Kelson, 1981; PRODYN of Henry, Farges, & Tuffal, 1984; RHODES of Sen & Head, 1997).

The optimisation methods usually lead to an overall reduction of waiting time and/or an increase of throughput. However, traffic demands often change over time and even during the day, where traffic control should respond to. This led to traffic responsive/adaptive control, where real-time sensor data (e.g. loop detectors, video, etc.) was used as input to choose a predefined control scenario (responsive) or was used to optimize current traffic control settings directly (adaptive). Nowadays, 91% of the traffic control installations in the Netherlands is vehicle actuated, 8% semi-fixed and 1% fixed.

The optimisation of traffic control settings did not end with intersections. Motorway control policies gained importance in the field of research in the late 1980s and 1990s (like in the Netherlands the Dutch Motorway Traffic Management system). This led to the development of ramp metering strategies like ALINEA (Papageorgiou, Hadj-Salem, & Blosseville, 1991). In the last decade, researchers (e.g. Taale, 2008) also created integrated control policies in where both urban and motorway control policies were combined. This further extended the optimisation domain of traffic control.

To categorise the different traffic control optimisation developments, van Hoeckel (2016) proposed the categorisation (shown in Table 2). Here the approaches are differentiated on the basis of ow two dimensions: optimisation time scales and optimisation domain. The first consists of strategic (usually years), tactical (usually days) and operational (usually minutes) and the second of local (adapting traffic control), zonal (coordinating traffic control), regional (steering traffic with traffic control).

Table 2 - Categorisation of non-anticipatory traffic control models (from van Hoeckel, 2016)

		Time scale		
Optimisation domain	Function	Strategic	Tactical	Operational
Local/single	Adapting	Fixed based on historic profile	Responsive	Adaptive
Zonal/artery	Coordinating	Fixed coordination	Responsive coordination	Adaptive coordination
Regional/network	Steering	Policy evaluation	Accident rerouting	Regional traffic control alignment

In the decomposition above calculations tend to get more computationally demanding when optimisation domain becomes larger and the time scale smaller (so top left is usually less computationally demanding). Although this is often compensated by the level of modelling (and optimisation) detail. The scope of this research is the network optimisation domain and the focus on the operational time scale. In this, both traffic information as traffic control can influence each other. This will be described in the next subsection.

2.3.3 Integrated Network Traffic Management

Traffic control can influence the travel time of drivers. Subsequently, their perceived and their to be experienced travel time can influence their route choice, which may impact the travel time that other drivers experience. So traffic control optimisation needs to incorporate changes in traffic flows as a result of changed travel times (as pointed out by Allsop, 1974). Traffic information services play a vital role in the perception of (future) travel time and therefore in the decision-making of drivers. So, both are a type of traffic management that affect each other which affects system performance. Therefore, this calls for an integrated approach that incorporates the effects of each other.

To describe this in more detail, the following process decomposition has been made (see figure below). Here the blocks represent processes that have been segmented (per group of) actors and the arrows represent flows of information. The type of arrow indicates the speed and/or the completeness of the communication (as stated in the legend of the figure). The GNSS (satellite positioning), the telecom providers are excluded because they solely have a facilitating function and to simplify the diagram. This figure starts at the travel demands (1) of drivers that gives input for their route choices (2) which enable the traffic interaction (3). This results in a certain network distribution and travel times. Which in term may be observed or measured to provide feedback for (future) route choice (slow through day-to day learning or fast via navigation in process 8 to 11) and may be used as input (4) for road bound traffic information and/or to determine an appropriate control strategy (6). The resulting information (7) and control (6) may then also affect the traffic interaction (3) and route choice (2). In the process 8 to 11 traffic data may be collected (8), combined and processed (9) and then distributed to the drivers (e.g. through 11) via diverse platforms (10).

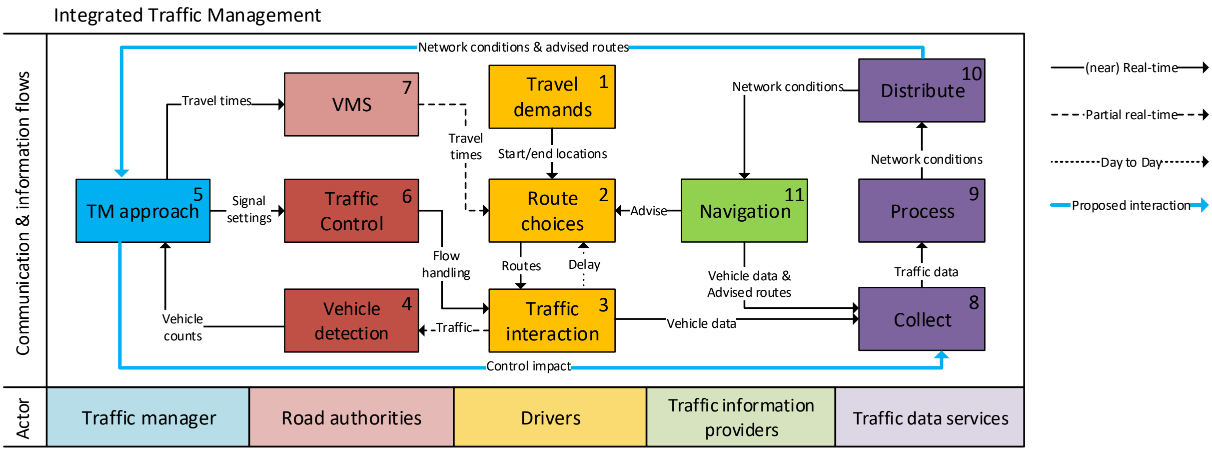


Figure 6 - Process decomposition of OANM with control demarcation (on the basis of van Hoeckel, 2016)

It is clear to see that the route choices are influenced by two separate types of traffic management and their actors. Without alignment of the two (proposed in blue) traffic will experience more delay (moreover in Section 3.2). Therefore, this calls for an integrated approach that incorporates the effects of each other.

The complex interaction between traffic control and route choice may be modelled with traffic models and game theory. If this is modelled correctly, future traffic distribution, future travel times and optimal traffic control may be predicted.

Traffic models describe and predict vehicular flows on roads for (amongst others) the prediction of congestion, traffic safety and emissions. The first traffic model originates from 1934 (Greenshields, 1934). Since then and especially in the last two decades more traffic models have been developed (Wageningen-kessels, 2013) facilitated by new computational possibilities and new data sources (like FCD) and data storage. In traffic modelling two kind of network distributions are imperative: user optimum and system optimum. The first assumes that each driver chooses its shortest route whereas system optimum assigns each driver a route (to reach its destination) that is optimal for the network distribution. The latter results in an overall reduction travel time but may give unequal distribution of travel times (i.e. one driver may be forced to have an extremely long travel time if that is better for the system as a whole. Furthermore, The first assumes a perfectly informed and selfish driver and the second implicitly assumes a forced route choice.

Game theory provides a framework to mathematically model behaviour in strategic situations (called games), where more than one player (also called agent, decision maker, actor or person) is involved and the success of an individual depends on the choices of others. It describes that the amount of and the timing of (trustworthy) information that a player receives can be crucial for the decision one makes. A Stackelberg game (von Stackelberg, 1934) employs this to create a hierarchy in decision-making (one player choses after the other) and can be used to influence ones choice. This can be used to the advantage of a traffic manager, as pointed out by Fisk (1984) to steer traffic to a Stackelberg equilibrium (between the user optimum and the system optimum). Here, the sequential choice of a traffic manager (as leader) is used because he has the possibility to predict the traffic distribution as a result of his traffic control settings. By assessing all the options, the traffic manager is able to select the best possible outcome. This allows for the steering traffic to improve network conditions while preserving freedom of route choice.

2.3.4 Online Anticipatory Network Management

The previous entanglement between should be incorporated but can also be used as an opportunity to steer traffic. The approach that uses this opportunity is called Anticipatory Network Management (ANM). It finds its origin when Fisk (1984) proposed the introduction of a traffic manager that a leader could be introduced that steers the followers in the network. Whereafter, Chen (1998) was the first to create an ANM approach that involved a Stackelberg game which allowed for the steering of drivers with traffic control to reduce network congestion. This approach relies however on day to day learning of new travel times (tactical time scale). To make it more dynamic Taale (Taale, 2008) suggested the use of DRIPs and Hoeckel investigated the use of connected navigation devices (operational time scale). This was called Online Anticipatory Network Management (OANM) and was able to steer drivers with online adjustable traffic control towards the network optimum, while providing drivers with the subsequent traffic information.

Example of ANM and OANM

To illustrate the concept of ANM and OANM and their benefits, the network of Figure 7 is introduced. This network is often used as a test network or as illustrative example in the literature since its introduction by Dickson in 1981 (Cantarella, Improta, & Sforza, 1991; Dickson, 1981; Rinaldi, Tampere, Himpe, & Holvoet, 2013; Taale & van Zuylen, 2001; Taale & Van Zuylen, 2003).

Let us assume this small network with nodes A to E and some connecting links (that represent roads) as presented in Figure 7. In this small network the route A-E-B is a relatively short urban route, while the outer route A-B is a longer bypass with more capacity.

Normally traffic from A to B is assumed to travel via node E instead of the bypass since they know that it is the shorter route. Because of this, the traffic from C to D can have an increase in delay because they have a longer waiting time at intersection E that also has to process the traffic from A-B. This results in underutilization of the bypass and a significant reduction of quality for the smaller demand C to D. If this is the case and the waiting time of C-D is longer than the time it would take for the traffic A-B to travel via the bypass, then the network distribution is suboptimal.

However, many intersections in the Netherlands are traffic actuated (or responsive) to prevent long queueing in front of the intersection. These traffic actuated intersections distribute the green rates are proportional to the relative amount of traffic (traffic demand). If, in the introduced network, it is assumed that node E is an intersection that is traffic actuated. Then traffic from A to B can experience that the traffic actuated intersection will give them more green time (shortening their average travel time) in response to an increase of their demand. So once again they will 'learn' this route is (or can become) better than the alternative. This can even result in more time delay than non-actuated traffic control.

Alternatively, an approach (ANM) that is able to assess the network scale benefits of diverting demand from A to B onto the bypass will give less green to the A-E-B flow, ensuring good quality for the C-D demand.

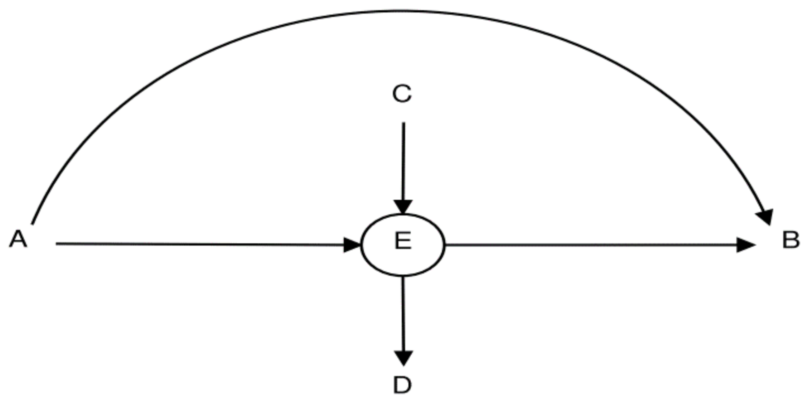


Figure 7 - Small illustrative example network (from Rinaldi et al., 2013)

The example above is simple and easy to find an optimum for, but in reality, more complicated networks and dynamic demand patterns (traffic flows that vary over time) exist. Because of the latter, the optimal solution and the traffic control settings will vary over time, especially during rush hour. So this requires an approach ANM approach that is able to steer traffic on a dynamic way by frequently recalibrating the traffic control. Van Hoeckel (2016) has substantiated that in order to be able to steer traffic on a time dynamic way, drivers have to be able to timely perceive the changes that a traffic manager makes. Without added traffic information this takes days because it requires multiple trials per driver. Furthermore, changes in travel time are naturally hard to be perceived because:

- the average travel time differences might be small and can have a variance due to changing traffic conditions;
- a driver is focused on the driving task so he has limited awareness of travel time; and
- a driver may have a different personal travel time experience (e.g. standing still might feel longer than driving slow).

Rather than relying on drivers (or their devices) to perceive the travel time changes the concept of Online Anticipatory Network Management (presented in van Hoeckel, 2016) suggest a proactive way of informing drivers. This can be achieved by sending the future predicted travel times that incorporate the upcoming traffic control settings (and network conditions) to a connected navigation device. These are able to supply the driver with personalised prescriptive information of the effects of traffic conditions of all roads and locations that they will encounter during their trip at the predicted time of passing. This limits the cognitive effort that a driver has to do to acquire the information while providing more and better information than the classical forms of traffic information that only include uniformed information on certain locations or routes, which can only be accessed at certain moments in time or at certain locations and can usually not give any implication for the total preferred route of the driver. Besides a comfort enhancing function of these connected navigation device, this approach includes future traffic control settings and predicted network conditions. So, in general the drivers are better able to avoid congestion and therefore better able to distribute itself. Finally, it may also slightly influence the elasticity of traffic demand because drivers may be influenced by their predicted (and already steered) expected travel time.

The OANM approach is a special anticipatory form of integrated network traffic management that may increase network performance and allow road authorities to regain partial control over the network by steering route choice behaviour with its traffic control. The described approach is however a mere theoretical concept at this point in time. In reality, the traffic control systems and the in-car traffic information system are owned and operated by different actors. These may not want to work together which is required for this approach to function.

2.4 Network traffic management in the Netherlands

Technically, the Netherlands seems to be an ideal location for (integrated) network traffic management. It has, from international perspective, a dense meshed road network that is equipped with high quality measuring devices (Wilmink et al., 2016, p. 38) and is well maintained, is relatively rich, and its inhabitants have a relative good mobile connectivity (GSMA, 2016; The World Bank, 2015) and are well educated (to design and use new developments). Furthermore, the Netherlands performs relatively well internationally in respect to traffic management developments (Soekroella et al., 2014).

However, for INTM various parties will have to cooperate. Some of these parties are private parties that have started to offer traffic information. Furthermore, the public domain in the Netherlands is characterised by its decentral governance, where authority is geographically divided over many different road authorities (as discussed in Section 2.1). These road authorities operate fairly independent and take the initiative to improve regional accessibility in most zones. Since neighbouring road authorities are also affected by this, they too are involved (to some extent) in this process

(Rijkswaterstaat, 2014, p. 14). Last decade a transition was set in motion where road authorities have engaged more in these regional collaborations to reduce institutional obstacles (Raad voor Verkeer en Waterstaat, 2007, p. 32).

However, this collaboration may be limited because the potential of (integrated) network traffic management and thus the interest varies for each traffic authority. This potential varies with the number of traffic control installations, the size and meshedness of the zone, the usage of the roads and finally the occurrence of congestion in the zone. The latter occurs mostly on motorways, important provincial roads and city access roads. Here, ninety per cent of the known bottlenecks exists (Raad voor Verkeer en Waterstaat, 2007, p. 40). Furthermore, the collaboration may also be affected by the extent to which the operation of traffic management has been transferred to private firms.

To improve the rate of traffic management realisation the national government has been making substantial investments to develop and implement smart mobility in a programme called Beter Benutten (Optimising Use). In this program the national government, road authorities and businesses work together to improve road, waterway and railway accessibility in the busiest regions. In doing so, it should encourage cooperation between the private sector, road users and the government (Government.nl, 2015). For this, the Ministry of Infrastructure and the Environment together with the twelve regions (see Figure 8) allocated more than 70 million euros for intelligent transport systems until 2018. It encompasses around 200 projects and should stimulate innovative forms of traffic management, leading to better traffic distribution. Its goal is to reduce 'door to door' travel times with at least 10% (Rijksoverheid, 2017).

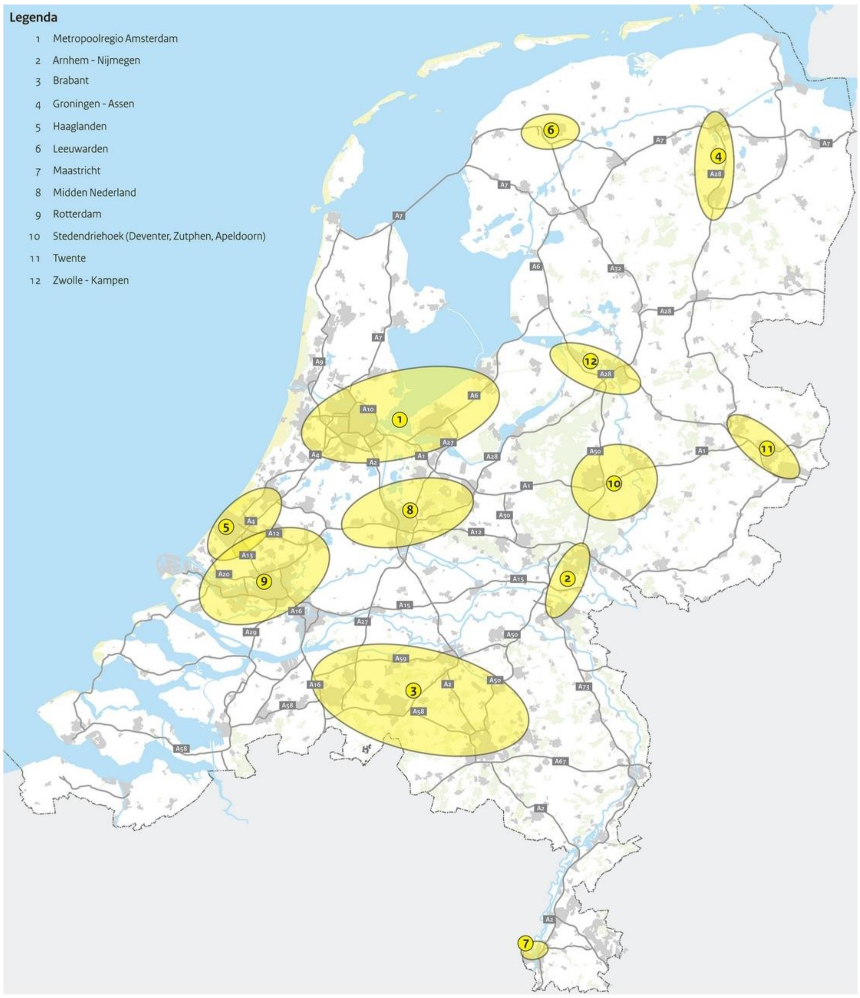


Figure 8 - Beter Benutten regions (Ministerie van Infrastructuur en Milieu, 2017)

2.5 Conclusion

The governance of the public road infrastructure in the Netherlands is geographically divided over more than 400 road authorities. These form a patchwork of zones and can be differentiated based on the size of a road network, its types of roads, the installations on it and its usage. This has an impact on the way a zone is and should be governed.

Aside from the geographical variance, the role of traffic authorities has also changed over time. To allow for a higher average traffic density on roads, the tasks of road authorities have grown (without legal obligation) to include traffic management. From some regions, this task evolved into a traffic manager that continuously steers traffic conditions to preserve road quality and increase its throughput.

Within traffic management, especially network traffic management offers potential to combat congestion problems caused by the increased average density of roads. The task of network traffic management is performed by providing traffic information and optimising traffic control because they both may affect driver routing behaviour.

Historically, providing traffic information was mainly done by road authorities but has been (partially) taken over by private traffic information providers (via in-car devices). These offer more service to the drivers by supplying prescriptive information on demand. This results in a situation where traffic is increasingly steered by private firms rather than governmental agencies, which is further empowered with the rise of Floating Car Data (FCD).

The optimisation of traffic control and traffic modelling has evolved last decades to better manage traffic. A diverse range of approaches currently exists that use real-time traffic data and models to predict driver routing behaviour. However, there is an entanglement between managing traffic with traffic control and traffic information.

Integrated Network Traffic Management (INTM) is an approach that can combine the both and may improve network conditions further. One of the possible developments in the field of INTM is Online Anticipatory Network Management (OANM). It aims to redistribute traffic flows and increase network performance by determining and applying traffic control settings that affect travel times, route choices and thus network distribution, while informing drivers about the modified travel times and anticipating their reactions. This shows great potential to increase network performance by optimally using the entanglement between traffic control and traffic information. Additionally, it may allow road authorities to regain partial steering control of the network that they have lost with the advent of private traffic information providers, while allowing them to operate. Currently, OANM is still conceptual and the approach is likely too computationally expensive for large and detailed regions. However, technological developments are likely to enable this (or a similar) approach in the future.

Technically, the Netherlands seems to be an ideal location for (I)NTM. However, the realisation of such an approach requires further collaboration among and between public and private parties. For NTM a patchwork of zones requires the collaboration among road authorities, while not every road authority stands to benefit (equally). For INTM road authorities have to collaborate with (private) traffic information providers even though they have no direct interest to do so. Although efforts have been made in cooperation groups and with national investment programs, collaboration is not self-evident.

The next chapter will analyse the system of NTM in order to identify the underlying problems that hinder INTM. Chapter 4 will then propose and investigate OANM as a partial technological solution to these problems by, amongst others, comparing them to trends that build upon the developments described in this chapter. Hereafter, this chapter has introduced and presented background information about actors that will be used to substantiate various roles, interests and perceptions in Chapter 5.

3 System of network traffic management

Currently, most of the involved actors are frustrated by the progress, while they acknowledge that there is a lot of technological potential (see the interview results in Appendix D). To identify the underlying problems which may be cause by uncertainties, this chapter will attempt to answer the following sub-question: *"What are the problems and uncertainties of current network traffic management system that hinder its development, implementation and operation?".*

It will attempt to answer this by analysing a wide range of related research (presented in Appendix E), logical induction backed by theoretical literature and the authors previous work (van Hoeckel, 2016). This is done from a technological point of view (as discussed in Section 1.5 and 1.6) and in the systematic approach, in an attempt to identify and, if possible, specify problems and uncertainty. Within this technological point of view economic elements will be included because it is seen as a technological system that manages the limited availability of resources. Although this chapter will focus upon the technological, institutional and process elements may also be discussed as they can impact the technological system.

As indicated in the previous chapter (and to be substantiated in upcoming chapters) multiple actors will need to cooperate to resolve the problems. This collaboration is more likely to succeed on the basis of negotiated knowledge (Koppenjan & Klijn, 2004). Thus this chapter will try to contribute to negotiated knowledge, which consists of a consensus about problem formulation and an agreed scientific validity. The problems that will be described in this chapter will therefore be aligned (supplemented, validated and prioritised) with the use of semi-structured quantitative face-to-face interviews (presented in Appendix D).

The previous mentioned systematic approach to structure the problems and the uncertainty will be introduced in the upcoming section. Hereafter, its individual elements will be discussed that structure the remaining chapter. In the end a structured list of problems and uncertainties can be concluded from this. In addition to this, the respondents problem discussion is added.

3.1 System layout

As a first step, NTM is conceptualised using basic system analysis. This is an approach from the 1950s and 1960s that is often applied to investigate and solve problems in large systems (Enserink et al., 2010). Using this approach, the system is conceptualised in a model of system, input and output. For policy analysis, its input is differentiated in external input and policy input. External input may affect the system but is beyond the control of the policymaker. Policy input are the measures that policymaker can use to influence the system. The output of a system may be measured according to a set of criteria. These criteria express the wanted and unwanted values of system performance that are relevant criteria for the evaluation of policy input (van Geenhuizen & Thissen, 2002). This is presented in the figure below, where the system boundaries are marked with a solid blue line.

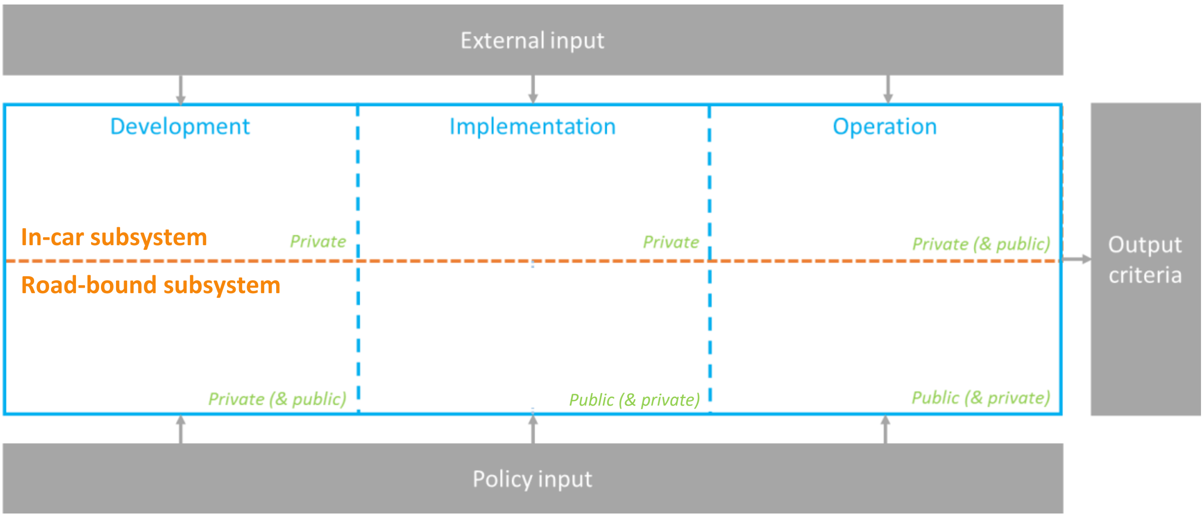


Figure 9 - System decomposition of network traffic management

The presented system stretches beyond the physical network traffic management system (where operation takes place), because it is exceedingly affected by its development and implementation of various different traffic management approaches. To structure the processes that take place within this system, this research decomposes the system into three stages (separated by the dashed blue lines in the figure): development, implementation and operation. The development is assumed to be a demand and supply driven market that produces products or services[1] that are ought to be implemented. The implementation hereafter is where the application of the selected product or service is planned (and possibly evaluated for its area of application) and applied. Hereafter, the implemented product or service is operated and is able to manage traffic.

Another division is made to distinguish between two subsystems. NTM consists of traffic control and traffic information as seen in previous chapter. The first is mainly done via round-bound infrastructure and the second via in-car equipment. This division between these subsystems is indicated in the figure in orange.

In this decomposition, strong entanglements between the subsystems and between the stages exist. The entanglement between the subsystems is increasing because the both are becoming more dynamically managed and road users are using more dynamic traffic data. The entanglement between stages exists because of the strategic interaction of actors. Developers try to develop product and services suited for implementation and operation and hence tries to anticipate the changes that will occur. In the implementation stage, it is tried to plan the application of the chosen traffic management products and embed them with minimal disruption on operation. Finally, in the operation, the implemented developments are employed and but may provide feedback to steer future developments or implementations. However in reality, these stages and subsystems involve different parties (indicated in green) where transaction cost may that hinder feedback.

To further analyse the system literature (Enserink et al., 2010) suggested the use of a causal relation diagram. However, the attempt made in this research showed that: 1) the system consisted of so many relations causing a graphical representation that was not well interpretable anymore; 2) many of the relations did not have a clear direction and thus caused for limited conclusions; 3) And the system

[1] The difference between a product and service is that when buying the latter one also buys the embedding and operation of a product from the same party.

became too complex that increased the risk of relations to be forgotten; 4) If it graphical representation is too complex then its validity is difficult to be checked and wont contribute to negotiated knowledge. Thus, as an alternative the resulting system elements and output will be discussed in a descriptive way in the upcoming sections: operation (Section 3.2), output criteria (Section 3.3), implementation & development (Section 3.4).

3.2 Operation of network traffic management

To analyse the problems and characteristics of operational network traffic management the decomposition of Figure 6 (presented in Subsection 2.3.3) is used and a control perspective is applied to structure this section (see result in Figure 10). This perspective decomposes the operational system into a plant, a sensor, a controller and an actuator, which are defined as follows:

1) The plant is where drivers make their route choice and interact with other drivers. Here, disturbances may occur that cause for a suboptimal distribution of traffic.
2) The sensors measure the plant and its possible disturbances and sends this data to the controller.
3) The controller is an optimiser that determines the best possible control settings (according to a set of criteria), using the sensor input and sends these settings to the actuator. This optimisation may be done by assessing the effect of certain control settings in a model.
4) The actuator is a physical object that intervenes in the plant according to the instruction of the controller (e.g. traffic signal control or Vehicle Message Signing).

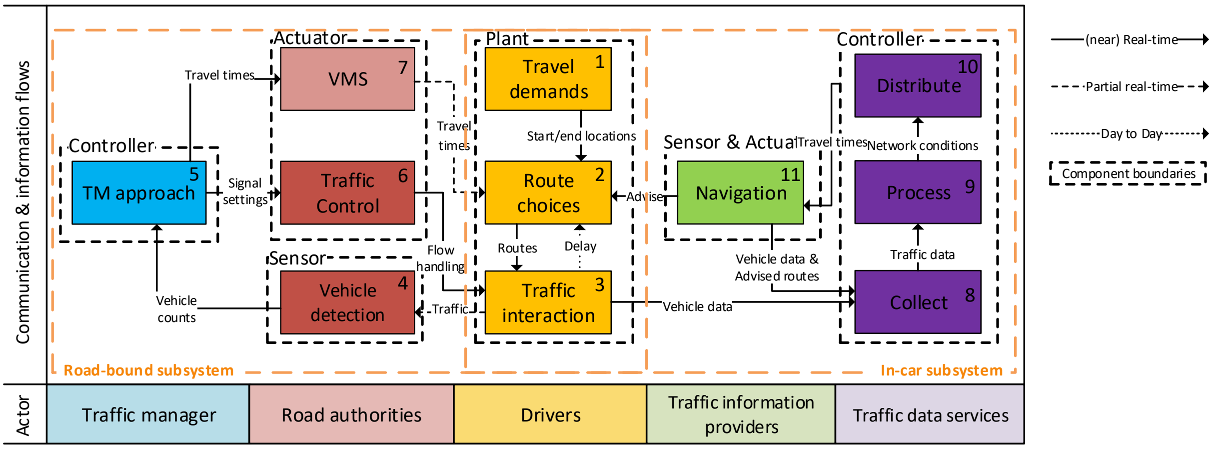


Figure 10 - Process decomposition of operational NTM with control demarcation (based on van Hoeckel, 2016)

When the control perspective applied it is clear to see that the traffic (plant) is steered by two non-aligned controllers. Herein, private initiatives have partially taken control of the system with their traffic information services and the advent of the in-car subsystem. This is one of the problems.

This section will attempt to identify all (or as many as possible) problems regarding the operation, using the decomposition of the control perspective. It will first analyse the characteristics of the plant, then the road-bound subsystem, followed by the in-car subsystem and finally their interaction.

3.2.1 Network traffic management (plant) characteristics

Traffic network management or the plant (in previous decomposition) is subjected to technological and economical perspectives. These has some characteristics and conflicting interests that make it difficult to manage.

From a technological perspective, managing the road network can be considered relatively difficult. Van Lint et al. (2013) state that traffic processes are the result of collective human behaviour, which implies that these are typically:

- **dynamic:** the traffic evolves continuously over time and space;
- **non-linear:** an increase in one traffic variable (for example density) can invoke changes in other traffic variables of varying proportions depending on the situation;
- **stochastic:** similar situations can result in different effects;
- **unstable:** disturbances can cause disproportional consequences;
- **hysteretic:** the effects traffic jams may remain visible long after the original jam has been resolved.

These characteristics become more visible when the network is used more intensively. It may cause a traffic jam to propagate over the network like and oil spill, where its propagation and effect are very difficult to predict.

From an economic perspective, a road has certain density advantage as indicated by Hof, Poort, & Baarsma (2007) that is vital for traffic management. When a road used by 1.000 cars a day can require the same initial investment as road used by 100.000 cars a day. This causes a sharp decrease in cost per user when the road is used more intensively. Of course, the costs of maintenance increase with its usage. But that does not only depend on the number of users and the increase of costs per user is only limited. Furthermore, there remains a limit to its usage. To prevent this limit from being reached, the road can be constructed bigger or later expanded. In this process certain economies of scales apply; the construction of a four-lane road is not twice as expensive as a two-lane road. So the bundling of traffic, forming intensively used roads leads to a better return on investment. A process that can be facilitated with traffic network management[2]. However, congestion on it can also have various economic repercussions.

Thus, while there are economic interests to drive up the density, it makes traffic more unpredictable and NTM more difficult. Alternatively, NTM allows for more intensive road usage which increases the return on new and existing roads and reduces the need of new roads.

Another technological aspect is when the considered network of NTM has more routing options, with a comparable fastest travel time, its steering potential and complexity increases. The amount of routing options are dependent on the network itself but also of the geographical scale of the NTM zone (assuming that the network is a continuous controllable network). Thus the size of the optimisation zone of an NTM approach can be a strong network externality that may be limited by the computational burden which grows simultaneously.

3.2.2 Road-bound subsystem

The effect of network traffic management in the road-bound subsystem grows with the number of routing options (as seen in previous subsection) and the number of traffic control installations. These both usually increase with the size of the optimisation zone.

However, such a zone always has boundaries and between them there is an interaction. A traffic manager cannot control the traffic control in the other zone even though it may still affect the traffic in his or her zone. In Section 2.1 it was noted that there exists a geographical patchwork of road authorities that usually leads to the same patchwork for traffic management. This limits the amount of steering potential for an individual traffic manager. Each traffic manager has its focus primarily on

[2] Comparable solution can be achieved with variable road pricing but that may lead to difficulties in price setting and can induce high transaction costs (Hof et al., 2007). Furthermore transparent and non-discriminating prices might be an issue.

its own zone (Raad voor Verkeer en Waterstaat, 2007, p. 35), which results in suboptimal network usage (identified by Taale, 2008). Potentially, strategic utility maximising behaviour of traffic managers may even block the through traffic of a zone to increase local performance, while placing the burden of the traffic in the zones around it. Fortunately, this does not seem to occur in reality, the amount of regional collaboration between road authorities and their traffic managers has increased (Technische Universiteit Delft, MARCEL, & Berenschot, 2010) and open communication standards to enable operational interaction have been developed (e.g. DVM Exchange, 2017).

But form a traffic network management perspective it remains better to manage a full zone without uncontrollable gaps for synchronised control and the steering of traffic. Furthermore, this should ideally result in a collection of continuous interacting zones of a flexible size (dependant on approach complexity, network complexity and steering timeframe), rather than the current traffic management zones patchwork-like structure that is bound to the ownership of the physical infrastructure ownership). The size of these zones may increase in time with the development of computational possibilities, traffic management insights or distributed approaches.

The road-bound subsystem and its traffic manger may also inform drivers via the road bound infrastructure, but its effects are expected to diminish because it provides less service to the drivers than the in-car subsystem. This will be analysed in upcoming subsection.

3.2.3 In-car subsystem

The in-car subsystem consists of many types of traffic information providers and traffic data services. Some of them offer a form of navigation, while others are providers of circumstantial traffic information (e.g. the locations of speed control). Connected navigation has the focus of this work because of its role in NTM. There are also and parties that offer a non-traffic related service but that still collect valuable traffic data.

The advent of private traffic information and the in-car subsystem provided the driver with more service than before with the use of connected navigation devices (see Subsection 2.3.4). So, in general the drivers are better able to avoid congestion and therefore better able to distribute itself. Although, there remain paradoxical situations where informing road users of traffic conditions may actually decrease overall network performance (a phenomena related to the Braess paradox described by Braess, 1968).

The in-car subsystem is in contrary to the road-bound subsystem often not bounded to geographical boundaries (aside from boundaries where there are no roads). However, it only reaches a percentage of the drivers where traffic control affects all drivers that pass a certain location. This percentage is effected by its number of users on a market of many rival products and services. But its accuracy and effect grows with its number of users it reaches. At a certain level of users, traffic information providers have to include the effects of their own advice to prevent causing congestion. However, since there are many traffic information providers, they do not know what advice other drives receive and this can possibly cause for oscillating route choices.

The in-car subsystem is a consumer orientated market. In the past years, the business model of most traffic information providers has changed. Previously, drivers bought a navigation device making them the direct client. Because of fierce competition and a lack of willingness to pay for online traffic information and the value of the traffic data, diverse companies started to offer their traffic information services for free (also called freemium) to gain or maintain their userbase. Hereafter, the location data of these users is gathered and sold to diverse interested parties (governments, traffic information services, consultants, researchers according to interview respondent #2 Appendix D). This led to a shift in their business model and created a multi-sided platform (described by e.g. Evans, 2003, 2012; Evans & Schalensee, 2007; Hagiu, 2009; Hein, Schreieck, Wiesche, & Krcmar, 2016). Important in this shift, is that the service to the user remains important to maintain a certain user base but is often not the direct client (with exception of commerce trough advertisements). The current direct clients are often buyers of data or car manufactures that include the product within their cars. Nowadays, almost every new car has a form of navigation. A trend which is likely to continue with the arrival of autonomous cars. By including navigation within the car, a product which has a marginal effect on the selling price of the car, drivers are prone to use it in comparison to other navigation equipment because it is well integrated within the car. In conclusion, car manufactures have a market advantage and are penetrating the traffic information market.

3.2.4 Traffic management operation subsystem interaction

As stated, the NTM system consists of two subsystems. A small change made by either of their controllers may have a relatively big impact on the network because of the volatile nature of the traffic management system. This in turn cannot be predicted by the other controller. Furthermore, the operations in these subsystems are not aligned because the operating actors have different steering goals, are using different traffic data sources to predict traffic conditions, operate on different scales and using different models. This reduces the precision of the predictions and their ability to steer the system. The reason for this is explained in this subsection.

The difference in steering goals is caused because traffic mangers and traffic information providers often manage with different interests. Traffic managers want to optimise traffic for their region by including a broad range of interests (towards system optimum), whereas traffic information providers try to optimise the service for their users across zones (user optimum). So apart from the area of control, a traffic manager is ought to steer traffic from a societal point of view and does not guarantee shortest travel times for each driver. On the other hand, a traffic information provider is expected to steer traffic from the driver perspective. The first includes the interests of the individual driver but the second adds the perspective of local parties (e.g. the prevention cut-through traffic) and national interests (e.g. the prevention of pollution). Furthermore, there might be situations where it is better to give a certain road user a travel advice which is not his shortest to prevent degradation of the network and facilitate overall performance.

This deviation of steering perspective arises from the different definition of the client of traffic mangers and traffic information providers. As the traffic manager is appointed by the road authorities which are elected or appointed by elected persons, it has a certain responsibility towards society. However, the traffic information provider serves the interest of his clientele. To test the latter statement, let us compare what would happen if a traffic information provider were to be compelled to operate from a societal point of view. It would mean that (from the user perspective) the travel time for a certain individual would become longer than with a travel advice of another provider. If he is informed of this, not compelled by the altruistic point of view and switching cost are low, it is likely that he opts for a different provider. If this happens on a larger scale the traffic information provider is penalized in terms of less users for steering towards a system optimum, while the advantages are distributed over the entire system. This is similar to a “tragedy of the commons” often referred to in economics and described by Hardin & Baden (1977). For traffic management, it results in a situation where all traffic information providers indeed have an interest to remain strictly user orientated. From a technical perspective, this results in a sub optimal network situation and sometimes contradicting traffic advice.

For a traffic manager simply contradicting private traffic information is no solution. Because in-car traffic information has a better steering potential than road-bound traffic information (see section 2.3) people will tend to neglect road-bound traffic information. Simply prohibiting private traffic information is also no solution because it is probably better to have “selfishly” informed traffic rather than non-informed traffic seen that road bound traffic information is not likely to replace in-car traffic information for all users at all locations. So, this leads to a situation where a traffic manager is not able to control all traffic management approaches.

The difference in traffic data source is caused because both traffic mangers and traffic information acquire their own data. When both parties and controllers have their own data collection, they both produce a different and limited representation of reality, which makes the misalignment worse. A traffic manager only has regional data at specific locations but measures all vehicles, while traffic information providers have (inter)national data of a percentage of drivers across the network. This data was not shared up to quite recently. Since 2007 this was partially and unilaterally resolved when the government has initiated the National Data Warehouse (NDW, 2016) and is now planning on sharing the traffic control settings (Talking Traffic, 2016). The data of private traffic information providers is however not shared due to commercial value. Alternatively, NDW FCD is currently dispatched with some delay (Hoogendoorn, 2016), which may limit its usefulness for private parties. This leads to a situation where both controllers may act upon different measured data. Furthermore, controllers have less traffic data and merging the two types of traffic data is expected to improve the quality of the data (Klunder et al., 2013).

Finally, both subsystems operate on different scales and using different models that may affect their prediction and hinder alignment. The road-bound subsystem usually operates on a zonal scale while the in-car subsystem operates on a (inter)national scale. This often leads to a difference in modelling techniques and can thus lead to different predictions. To make matter even more complex, a traffic manager may potentially use multiple levels of controllers. As described in section 2.3.2 the optimisation domain may be different per approach that is used in a controller. This means that a traffic control installation is optimized for a certain demand on a network level but that this input may be temporarily neglected due to the stochastic nature of traffic (adaptive) or to create a green wave (coordinated).

To conclude, the traffic system is steered by two types of controllers operated by different actors a traffic manager per region and multiple (inter)national providers for traffic information and navigation, each with their own clientele. These actors control the system with different interest, mostly use different measured data and operate on different scales whit different models while no aligning of this control is being done!

3.3 Output criteria

The output of the system can be assessed by a range of actors. They judge the functioning of the system on the basis of their criteria and their perception. The traffic managers may use it to optimise their traffic control, road authorities may use it to assess the effects of a traffic management approach or compare their zone to a neighbouring zone, but also private firms and drivers may have their own criteria and perceptions.

When trying to improve the NTM in a multi-actor environment it is essential to have a common goal or to at least understand the differences present such that the interests of the actors can be taken into account. Since NTM also concerns the usage of public infrastructures it may also concern a public interest, which would affect the position of the government. The type of interest, the definitions quality of the involved actors and how to measure this will be discussed in the upcoming sections.

3.3.1 Serving public interests

The NTM system is closely related to the road infrastructure, but this does not directly mean that it requires the involvement of the government. Previous chapter has identified a partial switch from road-bound to in-car traffic management and with this, the switch from public to private. Furthermore, it has shown that the steering objectives of these parties differ and that the latter results are less societal gain from a technical perspective. Although the road infrastructure is perceived as 'public utility' that inhibit considerable positive effects on the economy and society (called "merit wants" by Musgrave, 1959), this does not necessarily mean that it is up to the government to intervene. In other words, should the government let private parties do the network traffic management steering in the future? Literature states that, only if it is of public interest, they should intervene.

To analyse if it is up to the government to intervene, an interest funnel may be used, where interests are separated on three different levels. These are defined as follows (on the basis of Lijesen, Kolkman, & Halbesma, 2007):

1) Interests: some that gains the attention of someone on the basis of its potential (dis)advantage.
2) General interests: an interest that offers potential (dis)advantage for society (as a whole).
3) Public interests: general interests that requires the involvement of the government.

The first and the second are clearly applicable. The third may however differ in the view of economics and public administration, where economic vision employs a stricter view on public interests (Lijesen et al., 2007). However, both views acknowledge that the allocation of an interest is context and time dependant. In the stricter economic vision it is doubtful if traffic management is to be considered a public interest while it is in the view of public administration. In the economic vision: interests can best be served by those parties that are in the best position to do so in terms of costs and prosperity. This means that terms like "reliability, accessibility and speed" are not considered to be public interests because it is quite possible to allow private organisations to act as providers of 'roads as a product' in return for a fee (Lijesen et al., 2007). There are however limitations regarding this view. In the economic view there are transaction costs (costs as actual costs, time and effort incurred in coordinating an economic transaction) involved with collecting this fee and the exclusion of non-paying users which might render it infeasible (for some roads).

However, from that same economic view there are signs that not intervening in the current situation could lead to market failure, which would make it a public interest from economic perspective. This would include: utilisation of network externalities and misalignment between controllers that influence the return on infrastructure (public good). Furthermore, there could be political motives to intervene such as guarantee universal service, safety, environment, diverting through traffic to neighbouring zones, user equality, speed of innovation and the representation of demands for non-user stakeholders.

While acknowledging it is up for debate, it will be treated as a public interest in this research, seen that there are strong reasons to do so. This does not mean that everything should be managed by public parties, but only that there is a reason to intervene when performance is below expectation. What this performance should be is evaluates in the next subsection.

3.3.2 Quality of the road network

Network traffic management will be treated as a public interest. But what is the desired quality that should be achieved? The road infrastructure is built for the collective. Since it is used more intensively than in the past, the distribution of traffic has become a huge determinant for the network quality. However, this quality is often ambiguous and consists of a trade-off between multiple factors. Although there are attempts to uniformise this like "SVIR Bereikbaarheidsindicator" (MuConsult B.V. & Move Mobility, 2014), there is still ambiguousness for the wide range of interests that a government tries or should represent. Moreover, there are traffic information providers involved in the system that manage the system with different interests. While the road authorities serve public interest, the private traffic information providers serve the individual interest for its users that is a select group of all road users (assuming a non-monopoly). To evaluated this, it is assumed that the managing parties want to provide service to their users. This includes the drivers and traffic information users but also local parties and the society in general (where some might transcend the boundaries of the country). To illustrate the wide range of quality factors (based on Lijesen et al., 2007) per 'client' that could make up the desired road quality, the following list is presented:

- Traffic information user
    - Travel time of route
    - Reliability & robustness of route
    - Availability & accessibility of software
    - Affordability of software
    - Aesthetic perception and user friendliness of software
    - Privacy
- Driver
    - Availability of infrastructure
    - Accessibility of destination
    - Speed on infrastructure
    - Affordability of infrastructure/route
    - Comfort & aesthetic perception of infrastructure
    - Safety of traffic interaction
    - Equality of infrastructure usage
- Local parties
    - Safety of living environment
    - Pollution (sound/air)
    - Accessibility and speed of region
    - Reliability and robustness of region accessibility
    - Aesthetic perception of infrastructure
- Society
    - Availability of infrastructure for economic and social goals
    - Accessibility and speed
    - Reliability
    - Affordability
    - Quality and comfort
    - Safety
    - Robustness and flexibility

While acknowledging that this list may not be complete and rearrangements could be made, previous list shows the ambiguousness of the road network quality and the factors that may be used as criteria. Each criteria can have a preferred value, scale and weight that may vary geographically, per time of day, per type and size of the road and per type of road user (e.g. person/goods; personal use/corporate use; public/private transit). This is a result from the traffic characteristics, the different economic values per road user and societal values that may change during the day (the nuisance of e.g. sound pollution may vary through the day). Furthermore, the setting of criteria may need to be evaluated (by further research) for its effect on opportunistic behaviour. In this research it is expected that this could be prevented by using a wide range of criteria. Finally, the preferred value, scale and weight between the listed factors is of political debate.

To conclude, there are a fundamental different variety of clients and interests in a network with complex characteristics, that result in a range of different factors, preferred values, scales and weights that should determine the quality of the network.

3.3.3 Measure performance for monitoring, control and evaluation

The measuring of road and traffic management performance monitoring, control and evaluation is currently being done. For monitoring and control this usually happens in a traffic control centre and for evaluation it is usually related to projects (e.g. in Beter Benutten, Ministry of Infrastructure and the Environment, 2016), with expectation of TomTom traffic index (TomTom, 2017). However, expressing the quality of the network quantitatively in different factors is still problematic. Here more problems arise. First some factors may be difficult to translate into quantitative factors (e.g. robustness). Second, a lack of traffic data, different models, modelling assumptions and external effect (e.g. weather) may impact the results. Third, although traffic models are able to determine the effects of a certain change, it become far more difficult to assess changes over time. Simply measuring the lost traffic hours over time as performance indicator, may neglect (non-linear) change due to economic growth or infrastructural change. Or alternatively, a performance increase due to changes in traffic control may lead to a better accessibility which in term may result to more traffic and a return of congestion. Fourth, currently a wide range of traffic management approaches are in use that have effects beyond its own region or work region independent (e.g. traffic information). Fifth, the usage and/or follow-up rate of traffic management approaches may change over time and may be unequally geographically dispersed that scatters the effect where it may become too low to have a significant effect. These reasons make comparisons of measured traffic management performance of the road network very difficult, especially continuous traffic management approaches. This allows for a wide interpretation of the evaluation of a traffic management approach and thus its results may be subjected to strategic interests. Therefore, it becomes difficult to decide where to invest, in what approach to invest, to compare approaches and to justify investment costs and control actions.

3.4 Development and implementation of network traffic management approaches

The development and implementation of traffic management will be analysed with a focus on the road bound subsystem because: 1) no direct reason are found (so far) that this private market requires government involvement; 2) it is likely to have a stronger effect on government spending since it concerns the governmental infrastructure; 3) the socio-technological problems are more likely to occur in and environment where public and private parties interact. However, since relevant problems may still occur in the stages development and implementation of the in-car subsystem, its analysis is advices for further research.

The road bound subsystem currently (almost always) requires both road authorities and private firms. Herein, the road authorities are the owner of the infrastructure and are the (potential) client for private firms that develop the traffic management products and services. This seems to originate from the requirement of very specific knowledge that can be applied by private firm on multiple locations and even countries and in multiple markets resulting in scales of economy.

In this collective action, parties cooperate on a voluntary basis, without a clear hierarchy and few rules. This leads to strategic uncertainty: it is not certain whether others will participate and if they do, whether an agreement can be reached and whether they will honour that agreement (March & Olsen, 1989). In this multi-motive game there is no overall goal, but each actor has its own reasons (usually rational profit maximizing behaviour) to participate. A company that decides to participate in the development of a project will invest time, money and knowledge, but the decisions of other participants may affect the outcome of the project. This involves risks: the interests of parties may be harmed by the strategic or opportunistic behaviour of others (Nooteboom, 2000; Williamson, 1979). Furthermore, a company may present its ideas, but others may decide to no longer participate while they have already taken note of the information. And finally, there are also transaction costs: the efforts are made to interact (information gathering, meetings, etc.) and political costs: parties have to accept compromises Therefore, collective action involves investments and risks that may hinder progress. This collective action may roughly depend on opportunity, awareness, motivation and resources for both parties.

These collective action problems can be seen throughout the stages in the interaction between public and private parties but also between public parties. To discuss this in more detail the individual stages will be discussed in the upcoming subsections.

3.4.1 Development of (network) traffic management

The development of (network) traffic management is analysed as a demand and supply driven market. In this both the supply as demand side have its problems that closely entangled.

The demand side is represented by many road authorities. These may be small and most of them are not specialized in the field of traffic management. Glachant (2012) states (regarding ICT projects) that '*public administration is not deaf or blind because of insufficient information, but rather because of a lack of expertise in ICT*'. This limitation similarly arises with traffic management because road authorities do not directly participate in the creation process. The requirement to change of job position each 3 to 7 years (Peter de Graaf & Robert Giebels, 2015) is something that may reinforce this. An alternative to having specialised knowledge when purchasing a product is employing functional criteria. However, as seen in the previous section this is quite challenging.

This limits road authorities in selecting the most appropriate traffic management approach an may cause them to underestimate the effects of traffic management. In road authorities combinations of different departments may fulfil the role of traffic authority. These departments each fulfil the need to represent a part of the diverse interests of the public. The limited hierarchy, multiple decision-makers, many stakes and system complexity often lead to case by case decision-making that can lead to rather specific demands and thus high setup costs. In this, traffic managers might offer some practical input but are likely to have limited knowledge about state-of-the-art systems and have the self-interest to preserve their own function. So they may resist automation and reorganisation that induces the risk of job loss. Consultants may be hired to fill this gap. Although they are more specialized, they are usually only aware of the information that they have been provided by the companies and they leave when the job has finished. Because of the latter, the consultant is more focused on the short run and the continuity of a certain investment policy may be affected (i.e. next consultant may steer investments in a different direction).

The supply side is mostly represented by commercial firms. The development of NTM products is complex because users interact with technology. To describe and predict this interaction, a wide range of disciplines are used (e.g. psychology, game theory, traffic engineering and control engineering). This technology is changing rapidly due to innovations in the area of ICT. Seen that it concerns changes to infrastructure that is important to society it also concerns topics like policy, process and project management and a wide variety of economics. Specialisation in the diverse fields leads to an increasing level of fragmentation of methods and knowledge (Nooteboom, 2000). So in the field of traffic management many disciplines and perspectives converge that can clash and jargon can lead to misunderstandings. Reaching consensus and a clear direction for development is likely to be hindered by this.

The previous described case by case decision-making leads to a situation where each of the many traffic authorities make a different choice. In term this leads to very specialized products that require more consultation (high transaction costs) that are limited applicable for other clients (limits scales of economy) and leads to an unpredictability of their demands (developing without a client is risky). Thus, the complex and multi-disciplinar nature of the problem, together with the uncertain demand, create a risky investment environment.

3.4.2 Implementation of (network) traffic management

The implementation of (network) traffic management occurs after the product or service has been bought. Here, various problems can occur that are discussed in the following sequence: acquisition and planning, application and the link to the in-car subsystem.

The previous demand supply interaction leads to procurement inefficiencies. The previous case by case decision-making and separately processing this leads to many different systems that may overlap and may cause limited interoperability (control disalignment, limited and delayed data exchange) and operational discomfort. Limited interoperability and patchworks of systems, which is a well-known problem according to Schuurman (2011). Different procurements and suppliers of the physical traffic management products may also cause (vendor) lock-in. However, this patchwork of systems may prevent (and be a response to prevent) total lock-in that could otherwise be a result of strategic behaviour of private firms to acquire a dominant position and protect this with their own standard. Furthermore, the in previous section described asymmetry of expertise and Information leads to post-contractual hidden knowledge. This can cause for cause high prices, lack of trust and wrong interpretation of demands.

The wide and diverse variety of road authorities is likely to result in even more case by case decision-making. This interoperability may then become an issue for NTM. This is one of the problems that is combated in collaboration groups such as 'Landelijk Verkeersmanagement Beraad (LVMB)'(Wegbeheerders Ontmoeten Wegbeheerders, 2017). But the agreements made in these groups are not binding to all parties (stated by interview respondent #2 in Appendix D).

This does not necessarily pose a problem when all road authorities have an incentive to cooperate. However, previous chapter has concluded that not every road authority stands to benefit (equally) from NTM. Moreover, ambiguous quality, limited benchmarking and the accountability spread over different departments may not simulate their incentive. This can cause bad network performance to remain hidden (see Section 3.3.3) or government officials cannot (or at least limited) be held accountable for this performance. This does not mean that road authorities perform badly though. In a survey held under road authorities in the Netherlands 61 per cent state not to have enough budget and time to acquire (first-hand) experience with new traffic management developments. Moreover, Kuin & Molemaker (2007) state that road authorities make use budgets, so they have the tendency to control costs but not to optimize performance. Theoretically, can bad performance lead to more congestion which could lead to more budget allocation to resolve bad performing zones. Additionally, the budget of traffic management is often in competition with improvements to the physical infrastructure.

Traffic management planning can also have sluggish procedures (Kuin & Molemaker, 2007) because it interacts with a physical system that is very large in terms of geography and investment (installed base). Furthermore, it has a relative long life span and its availability has to be maximized for the public, which makes natural replacements rare and intermediate changes relatively costly and difficult. So, physical changes to the infrastructure are naturally difficult and may require planning and coordination. Thus when traffic management involves infrastructure change procedures can become lengthy, especially when it involves traffic safety. This may be aggravated by an uncertain future where traffic authorities may postpone changes because they are not sure if an investment is worth it.

When an investment has been made it has to be applied. Often this requires adjustment for the local situation. This situation can vary widely because the many technologies available and the limited standardisation of infrastructure, data and communication protocols. The traffic control infrastructure data (e.g. the location of road bound sensors) is currently managed by the road authorities. These usually have technical drawings that can be used to extract the information required. However, databases regarding standardised traffic control infrastructure data do not seem to exist yet. This is one of the reasons that the implementation of traffic management approaches is so labour intensive, which result in high setup/switching costs.

The application of traffic management can also interfere with the management of the physical infrastructure. Maintaining and building the physical infrastructure has changed last decades. With the arrival of DBFM contracts and similar forms, the role of infrastructure manager could be privatized. With these contracts the burden of universal service obligation is often placed with the contractor where non-compliance is translated to monetary penalties. If, however a separate traffic manager operates in the same region two type of conflicts might arise. First, the traffic manager might require infrastructural change that is not required but must be facilitated by the infrastructure manager. Second, the performance of the one may affect performance and availability of the system and thus could effectuate monetary incentives for both of them. But besides the interaction with the physical infrastructure, NTM has a link the in-car subsystem.

The in-car subsystem and its traffic information is characterised by strong network effects. First there are the economies of scale where a certain device or especially with app where the development cost can be recovered by its number of users. Secondly, more data is acquired with more users and that leads to better traffic predictions and more valuable data (which may lead to more users). Third, geographical limitations to the service may be natural to a new product but offer less value that a service that works internationally. Fourth, since a user may be limited to a certain amount of apps and devices, complementarity services (that are difficult to include in new products) may constrain users to certain providers. Fifth, more users are likely to lead to more natural (mouth to mouth) advertisement. The only negative network externality is security as seen in the previous section. Thus, this leads to a market that is rather closed for new entrants. Harms & Noordegraaf (2015) describe it as niche market that poses a challenge to create feasible business model.

Road authorities have noticed that round-bound traffic information is becoming less effective. But they have the desire to inform drivers about e.g. road works and or to limit the usage of residential areas. So, various road authorities are trying and have tried to inform drivers via connected navigation equipment or related services. These usually results in time and budget bound trials that produces a service where: user experience is suboptimal because the product is not fully developed and tested; limited set of functionalities; limited time of availability; limited geographical use (Harms et al., 2015). This results in a suboptimal service in a rather closed market. As an alternative road authorities may want to cooperate with existing traffic information providers. The road authorities have however a rather small service area in comparison the traffic information providers, who have to interact with a lot of road authorities that may all have their own specific demands and have fairly little to gain. A situation that limits effective cooperation.

3.5 Conclusion and discussion

This chapter has described a large quantity of entangled problems and uncertainties for actors within the Network Traffic Management system that lead to suboptimal use of the infrastructure, for now, but also for the future. Moreover, because it is stated to be a public interest it is up to the government to do something about it. The list of problems has been composed from related research and theoretical induction whereafter it has been complemented and validated with interviews (Appendix D). The goal of this chapter is to serve as a basis for negotiated knowledge where there is consensus about problem formulation and an agreed scientific validity of problem formulations. Although this analysis combines and expands on multiple researches, reaching negotiated knowledge is out of reach for this research. In the upcoming sections the problems that were found to be important by the interview respondents are marked in blue. Some of the intermediate items of problems have been adjusted according to the view of the respondents. Upcoming sections will summarize the problems using the decomposition presented at the beginning of this chapter (Section 3.1).

3.5.1 Problems of the development

The development is characterised as a market of demand and supply of technological complex and multidisciplinar products between private firms and road authorities. In this collective action, strategic uncertainty and risk occurs because each actor has its own goals and may decide to withdraw form an agreement or dishonour the agreement made. Herein, the complexity of products increases the information asymmetry and the risk of the supply while the previous mentioned case-by-case decision-making of numerous road authorities cause for a variety and uncertainty in the resources limited demand.

Inefficient traffic management development is caused by:

- **Limited demand**: Road authorities are hindered in their acquisition of traffic management.
  - Road authorities have limited knowledge and information of the possibilities (especially the case for the smaller road authorities) which makes it difficult to make an informed decision.
  - Limited motivation to improve (ambiguous system performance and goals).
  - Limited resources for traffic management e.g. competing budgets (infrastructure vs. traffic management) and manpower available for acquisition.
- **Limited supply**: organisations are hindered in the development of traffic management.
  - Technological complexity and uncertainty, multidisciplinar environment.
  - Limited demand (previously described) .
  - Variety of demands between decentral road authorities (see disperse implementation approach) induces a limit scales of economy and a limited certainty of a specific product.

3.5.2 Problems of the implementation

The implementation of traffic management is characterized by a large scale case by case decision-making of many different road authorities that have limited incentive for improvement. This induces: high transaction costs because each road authority has to procure a certain similar amount of information to make decisions and limits scales of economy when purchasing, limits interoperability and induces procurement inefficiencies.

Inefficient implementation is cause by:

- **Incentive limitation**: Limited responsibility and incentives for improvements and efficient operation for road authorities.
  - Quality (to whom, factors & weights) unclear or has limited dimensions in most traffic management zones.
  - Measuring of quality difference is difficult due to the quantification of factors, variable demand, traffic dynamics, external influences and the different modelling techniques available to model this.
  - Limited benchmarking of projects and road authorities is being done and their results are difficult to compare because of the ambiguous quality and measuring. This may limit the opportunity awareness and external accountability of road authorities.

    - Limited budget and time. Moreover, perverse financial incentives exist when more budget is allocated to places with more congestion (the occurrence of this in practice is doubted by one respondent).
- **Sluggish procedures:** Traffic management implementations are sluggish because of its link with the physical infrastructure.
    - If traffic management is included in an infrastructure tender, it may take years before it is realised. By that time the traffic management market has changed and a better product could have been selected.
    - Traffic management sometimes requires adaptations to infrastructure that has a long life cycle and may thus invoke sunk costs. Since the technological future is uncertain it causes road authorities to postpone changes and thus block innovation.
- **Procurement inefficiencies:** The public-private interaction for the procurement of traffic management has technical related strategic behaviour.
    - Procurement separation in many systems may cause for overlap and limited interoperability (control disalignment, limited and delayed data exchange) and operational discomfort.
    - Post-contractual hidden knowledge because of Information asymmetry between traffic authority and private parties that cause high prices, lack of trust and wrong interpretation of demands.
    - The possible occurrence of lock-in effects after depreciation of an approach results in switching costs that may hinder market mechanisms.
- **Disperse implementation approach:** Uncoordinated decentralised implementations can limit large scale collaboration with private parties and can increase compatibility issues.
    - Scattered responsibility within road authorities accountability and complicate collaboration.
    - Data and mapping of traffic management infrastructure is not fully standardised so are different per region causing for high setup costs.
    - Specific demands result in high setup costs and limited interoperability between traffic management regions.
    - Road authorities fail to facilitate in-car traffic information directly to inform about their events and actions (road works etc.) because of closed market, project orientated goals and timeframe and its geographical scale and indirectly because they are too small to negotiate with large traffic information firms.
    - The possible occurrence of lock-in effects may prevent the cooperation between traffic management zones.
    - Disperse implementation approach is combatted in collaboration groups but is not binding for all participants.
- **Concession responsibility conflicts:** Arrangements between traffic manager and infra provider may cause conflicts because:
    - Entangled responsibilities to meet the required system performance.
    - Conflicting claim to make physical adaptations to the infrastructure.

3.5.3 Problems of the operation

The operation has various managing parties that have various interests, geographical boundaries, traffic management approaches and sources of traffic data. More specifically, road-bound traffic management form a geographical patchwork of zones and in-car traffic management each reaches a percentage of the drivers. Both are steering the same traffic that has difficult management characteristics (dynamic, non-linear etc.) and there is often no alignment between the measures taken. This causes for inefficiencies and unpredictable traffic behaviour. Meanwhile, there are economic interests to drive up the density, which makes traffic more unpredictable and NTM more difficult and the goals for traffic management are often ambiguous which can limit the incentive to improve it.

Inefficient operation is caused by:

- **Incompatible steering**: Traffic system is steered by two types of controllers of multiple actors that mostly use different measured data and control the system with different interest and on different scales while no aligning of this control is being done.
- **Disperse management:** The management of traffic control is divided into a patchwork zones where limited aligning of steering a sharing information is being done.
- **Incentive limitation**: Limited responsibility and incentives for efficient operation of traffic management and thus limited feedback for improvements of traffic managers because of ambiguous system performance and goals.
    - System characteristics make the effect of steering hard to predict.
    - Quality (to whom, factors & weights) unclear or has limited dimensions.
    - Measuring of quality is difficult due to the quantification of factors, variable demand and external influences .
    - No financial incentives for better performance.

3.5.4 Respondents problem discussion

The previous presented problems are discussed in interviews (Appendix D). An indication of its validity is acquired by conducted several interviews among various actors. Here, respondents we asked to state any problems that they could think of (with some guidance), whereafter they were asked to validate the problems found so far. In doing this, most of the problems were validated but some were added and some other minor problems were removed or adjusted (called 'aligned' in the summary). The rating of the importance was done by enabling actors to distribute 15 points over the list of problems decomposed into importance to their organisation and to society. The first may be used as way to engage them in the process strategy to be proposed in Section 7.2 and the latter as input to determine the most crucial problems for the government to resolve. When rating the problems for their importance the opinion of respondents fluctuated greatly (see Table 3).

Table 3 - Problem prioritisation of respondents

Phase/Problem	**Organisation importance**					**Society importance**				
Respondent	1	2	3	4	**AVG**	1	2	3	4	**AVG**
Development										
Demand/supply restrictions	4	10	0	0	**3,5**	4	2	0	5	**2,8**
Implementation										
Incentive limitation	0	1	0	0	**0,3**	0	0	0	0	**0**
Disperse implementation approach	1	2	5	5	**3,3**	1	5	5	5	**4**
Procurement inefficiencies	0	0	0	5	**1,3**	0	0	0	0	**0**
Sluggish implementation	0	0	0	5	**1,3**	0	0	0	0	**0**
Concession responsibility conflicts	0	0	0	0	**0**	0	0	0	0	**0**
Operation										
Incompatible steering	5	0	5	0	**2,5**	5	0	5	0	**2,5**
Disperse management	3	0	5	0	**2**	3	0	5	0	**2**
Incentive limitation	1	2	0	0	**0,8**	1	8	0	5	**3,5**

Although the prioritisation gives a mere indication, concession responsibility conflicts do not seem to be important at this moment. Whereas all respondents seem to agree that the disperse implementation approach is an important problem.

This variance can partially be explained by looking at the qualitative answers of these interviews. First, there seems to be a great variance in the occurrence of the problems among road authorities, thus this can affect the perception of actors. Second, most of the road authorities were thought to be (too) conservative because of safety risks or are obligated to use proven technology, which may be related to other problems. Third, for in-car subsystem, the following problems do not exist or are rather limited: lock-in effects, long procedures, dispersed management and concession conflicts. The time available in the interviews was also rather limited, which may have affected the results.

As a result of this chapter and the interviews there is a common problem perception among a select number yet diverging set of actors that fulfil an important role regarding INTM (the roles will be discussed in Chapter 5). In this common problem perception there is relative agreement about the problems but their importance varies among them.

3.5.5 System uncertainties discussion

This chapter has described a system is characterised by huge uncertainty. Van Geenhuizen & Thissen (2002) identified several sources of uncertainties. These sources can be found in the NTM system. Specifically, in the following:

- The **system boundaries** are changing (i.e. traffic information and traffic control are becoming more integrated).
- The **system** operates in a strongly segmented multi actor environment and combines numerous different other (sub) systems that develop in a fast pace. This causes for numerous and complex causal relations that are (at least) very difficult to determine.
- The **external input** has a wide range of factors that may influence the system (the physical system but also the positions of actors) at different stages.
- The **policy input** has a wide range of that may influence the system (the physical system but also the positions of actors) at different stages which may be difficult for the involved actors to predict.
- The **output criteria** are the among various actors.

This chapter has partly identified and specified the problems and (mainly substantive) uncertainty of the NTM system. Since, a lot of uncertainty remains, this will remain a topic of interest in upcoming chapters. The next chapter will try to deal with the uncertain future of the system by analysing it and focussing on a possible technological direction. As indicated in the previous chapter (and to be substantiated in upcoming chapters) multiple actors will need to cooperate to resolve the problems. This collaboration is more likely to succeed on the basis of negotiated knowledge (Koppenjan & Klijn, 2004). Thus this chapter has created a basis for a shared problem perception, although interview respondents found the problems of varying importance. This can be used in the final strategy presented in Chapter 7.

4 Prescribed future system

The system as conceptualised in section 3.1 may change over time due to multi-actor decisions and numerous external influences. Therefore, the system and its problems are time dynamic. Since that of this research envisions a policy strategy that tries to influence the system with a time scale of 5 to 20 years, estimations of the future system state has to be made. So this chapter will answer the following question: "*In what direction is network traffic management expected to go and how can this direction be realistically shaped for the benefit of society?*".

To cope with the uncertainties several strategies are used in this chapter, which will be introduced in each section if applicable. The structure of this chapter is visualised in the uncertainty trumpet Rosenhead (Rosenhead, 1989) where the vertical space defines the system direction (see figure below). This chapter will start by evaluating the trends found in the literature that may influence the system direction (in Section 4.1) to tunnel the likely outcome. Then it will analyse the remaining system direction and describe this in scenarios (in Section 4.2). This is followed by the proposition of Online Anticipatory Network Management (in Section 4.3) that was previously described in the background. Hereafter this proposition (in Section 4.4) is evaluated and a general strategy towards it is proposed (in Section 4.5).

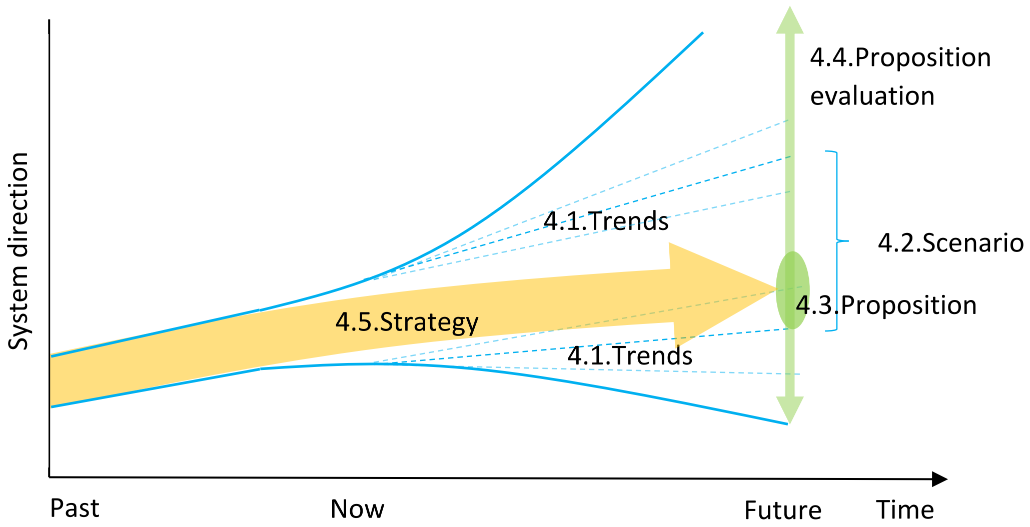


Figure 11 - Structure chapter four

4.1 System trends

The system and its actors may be influenced over time by external input and policy input. This influence is usually a gradual process where a trend may become apparent by comparing the past with the present. Seen the wide scope of the system, the literature has described a wide range of related trends that may affect functioning of the system. From the available literature the most important trends (based on the researcher's expertise) are extracted and described in the upcoming subsections. This includes governance trend for policy input and a transport and smart mobility services trend for external input.

4.1.1 Trend of governance in the Netherlands

Two applicable trends for the governance of the Netherlands have been found in the literature. The first is a in (for traffic management limited form of) privatisation and the second is decentralisation of governance of mobility.

The privatisation trend started with the telecom in 1989, whereafter a lot of sectors in the Netherlands have been liberalized (e.g. the electricity market and public transit) (Coevering & Werff, 2001). The reason for this are according to Coevering & Werff (2001): (1) reconsideration of the role of government in a market economy, (2) technological developments allow for competition in some sectors and (3) progressive academic insights about optimal regulation. In the infrastructure market this has led to the term "market, unless" (Ministerie van Verkeer en Waterstaat, 2007b, p. 35), which means that the government wants to outsource all her activities unless there is a reason not to. In the infrastructure construction this has led to the arrival of Design, Build, Finance and Maintain (DBFM) contracts. The main thought behind these contracts is to create and reward contactors on the basis of functional demands rather than technical demands. Furthermore, by including the operation phase they were automatically responsible for their design and construction. For traffic management this message became more nuanced and the government was focusing on public-private partnerships. One of the more recent examples of this is the iCentrale where are private party is ought to operate and maintain the traffic control centre that is now being developed (Mobility Matters, 2016).

The decentralisation trend originated from spatial planning and has been presented in 'Nota Ruimte 2004'. From spatial planning it has found its way into mobility via 'Nota Mobility' (Ministerie van Verkeer en Waterstaat, 2004). This decentral approach originates from the reasoning that a local road authorities know local traffic problems better.

4.1.2 Trend transport and smart mobility services

Transport and smart mobility services are changing due to a decline in information costs brought about by new information and communications technologies (Glachant, 2012). According to Deloitte (2015) five trends for transport and smart mobility services are to be expected:

- **User-centred:** User-centred mobility services put travellers in control.
- **Integrated and intelligent transport:** Intelligent systems will respond in real-time to manage capacity and predict and avoid disruption.
- **Pricing and payments:** Digitisation of tickets and payments will transform services beyond contactless payments.
- **Automation and safety:** will benefit from the exponential potential of cognitive technology.
- **Public and private innovation:** will work together to meet the mobility challenges of the 21st century.

For traffic management specifically, new information and communications technologies enabled FCD, various traffic information services, the automation of traffic control optimisation and driving and public and private collaboration as discussed in previous subsection.

These trends will be used to evaluate the proposition of upcoming section. This evaluation will be done in Subsection 4.4.1.

4.1.3 Identification of trend disruptions

The usage of trends might be dangerous because there might be events that disrupt a trend. Prematurely identifying such a disruption is extremely difficult especially in the considered complex system, setting aside the determination of the effects of such a disruption. However, neglecting possible trend impacts or disruptions could seriously impact the outcome of the prescribed policy.

Therefore, an effort has been done in identifying them and the following have been found (via induction):

- **Vehicle infrastructure communication:** Dedicated Short Range Communications (DSRC) may return traffic data to infrastructure. This may supply the traffic manager or for traffic control provider with more traffic data that may influence the power balance.
- **Removal of traffic control installations:** Due to vehicle automatization traffic control installations may become obsolete. Whether this will mean that influencing traffic control waiting time is still possible is unknown.
- **Variable road taxation:** The need to steer traffic to more societal preferable distribution may also be achieved with variable road taxation. This would reduce the need for OANM but not for INTM. Furthermore, this kind of taxation has long be debated in the Netherlands, but due to heavy opposition, politic choices and technical difficulties, it has never been approved and is not likely to be so in the near future (Meerhof, 2008).

The trend disruptions identified illustrate the uncertainty of the future. But the identified trend disruptions are assumed not to occur for several years and can be influenced by the government, which may reduce their threat for now. However, this list is far from complete so further research regarding this is advised.

4.2 Scenario planning

The future system direction has been tunnelled in previous section but still concerns quite some uncertainty that can be identified and possibly specified. This will be done with scenarios as introduced by Herman Kahn in the policy literature in the 1950s (Enserink et al., 2010). These are explorations of the future. Enserink et al. (2010) identified multiple dimensions to distinguish types of scenarios. These include: explorative or normative scenarios that a possible versus a desired image of the future; and context, policy or strategic scenarios that are based on external input, policy input or both. This section will start with the creation of an explorative context scenario. However, because the system is subjected to both external as policy input, the resulting explorative context scenarios will be evaluated regarding the INTM proposition, its social benefit and likeliness in the current governance trend (in Subsection 4.4.2), making it more like normative strategic scenarios.

The creating of context scenario can be done in short by identifying a wide range of external inputs, grouping them into driving forces and categorise these driving forces on the basis of their expected uncertainty and impact. Identifying the external inputs that affects the system over time has been done using a DESTEP method (an acronym for various dimensions e.g. demographic) for each of the three stages. Noticed in this process was that the variance in the timescale of external input per stage, where the development stage has on average a longer time scale and more variance than the operation stage. Hereafter, the found external inputs were grouped into driving forces and these driving forces were categorised on the basis of their expected uncertainty and impact (see Appendix A). The technological development direction was found to be both uncertain as impactful and is therefore used to construct two scenarios. There is however a third mixed scenario possible that could be preferable visualised in Figure 12. These scenarios are based upon the fact that the vehicles and the infrastructure become more connected due to various technology developments such as computation power (e.g. quantum computing), vehicle automation, satellite positioning (e.g. Galileo), traffic models (e.g. iLTM) and telecom (e.g. 5G). Some of these developments are discussed in Section 2.3 but whether these will continue to develop as they did in the past or are expected to, remains of course an assumption. The scenarios found are defined as follows:

- **Independent scenario:** Up to now vehicle to vehicle and vehicle to infrastructure communication went via the driver but technology increasing allows for the automation of this. It allows for a digitalised way of agent based interaction that enable a safe and locally efficient interaction environment. Thus, this scenario describes increasing autonomous technology that makes decisions based on interaction with other technology without a direct hierarchy.
- **Controlled scenario:** Simultaneously, developments of computation power and traffic models allow for more central control of vehicle to infrastructure and infrastructure to infrastructure communication that would otherwise be too complex to achieve. This would allow for a system wide optimisation of the network. Thus, this scenario describes increasing autonomous technology that makes decisions based on instructions from a central command.
- **Coordinated scenario:** Both scenarios could in theory lead to better network performance. The independent scenario would allow for fast adjustments to local conditions and the controlled scenario allows for the network traffic management. A combination between the both would probably be technical superior to the other scenarios but also the most difficult to achieve.

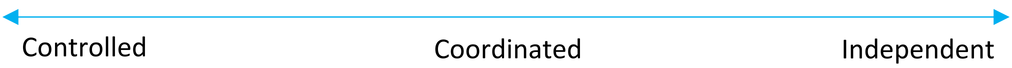


Figure 12 - Scenarios for the technological development direction

These scenarios will be used to evaluate the proposition of upcoming section. This evaluation will be done in Subsection 4.4.2.

4.3 Proposition for integrated network traffic management

In the uncertainty of the system and its future this research sees an opportunity to creatively shape the future. Hence it proposes the realisation of OANM (described in Section 2.3.4). It is a theoretical approach to resolve incompatible steering problem (described in Subsection 3.5.3). Although, it is not only an approach to resolve the problem, it allows for the steering of the network distribution from user optimum towards system optimum (Stackelberg equilibrium). Furthermore, it allows for the steering of traffic for public goals (environment etc.) while employing the user centred perspective. However, this proposition requires a collaboration among actors; it must be developed, implemented and operated and its operation requires traffic data exchange. This is however hindered by the (other) problems described in previous chapter.

4.4 Evaluating proposition to expected future

Specifically, OANM is chosen in this research since that it was found to be as socially beneficial. However, other approaches are of course possible. To limit the scope of this research these will not be investigated. However, in order to produce a robust applicable research, the research setup should allow for alteration of the proposed approach and the prescribed technological direction should be a realistic candidate.

To allow for alteration, the setup of this research therefore employs a methodology that may be used to analyse other technological futures, the process orientated strategy (described later on) allows for flexibility and the specific changes of OANM will separated from general INTM to show the direct difference. Furthermore, some of the recommendations might be generic to a range of possible futures.

The prescribed technological direction should be realistic. Thus it is evaluated to indicate if it is likely to be realised (accept the uncertainty and act consciously in its presence). Furthermore, by doing this one is able to specify what may impact the proposition and needs to be monitored or influenced. To evaluate the proposition one has to regard the stages of its realisation. First is its development and implementation then its operation. For the first, trends and scenarios will be evaluated by induction. Here it is assumed that if the proposition is in-line with the trend, then it is more likely to be realised. Furthermore, when a trend is identified and consensus in reached about this trend, this research states that it might even work reinforce the trend in multi-actor environments. Hereafter, the operation is evaluated.

4.4.1 Trend comparison

To evaluate if OANM is a realistic proposition, it is compared to the previous described trends. Regarding the governance trends, the involvement of private parties does not seem to interfere the development of OANM approach since it is a complex solution that may benefit from private specialisation. INTM and especially OANM is a network approach requires some central coordination which is in contrast to the decentralisation trend.

Regarding the transport and smart mobility services trends the following is stated:

- **User-centred:** Users remain in control and preserve their freedom of route choice
- **Integrated and intelligent transport:** OANM is an approach to real-time to manage the infrastructure;
- **Pricing and payments:** it is supplies an alternative form of pricing i.e. pricing with variations in travel time;
- **Automation and safety:** connected navigation devices will enable automated user-centred route choice (aided) decision-making (related to the autonomous driving development);
- **Public and private innovation:** Private traffic information can work together with public traffic control management using the OANM approach

So, it seems that OANM is a viable option but is in contrast with the decentralisation trend. But possible trend disruptions should be monitored to manage the possible effects of a trend deviation.

4.4.2 Scenario evaluation

The proposition made requires interaction between central optimising system (controller) and the traffic control, although the network may be decomposed into smaller zones that interact as agents as described by Rinaldi et al. (2016; 2013; 2013, 2015). This implies a controlled or coordinated scenario. However, the independent scenario is more easy to realise in a patchwork of traffic management zones (i.e. requires less agreements and compatible systems among actors). Moreover, the benefits of the controlled scenario are more dispersed over the network. Private firms that may operate traffic control in the future may possibly only become responsible for their zone and the benefits outside of their zone are more difficult to prove. Therefore, it is estimated that the independent scenario is more likely. However, these scenarios describe the outcome of the external inputs. But these scenarios may be influenced with policy input (e.g. investments or legislation) which may steer the future. This demands however an active national government which is less likely in the current governmental trends.

4.4.3 Testing market operation

OANM will only be a realised if its operation is feasible. Up to now, the main attention has been paid to its technical attributes but it also a market application in the in-car subsystem. The effects of OANM operation should be evaluate prior to application to reduce uncertainty of its feasibility. Its operation has two critical assumptions. First, it uses connected navigation devices to inform drivers of the effects of dynamic traffic control settings. Although not all drivers have such a device, de Mooij (2013) predicts that sixty per cent of all drivers in the Netherlands will have the online traffic information ability within ten years and all of the drivers between fifteen to twenty years. Second, when they have such a device they might not use it or opt for an alternative. To evaluate the usage van Hoeckel (2016) made a simple causal diagram (see figure below) of the usage to analyse the transition period towards OANM from the perspective of the traffic information provider. Since OANM is expected to improve the travel time prediction (by including of traffic control settings), it is likely to increase driver comfort. The traffic information providers that use this will gain a competitive advantage and the drivers will acquire more benefit from the service which will result in more users and/or usage. In term, this increases the amount of traffic data which could lead to a better prediction. Furthermore, automated driving was included as an external force which could increase the follow-up rate and the amount of acquired traffic data. Both are expected to result in a better prediction and thus strengthening the approach. Using this, van Hoeckel (2016) expected that implementation is a self-enforcing process that will not require big market push (under the condition that the approach works as expected).

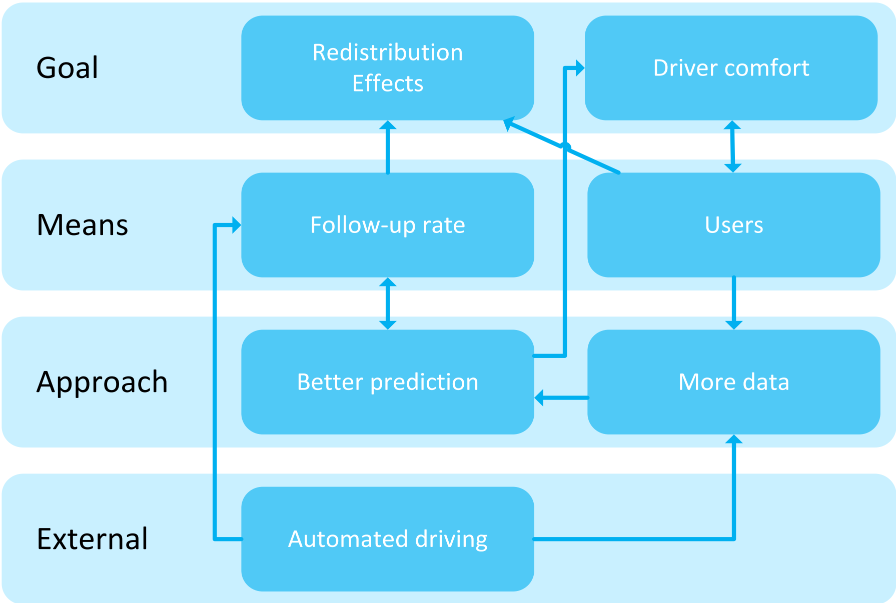


Figure 13 - Causal diagram of OANM implementation transition (from van Hoeckel, 2016)

For the road-bound subsystem, this research assumes that OANM will be economically beneficial (benefits higher than costs) for the government and society on the basis of the theoretical findings in the research of van Hoeckel (2016) and that traffic management solutions are usually more profitable than infrastructure creation or congestion.

4.5 Realisation strategy

Previous sections have shown that the OANM is expected to be socially beneficial and a possible candidate for the future if the government is willing to adjusts its policy. Then the question arises: how can this direction be realistically shaped for the benefit of society?

To create a general strategy for this, a SWOT analysis is an established (but rather basic) method that can be used (Dyson, 2004). It originated in a publication of Learned et al. (1965) and aims to identify positive and negative factors of usually an organisation (internal) and its environment (external). This decomposes a grid which consists of the strengths, the weaknesses, the opportunities and threats. When the factors of this grid are found strategies can be developed that build on the strengths, eliminate the weaknesses, exploit the opportunities or counter the threats. However, a variation of the SWOT analysis, the TOWS Analysis (Weihrich, 1982), may assist in this process. In a TOWS analysis combines the identified internal and external factors in pairs to create strategies. This has been done in Appendix C.

It shows that the OANM approach offers the opportunity to cost efficiently increase the network efficiency and that the approach can be exported to foreign countries. Although the proposed approach is complex, its scalability issues and the technical complexity can be compensated with new computational developments, new traffic modelling techniques and by using the knowledge of the many involved parties. Traffic data is required for OANM but autonomous driving, GNSS development and mobile telecom development offer opportunities to gain more and better traffic data. Moreover, the public may oppose the implementation so they need to be convinced of how their interests are improved (reduced average travel time, increased comfort and maintained privacy) in an easy understandable way. So, if the collective of road authorities would show interest in OANM and a strategy is deviced to bring the required parties together, it is likely it could be achieved.

4.6 Conclusion

This chapter has analysed the future of INTM and evaluated the realisation of OANM in this future. The future was analysed by acquiring the trends regarding INTM from the literature, whereafter the remaining uncertainty was described in three scenarios: controlled, coordinated and independent. Hereafter, OANM is suggested as future INTM approach in this research since it was found to be socially beneficial. However, it is acknowledged that this is just one of many technological approaches.

The proposed OANM approach seems like a viable candidate within the trends, except for the decentralisation trend. Furthermore, it is achievable in the controlled and coordinated scenario where the latter seems to be the preferable one. However, the independent scenario seems more likely without government involvement. Moreover, the proposed OANM approach still has to be developed (by actors) and its implementation and operation requires collaboration between the actors and subsystems, which is hindered by the problems described in Chapter 3. Thus, there is an opportunity that is possible and desirable to realise, but unlikely without a collaboration of many of the involved actors and the involvement of the national government.

For the remainder of this research OANM is suggested as specific future INTM approach. But the collaboration required and the future of the system remain uncertain. Therefore, the next chapter will analyse the actors and their network to evaluate how they will perceive, respond to and interact regarding the prescribed future. To account for the uncertain future and to offer flexibility, the specific changes of OANM will separated from general INTM to show the direct difference. Furthermore, the final strategy (Chapter 7) must cope with and possibly even utilise (by suggesting OANM) the uncertainty of the future.

5 Analysis of actors and their network

The INTM system (presented in Section 3.1) and the prescribed future involve many actors because it integrates functions of systems and requires resources owned by multiple actors and it affect the interests of a range of actors. Each of these actors have their own role within the system and their decision-making may affect the system as well as the outcome and choices of other actors. This decision-making is a result of an actors (strategic) interests and is affected by his/her perception. Negligence of the strategic interests and perceptions (and the network in which they occur) may result in strategic problems and uncertainties that can hinder the prescribed future. Therefore, this will be investigated to reduce the uncertainty or to identify and, if possible, specify remaining uncertainty such that the final strategy can cope with this. Thus, this chapter will answer the following research question: "Who are the actors involved and how will they perceive, respond to and interact regarding to the prescribed future?".

To analysis this, this chapter will present and discuss the results of the actor analysis in Appendix B. The basic method used is a stakeholder analysis (Bryson, 2004b; Freeman, 2010). This method collects and structures information regarding actors, resulting in specific participation strategies for each of them. It focusses on resources and interdependencies and is practical to apply but its analytic quality is not strong because it has limited specificity and logical interconnectedness (Hermans & Thissen, 2009). To improve the quality of the analysis, steps to evaluate the perceptions and network has been added. The main findings of this will be presented in this chapter employing the following topics: the changes involved with the prescribed future, the involved actors, how actors are clustered in the network, the interests of the actors regarding the changes, the perception that actors may have regarding these changes, and how the decision-making is expected to take place.

5.1 Changes with the prescribed future

The actors involved in the system (to be identified in the next section) will be affected by the prescribed future (of previous chapter). This future involves the creation of INTM and more specifically OANM. To evaluate how the prescribed change impacts the actors, it has been decomposed into smaller elements on the basis of the researchers expertise regarding the OANM approach presented in van Hoeckel (2016). In this decomposition, the changes have been grouped in mandatory changes for INTM and OANM and optional changes, such that the research is reproducible for possible alternate INTM futures (as proposed in Section 4.4). But, it has to be noted that the listed changes are not yet very specific because the changes itself are susceptible to the behaviour of the actors and hence causes uncertainty. It is expected that the listed of changes are a snapshot (i.e. when the process continues more changes may become apparent). While taken this into account, the following changes are identified:

Mandatory changes with INTM

- **Traffic control settings to traffic information providers**: this allows navigation to include the travel time change of traffic control.
- **Improved network distribution and travel time prediction**: the previous data exchange supplies drivers (or their devices) with more information which allows them to better choose routes.
- **Automation of traffic management (assumed)**: It is assumed that traffic management can be more dynamic with INTM and will therefore require automation to determine and execute traffic control changes.

- **Software steering of traffic control (assumed)**: It is assumed that the previous automation is mainly software driven. In practice this means less hardware programmed interactions (i.e. the shift from a smart traffic control installation to server based optimisation)
- **Requires FCD (assumed)**: It is assumed that in order to make better traffic conditions predictions (especially for areas with intersections but without traffic control loop detectors) more traffic data and especially a mixture of traffic data sources is required.
- **Investment of governments, traffic management providers, traffic control providers, traffic information providers** (transition cost): the proposed change will require an investment of diverse parties that they may later earn back.
- **Costs of change** (transition cost)**:** any change to the infrastructure or information service may cause temporal disutility and/or discomfort for drivers and traffic information users.

Additional mandatory changes with OANM

- **Central steering of traffic control**: OANM will require some form of network wide optimisation as described in the controlled and coordinated scenario (Section 4.2).
- **Additional improved network distribution**: OANM will improve traffic distribution (towards Stackelberg optimum as described in Section 2.3.4). It will affect highly used and congested roads of meshed networks with lots of traffic control the most.
- **Steering for societal goals**: By imposing longer travel times with traffic control for e.g. residential areas, drivers can be motivated to drive around them.

Optional changes that may improve the system

- **Aggregated route advice to traffic management authorities**: By using (aggregated) route advice traffic conditions predictions accuracy may increase.

This decomposition has been validated by one of the interview respondents (#2 in Appendix D). The resulting mandatory changes will be used to analyse the interest of actors (in Section 5.4) and to form the games if they may cause a dilemma (in Subsection 5.6.4). The resulting optional changes will only be included in the game if they may cause a dilemma's (in Subsection 5.6.4) since they should be considered because of their potential positive effect but are not crucial for the realisation. But first the actors are identified in the next section.

5.2 Involved actors

The section will identify the actor of the INTM system. For this, this research adopts the definition of an actor of Enserink et al. (2010) as "a social entity, person or organisation that has a certain interest in the system and/or is able to influence the system directly or indirectly". This definition is wider than the definition of a stakeholder since it includes entities that do not have an interest but are able to influence the system and is chosen because it prevents the negligence of a possible reasonable impactful actor.

To identify actors Mitroff (1983) and Enserink et al. (2010) described several approaches. From these approaches a combination of the positional (review existing policy making structures) and reputational approach (ask key informants to identify important actors) are chosen for practical reasons, along with the system analysis made in Chapter 3. The first is conducted with desk research by reviewing legislation, tendering documents, policy pieces. Hereafter, the reputational approach is used by utilising the knowledge of the research supporting company to verify and complement the list. Then the result is a list of numerous actors that are, often 'composed' (i.e. involved in the problem(s) with more than one of its parts) and active in multiple functions. To structure them, two value chains have been constructed (listed in Appendix B) to identify and group actors on the basis of their function in the chain. The considered chains are "traffic management development & implementation" and "operational traffic management". At the end of both chains the public has a certain experience which is included although they do not have a direct function but they do have an interest. The result is presented in the table below.

Table 4 - Actors, their role and group

Actor group (function)	Role	Cluster
European Union (supranational government)	Government policy developer	Public organisations
Government of the Netherlands (national government)	Government policy developer	Public organisations
Rijkswaterstaat (national road authorities)	Supervisor, Traffic information providers	Public organisations
Province road authorities	Supervisor, Traffic information providers	Public organisations
Municipality road authorities	Supervisor, Traffic information providers	Public organisations
Water board road authorities	Supervisor, Traffic information providers	Public organisations
Traffic manager	Traffic manager	Public/Private
Project contractor	Traffic control facilitators	Private firms
Traffic control providers	Traffic control facilitators	Private firms
Traffic management developers	Traffic control facilitators	Private firms
Consultancy firms	Advisory development parties	Private firms
Research institutions	Advisory development parties	Public organisations
Navigation providers	Traffic data collector, Traffic information providers	Private firms
Automobile manufacturers	Traffic data collector, Traffic information providers, Facilitating parties	Private firms
Smartphone application developers	Traffic data collector, Traffic information providers	Private firms
Private data processor and/or (re)distributor	Traffic data processor and/or (re)distributor	Private firms
Public data processor and/or (re)distributor (NDW)	Traffic data processor and/or (re)distributor	Public organisations
Drivers	Drivers, Traffic information users	End user
Locals	Locals	End user
Facilitating parties	Facilitating parties	Public/Private
Interest groups	Interest Groups	End user

These actors can be clustered on the basis of their characteristic and interdependencies (already shown in previous table). This will be explained in the next section.

5.3 Actor network

The actor network of the INTM is complex. Its problems are complex and require a multitude of specialised actors that often solve problems in an interorganisational context. In this context organisations are mutual dependent. Moreover, the actor may make strategic decisions to acquire or dispose a certain resource which allows them to reposition themselves. This ability and a multitude of clients can make actors fairly independent of a single actor and thus limits the influence of a single actor. The number of possibilities to steer society from one central position are perishing (Hanf & Scharpf, 1978; Rhodes, 1997). This causes the government to no longer at the top of the societal pyramid. Hierarchies are replaced by networks that cross public and private domains. The amount of places where people, groups, and organisations are making decisions of importance are increasing because of professionalism, specialisation, decentralisation, individualism and informatisation (Castells, 2000). It results in a paradoxical situation of increasing fragmentation and interdependencies (Koppenjan & Klijn, 2004, p. 3). This seems to be applicable on INTM.

The result appears to be a network where there is some hierarchy between some actors according to the characteristics of hierarchies and networks as described by Bruijn & Heuvelhof (2008).

Hierarchy	Network
Uniformity	Variety
Unilateral dependencies	Mutual dependencies
Openness/receptiveness to hierarchical signals	Closedness to hierarchical signals
Stability	Dynamic

Table 5 - Characteristics of a hierarchy and of a network (de Bruijn & ten Heuvelhof, 2008)

To analyse this further, the network is decomposed on the basis of the created formal relations diagram into three clusters, these are: public organisations, private firms and end users.

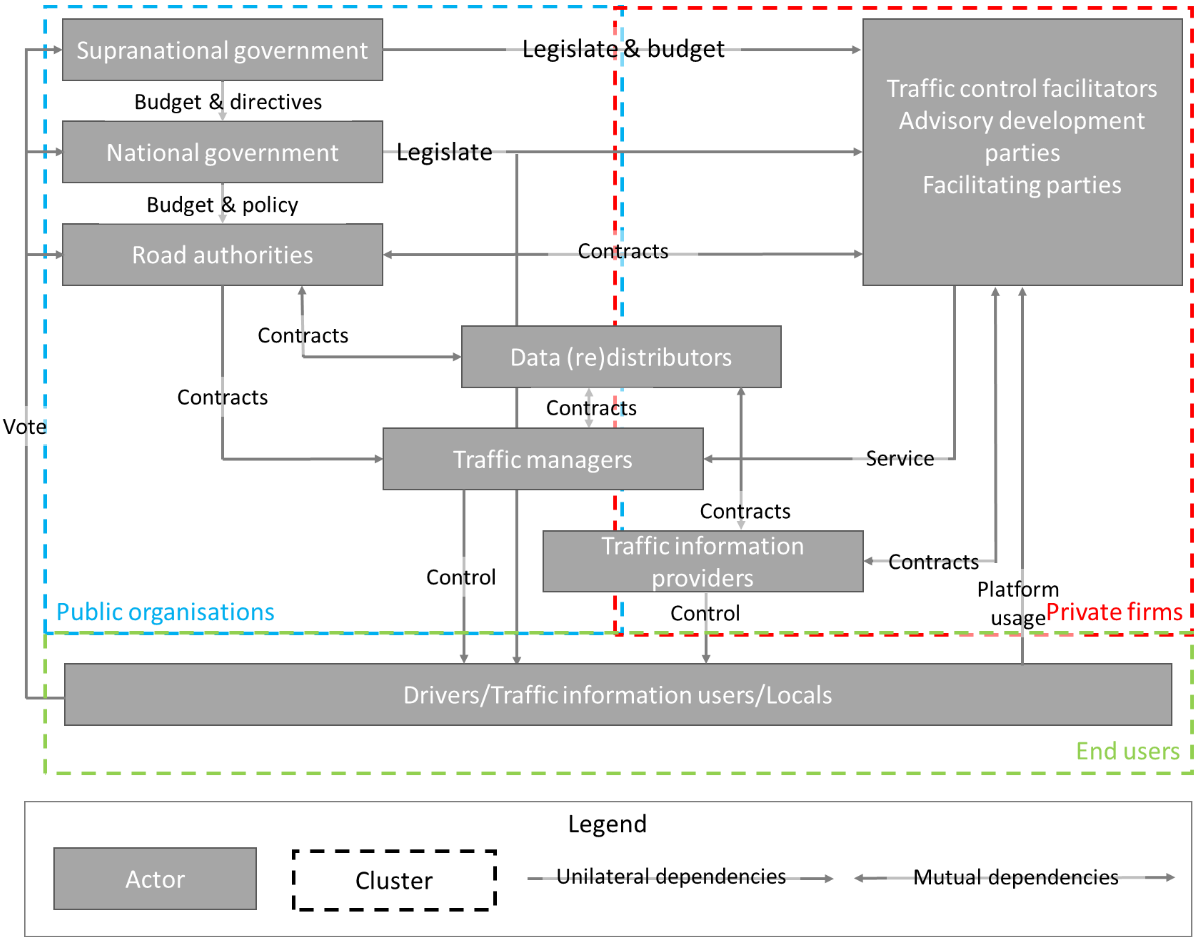


Figure 14 - Formal relations diagram

Aside from network and hierarchical characteristics, this research states that network clusters are important because:

- Perception and institutions: The network or cluster of an actors affects who he interacts with. This can affect the information that the actor receives and the way he interprets this information. The latter because people in different networks or clusters may have a different background, may be subjected to the strategic interests of the network or cluster and may affect each other's ideology. Where networks interact clashes of perceptions and institutions may occur (moreover in Section 5.5).
- Coalitions: mutually dependent actors can form coalitions more easy (moreover in Subsection 5.6.2.
- Power: The position someone holds in the network may enable him to acquire resources, organise and possibly influence the actors around him (moreover in Subsection 5.6.2).

The upcoming subsections will discuss the different clusters.

5.3.1 Public organisations

The first cluster concerns the public organisations. In this research the government and its parts are decomposed, which is represented in the following diagram. Here, four layers are distinguished. A supranational, national and local/regional government where the latter forms one road authority (RA) with its departments that has multiple agencies (assumed to be three according to the decomposition of Section 2.1).

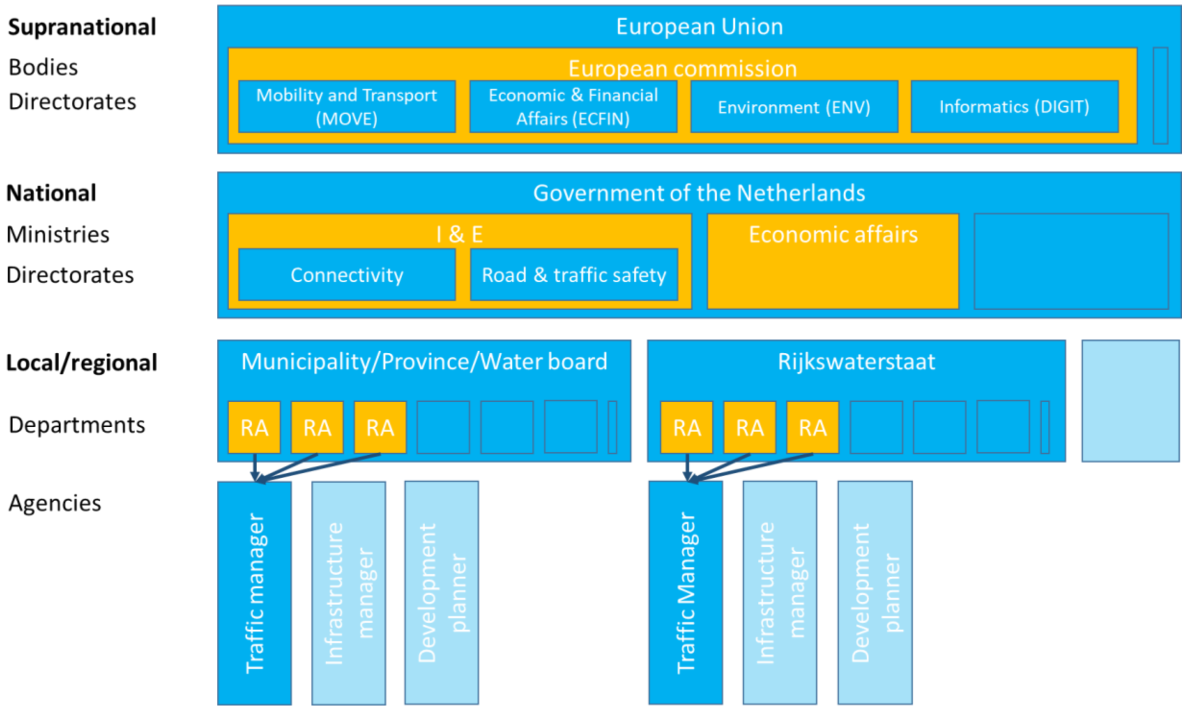


Figure 15 - Decomposition of public organisations

This somewhat simplistic view helps to evaluate the relations. This research states that there is variety among the regional governments (substantiated in Appendix B), there is some unilateral dependency (e.g. budgets) between the regional and national government, there is some closedness hierarchical signals and the patterns are rather stabile. Based on the characteristics of Bruijn & Heuvelhof (2008) it is stated that the relation between governments in the Netherlands is a mixture between a hierarchy and a network. This can affect the feasibility of nation-wide organisational change (institutional design). The stronger the network signals the less likely that a command and control like intervention will work.

5.3.2 Private firms

In the cluster of private firms, actors continuously change their position by engaging into new markets and creating new products. Some examples: TOMTOM (traffic information provider) tries to acquire a role as a traffic management provider (according to an interview with Goddijn in Eindhovens dagblad, 2017), Sweco (consultant) tries to become a traffic management provider (interview: van der Bijl, Appendix D), Trinité automation (traffic management provider) tries to acquire a role as a traffic information provider (TrafficLink, 2017). These dynamics characterises the current market conditions where there is lots of potential gain but huge uncertainty. Although these dynamics are important, they are obviously dynamic and thus due to the uncertainties difficult to predict. But is may mean that an actor who plays a marginal role in today's network can occupy a central position in the future (de Bruijn & ten Heuvelhof, 2008). Seen that research envisions a more general picture and a longer time scale, these dynamics will be left for further research.

Besides the dynamics, there is also vertical integration. For example Vialis that went from a traffic control provider to a traffic service provider that also included traffic management provider, contractor, data processor, traffic information provider (interview: Hartman, Appendix D). There seems to be good reason for it. Besides that providing al services have a complementary value, the value of traffic data can be improved by merging it, the same modelling techniques may be used and the user base of the traffic information services may be improved.

Besides vertical integration, coalitions may be formed. For example TNO is engaged in very specialist research but is rarely by itself engaged in creating a product. To acquire the benefits of vertical integration it seeks alliances with its 'rivals'.

This makes up for a cluster with a variety of dynamic entities that are often mutual interdependent. Thus this cluster shows many network characteristics.

5.3.3 End users

The cluster end users consists of drivers, traffic information users, locals and interest groups. These often concerns the same individuals (in multiple actor groups) and are characterised by being the final actors in the value chain. Their individual power is rather limited and indirect. Furthermore, as group they often have diverging interests. However, there are many of them. So, if they become organised they can have an impact.

5.4 Actor interest to prescribed future

This section will determine if an actors have an interest and if they are a proponent or an opponent to prescribed future. To do so, this research assumes that it depends on their perceived current situation, expected future situation without change versus with change (in comparison to their desired situation) and the perceived costs of the process in between (transition costs). This can be explained as follows:

1) the current situation has a certain perceived (dis)utility that will endure for a certain period of time if no change is made;
2) the future situation has a different perceived utility which may endure for a certain (different) period of time;
3) the proposed change is not likely to occur instantaneously but over evolves in a process in a certain period of time, this process may e.g. require investment, cause discomfort or result in income loss;
4) The to be gained or lost utility is the perceived difference between the situation with and without change minus the perceived costs of the process in between, each for a certain period of time;
5) The to be gained or lost utility in the future situation in comparison to the current situation results is the opposition or proposition of an actor.

This is illustrated in the image below that presents the perceived utility over time for the changed (blue) and the unchanged (black) conditions. The difference in certain perceived utility (green), uncertain perceived utility (light green) and disutility (red) has been marked.

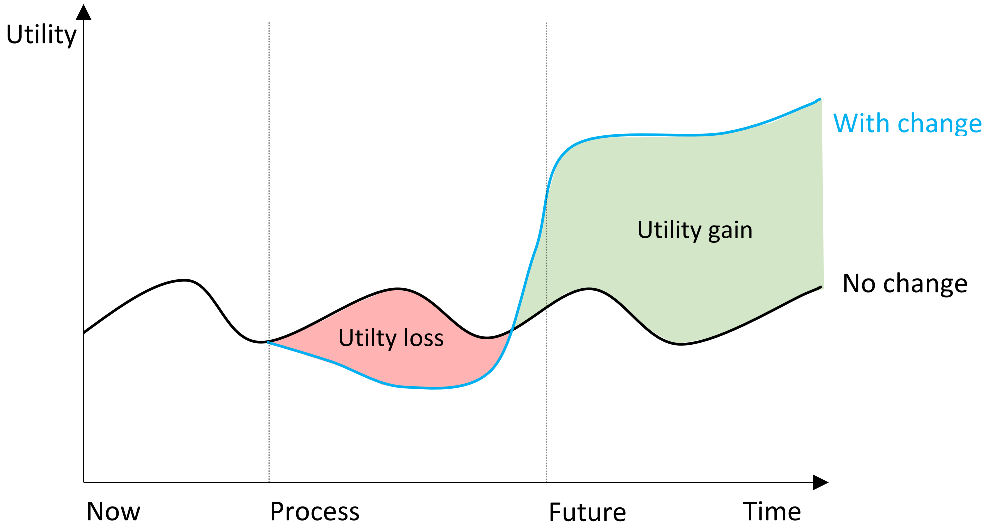


Figure 16 - Perceived utility difference between changed and unchanged situation over time

Implicitly this assumes rational decision-making based on maximal utility. Humans however, often lack information, the cognitive resources or the required aspiration level to maximize their utility. Therefore, one may opt for a satisfactory level of utility, called satisficing utility Simon (1955, 1956), and/or is affected by past decisions, called habit formation by Duesenberry (1952) and Pollack (1970) and/or has an aversion to risks (described by e.g. Chorus, 2012). However, this will be left for further research. Furthermore, it states perceived utility because that is what the actor will act upon. It is an estimation of the outcome based on the information available, past experience of an actor amongst others. Thus this is closely related to uncertainty and risks. But no uncertainty was included in the utility assumption while (especially) the utility of the future situation with change is likely to have more uncertainty than that without change. But this may influence their perception of people, especially because people tend to underestimate risks (O'Sullivan, 2015) and simultaneously tend to be 'risk-averse for gains' but 'risk-seeking for losses' (Kahneman & Tversky, 1979). While it is difficult to determine the actual gain with this uncertainty it is even more difficult to predict the perceived gain and the resulting behaviour.

This research has identified this uncertainty and suggests a pragmatic approach to deal with this by first attempting to describe the actual gain (in this section), whereafter the perception of actors is described from a theoretical point of view (in the next section). Thus upcoming subsections will discuss the interest of actors involved per actor cluster (the interests per actor can be found in Appendix B). Note that it will not discuss all changes that happen between now and the future but only the mandatory changes described in Section 5.1.

5.4.1 Public organisations

The impact of INTM on the government is mainly determined by the expected increase road network efficiency. Therefore it should reduce government spending on roads, general energy consumption and thus pollution.

The OANM approach may increase this further and may allow the government to steer traffic away from undesirable locations. On operational level the automation might reduce the workload and thus reduce the number of jobs. The OANM approach will affect highly used and congested roads in meshed networks with lots of traffic control the most. Congestion occurs mostly on motorways, important provincial roads and city access roads and meshed networks with lots of traffic control exists mostly in cities. So, it is expected that cities and thus large municipal road authorities benefit most from the proposed approach. But because ramp metering may also be used it is also of importance to Rijkswaterstaat.

5.4.2 Private firms

The impact of both INTM and OANM on private firms is diverse because they have diverging and competing interest within the actor group. Usually, they are mainly driven by commercial interests but there may be influence of a corporate social responsibility. To specify this further, the main actors in this cluster will be discussed (the other actors can be found in Appendix B).

Traffic information providers will receive traffic control setting with INTM that will improve their travel time prediction. Since the drivers and traffic information users are impacted positively, the user base of traffic information providers is likely to be positively affected (even if all providers use it and the market share does not change, the traffic information usage is still likely to increase). Furthermore, FCD is likely to be bought which is beneficial for them and/or data (re)distributors. It is predicted that they will not have objections to OANM. They might even benefit because by dynamically changing traffic control settings the information of the settings becomes more valuable since it has a larger uncertain impact on the drivers' travel time.

Traffic control provider that focuses on hardware may be affected on the long run because the intelligence is likely to shift towards the software with INTM. However, initially they will receive extra request for new hardware that can be adjusted by software.

Traffic management systems developers want to develop and sell their products. Some of them may developing independent traffic management products and may not benefit directly but the rest is stand to benefit from the INTM development.

Consultants now benefit for advice that is sold each time a controlled intersection has to be adjusted. With the arrival of automated software optimisation this will be reduced. Therefore they will be negatively impacted on the long run. On the short run however, they might have an increase of sales because of the transition process.

5.4.3 End users

The impact on drivers and traffic information users are discussed by van Hoeckel (2016). In this research it was substantiated that it improved the accuracy, robustness, accessibility, completeness, timeliness of traffic information. INTM without OANM has a similar effect but the traffic is distributed in user optimum instead of a Stackelberg optimum and it does not include the option to steer on the basis of public goals. For a driver it means shorter travel times in general although it might slightly increase travel times for some drivers at certain moments as long as the public goals remain rather user centred (this may be a big if). The driver that uses the involved traffic information system will additionally receive more arrival time certainty and will not receive contradicting information. So overall it can be stated that drivers will benefit from INTM and OANM in specific (even when they do not use the system themselves because travel times are likely be reduced). A boundary condition for this is that traffic data is anonymised and privacy is maintained. A possible utility loss in the transition process may occur due to traffic control and traffic information (optimisation) failure, hinder due to infrastructural adjustments and switching costs (actual or cognitive) for traffic information applications. The other proposed changes are of fairly little concern to drivers. They should improve road conditions and data exchange could pose a privacy risk.

The impact of INTM on locals (and society) is mainly determined by the expected increase road network efficiency. The other proposed changes are of fairly little concern to locals and society but it is ought to increase implementation and operation efficiency.

OANM in specific should allow for public steering and should therefore result in more network efficiency. These should lead to a reduction infrastructure costs, a reduction travel time and costs, a reduction environmental damage, an increased safety and an improved living/working area. The possible utility loss in the transition process may occur due to traffic control and traffic information (optimisation) failure, hinder due to infrastructural adjustments, and initial investments government (via taxation).

5.5 Perception of actors

The previous described interest may be perceived differently because of information received, ones cognitive ability, ones interpretation (affected by ideology, background, strategic interests) and past experience (with a certain actor). Inductive reasoning supplemented with the conducted interviews enable this research to make general statements about the perception of actors. However, acquiring empirically significant data about this is left for further research. Thus, this section should be interpreted as indicative or explanatory only. It may indicate by perceptions are important yet difficult to factor.

5.5.1 Public organisations

Government consists of people. These people hold a certain position. Some of these people may be afraid to lose their position as a result automation and the sharing of traffic data which might reveal marginal road performance. Furthermore, it is a change that involves more inclusion of private firms in a previous public domain. This may result conservative and/or controlling behaviour

5.5.2 Private firms

The perception of private firms may be affected by their own ambition. If they have invested heavily in their data and/or innovation their expectation of its potential is likely to increase and so is their perceived value it. However, this perceived value may mismatch with the perceived gain of other parties. Potentially, because the client may be unaware of the technological possibilities and complexity. Alternatively, the prices may be too high in order to realise a short payback period. This may however prevent a scale of economies and actually freeze up the market. When however the first market players the others are likely to follow soon as they want to secure their return on investment.

5.5.3 End users

Drivers and traffic information users will probably (without government involvement) not be involved before the end of the implementation stage of traffic management (see next section). Hereafter, the incremental change of both INTM as OANM for the individual driver is likely to be small and due to the traffic conditions and due to the cognitive effort required for driving (for now) hard to perceive. Furthermore it might take time for the traffic distribution to change as a result and the effect may increase over time with the increase of its users. So the benefits will be difficult to perceive and may be forgotten over time. This leaves room for personal ideology and perceptions based of individual experienced that may be biased (e.g. although travel times may have decreased with five per cent an individual driver may state that he always has to wait for a red light when traveling to work). The expected gain (which includes perception and uncertainty) of the public matters as seen in the failed implementation of the variable road pricing scheme proposed in the Netherlands where the majority of drivers voted against road pricing but may support it one it is implemented (OECD, 2015, p. 179). For OANM people may not like the feeling that their route choice and freedom is influenced in any way and people may have a tendency to naturally reject government intervention because of their ideology. Furthermore, it requires trust that the power of steering and data collection (privacy) will not be misused.

For locals (and society) INTM and especially OANM is social desirable e.g. as an alternative to the creation of more infrastructure and the prevention of trough traffic it may offer better outcomes than for example speed bumps. However, it may be difficult for people to understand the approach.

5.6 Decision-making in the INTM system

This section will describe how the decision-making in the INTM system takes place. Each of the previous described actors holds a certain place in the network of actors because of the established resource distribution and sets of rules (arena). Within this arena series of interactions will occur around a range of issues. These series of interactions can be called games (Scharpf, 1997). The strategic behaviour of actors in these games will be determined for a large extent by their position in the network and the other games the actor is involved with. This section will analyse which games are likely to be played, by who and how actors are likely to behave. It will start by describing the structure of the decision-making, then how it is affected by the actors and their resources. Hereafter, possible games and coalitions are investigated.

5.6.1 Arena

An arena where the decision-making takes place can be described by the stage model (Mintzberg, Raisinghani, & Theoret, 1976), the stream model (Kingdon, 1984) and the rounds model according to Teisman (2000). The difference in them is illustrated in the figure below.

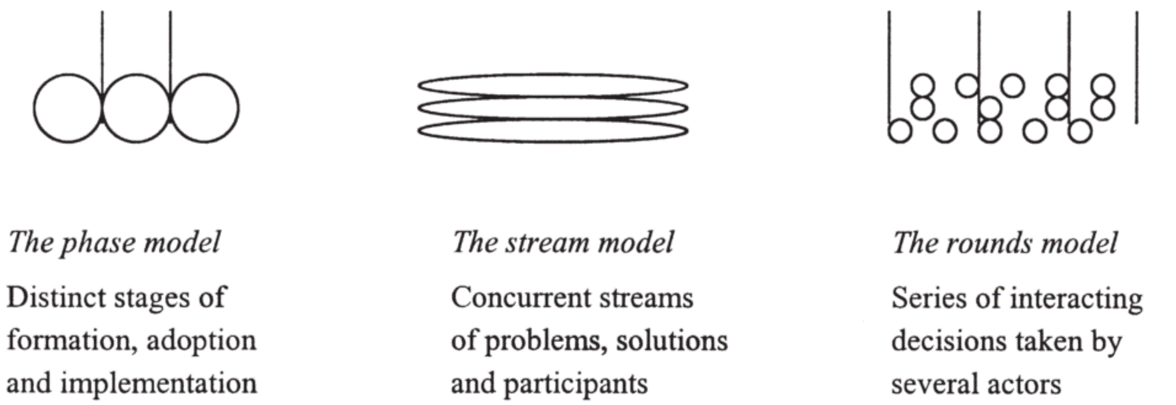


Figure 17 - The three models for the analysis of decision-making processes (from Teisman, 2000)

Chapter 3 decomposed the realisation of INTM approaches into stages. In reality, changes for road bound traffic management may occur in a number of distinct stages, because of problems, opportunities or politics as well as a result of the interaction between the various decisions taken by different actors. This can be described by a combination of the models. More specific, this research states that overall a stages model is apparent; wherein all stages can be described by a rounds model, with exception of the implementation stage that also shows characteristics of a streams model. Where a stage (the name "stage" is maintained for continuity) does not have a clear starting point and end point and where multiple changes may occur simultaneously, especially when many parties are involved. This is graphically presented (and simplified) in the figure below where the lengths of the blocks are indicative and non-relative (i.e. the size of the blocks and their starting positions can be different than presented). It is advised that further research investigates the application and implication of a combination between the models.

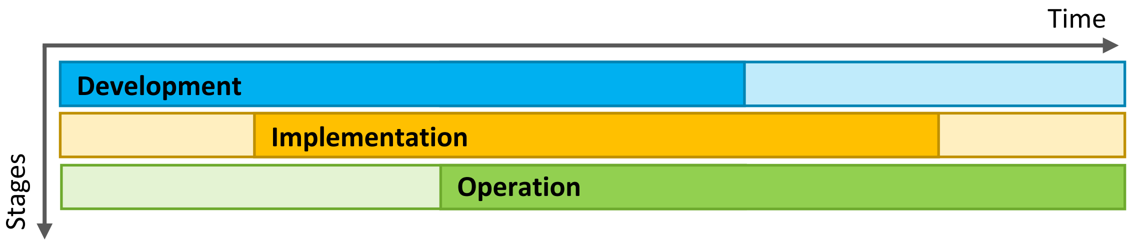


Figure 18 - Stages involved over time with the realisation of INTM approaches

For the actors these stages have an important implication. Because some actors are only active in some stages, some will interact with each other. To assess which actors are active in which stages the following table has been constructed.

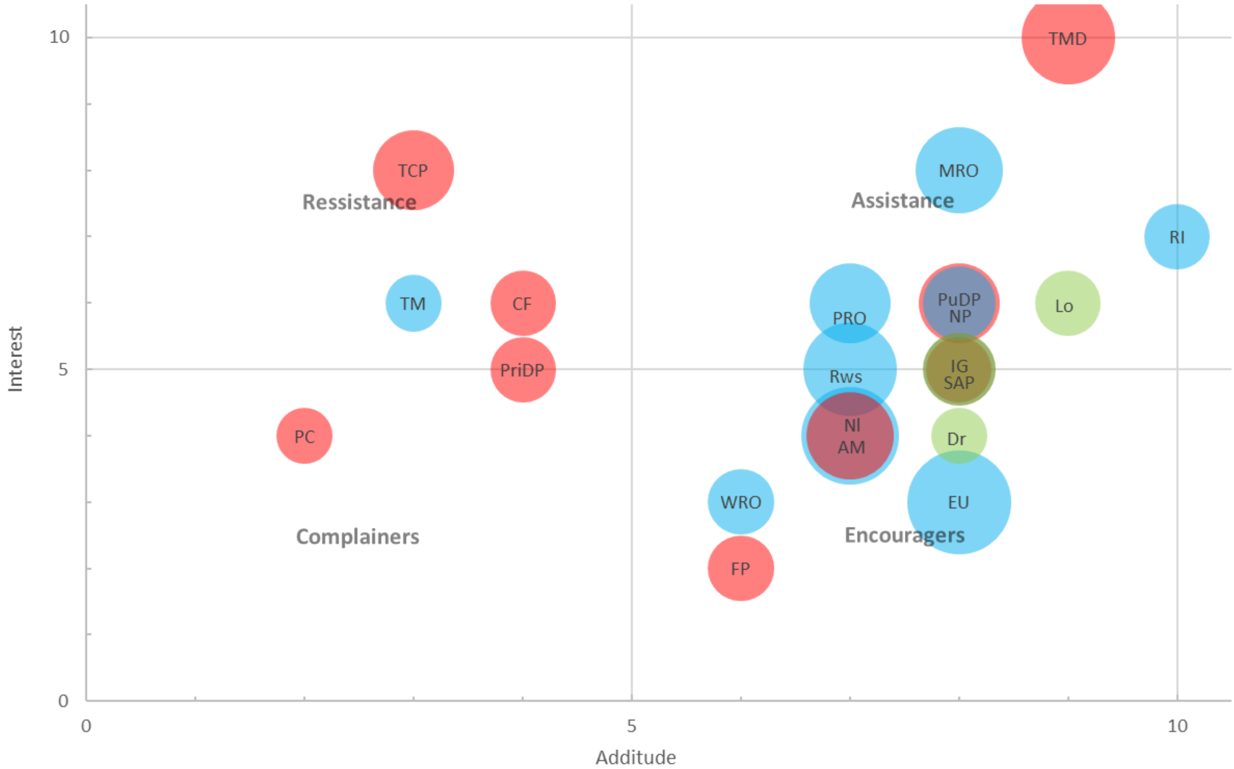
Table 6 – Actors involvement per stage

Actor (function)\Stage	Development	Implementation	Operation
European union			
Government of the Netherlands			
Rijkswaterstaat			
Province road authorities			
Municipality road authorities			
Water board road authorities			
Traffic manager			
Project contractor			
Traffic control providers			
Traffic management systems developers			
Consultancy firms			
Research institutions			
Navigation providers			
Automobile manufacturers			
Smartphone app developers			
Private data processor / (re)distributor			
Public data processor / (re)distributor			
Road users, traffic information users			
Locals			
Facilitating parties			
Interest parties			

This may affect the power of a party, the coalition building between parties, where conflicts of institutions might arise, how the government wants to include an actor in the process and how likely they are to achieve this. Additionally, the rounds model that decision-making takes place in rounds that can be nonsequential and the streams model shows that there may has to be a window of opportunity to invest in traffic management.

5.6.2 Players

In the decision-making some actor may have a more important role than others; some of them are players while others are for example fence sitters. The interest, perception and resources (to be described in next subsection) are used to assess the level of actor interest, power and to quantify their attitude (see Appendix B). Additionally, the interviewed actors (in Appendix D) were asked about their own interest, power and attitude regarding the realisation of OANM. They have a certain interest in the proposed change that is change the nature of their existence (interest 10), may not be relevant at all (interest 0) or somewhere in between. Furthermore, they may be an extreme proponent of the proposed change (attitude 10), they may be extremely opposed (attitude 0) or somewhere in between. Finally, each actor can a certain influence on the outcome that may vary from very influential (power 10) to not influential (power 0). On the basis of this actors are be classified (e.g. in a power interest grid as suggested by Eden & Ackermann (1998) in Appendix B). An unconventional presentation of a similar classification is shown in the image below. It is a classification into four groups: complainers, encouragers, resistance and assistance as well as presenting the previous found network decomposition (in colour) and actor power (shown in circle size).



Legend			
Abr.	Actor group (function)	Symbol	Meaning
EU	European Union		Power
Nl	government of the Netherlands		
Rws	Rijkswaterstaat		
PRO	Province Road Authorities		
MRO	Municipality Road Authorities		Public party
WRO	Water board road authorities		
TM	Traffic manager		
PC	Project contractor		
TCP	Traffic control providers		Private party
TMD	Traffic Management systems Developers		
CF	Consultancy firms		
RI	Research institutions		End user
NP	Navigation providers		
AM	Automobile manufacturers		
SAD	smartphone App Providers		
PriDP	Private data processor and/or (re)distributor		

PuDP	Public data processor and/or (re)distributor		Public/private party
Dr	Drivers		
Lo	Locals		
FP	Facilitating parties		
IG	Interest groups		

Figure 19 - Attitude, interest, power diagram

This image in decomposed into four colours. From this is concluded that the majority of actors and powerful actors are in favour of the proposed change. Herein, the attitude among private parties varies considerably while the attitude of end users and public parties seem to be in favour. Furthermore, the following actor groups may be considered to be players (high interest, high power) traffic management developers, municipal road authorities traffic control providers, navigation providers, provincial road authorities, Rijkswaterstaat and public data processor. The government of the Netherlands, the European Union and automobile manufacturers are expected to be context setters. In addition to this overview the actors' individual predicted behaviour without intervention (the strategy of this research) is presented in Table 22 of Appendix B and indicates why intervention is necessary an what can be expected without it.

The information presented in the previous figure will help to predict coalitions (Subsection 5.6.5) and can to assist in creation of actor dependant process strategies (Subsection 7.2.4).

5.6.3 Resources

The power of actors in the decision-making is affected by the resources they can contribute. In this, resources are "the practical means or instruments that actors have to realize their objectives" (Hermans, 2005). Thus this can be a range of means varying from the knowledge to develop traffic management approaches, the traffic data that serves as an input or the ability to protest and thereby hindering the prescribed future. The resources involved to realise or block INTM are scattered over a wide range of actors some of which are important, not easy to replace and not interchangeable (see Appendix B step 7). This means that a multitude of actors will need to work together in order to realise INTM. The actors in the following table are considered to be critical. Here parties are differentiated according to de Bruijn et al. (2010) on the basis of their power type and attitude. Parties with productive power have the means to make a positive contribution in the realisation of something (e.g. money). Blocking power means that parties only have the means to obstruct the realisation of something. Diffuse power means that the power position is uncertain, may change or that it is unclear whether an actor is willing to use their resources.

Table 7 - Type of power and attitude per actor

Actors with power	Production	Blocking	Diffuse
Proponents	Rijkswaterstaat, Province road authorities, Municipality road authorities, Traffic management systems developers, Navigation providers, Public data processor	Locals	Smartphone app providers
Opponents	Traffic control providers	Traffic manager	Private data processor
Fence sitters	European union,	Drivers	Facilitating parties

	Government of the Netherlands, Automobile manufacturers		

Whether these actors will use their resource/power or not depends on their interest and attitude. By categorising actors as dedicated vs. non-dedicated, critical vs. non-critical, similar vs. opposing interests, a general actor engagement strategy is created (see Appendix B). The result of this is shown in the table below.

Table 8 - General engagement strategy

Strategy	Actors
Involve	Rijkswaterstaat, province road authorities, municipality road authorities, traffic management developers, navigation providers, smartphone app providers, public data processor, locals
Engage	European Union, government of the Netherlands, automobile manufacturers, drivers, facilitating parties
Listen to	Traffic manager, traffic control providers, private data processor
Inform	Research institutions, interest groups
Monitor	Consultancy firms
Ignore	Water board road authorities, project contractor

Thus many actors should be involved or engaged. However, whether an actor wants to use its resources also depends on the development of individual issues (or on agreements with other actors). When no agreement is reached on the details an actor might withhold its resources. These individual issues can be resolved in series of interactions, called games. These will be discussed in the next subsection.

5.6.4 Games

Games between actors can originate from the technological problems (from Section 3.5), strategic problems and institutional problems (to be described in Section 6.2). In these games an actor strategically interacts with another actor in an effort to resolve the problem. If actors start to interact (possibly indirect) about this issue it can be seen as a game. This research will attempt to identify issues that are or could be games along with the actors involved. The following issues are found via induction and/or interviews:

Development

- Traffic management steering controlled versus independent: Both approaches have their advantages but may be incompatible.

Implementation

- Traffic control hardware versus software: Traffic control can be steered via primarily via hardware or via software. The first may be more robust and the latter more flexible to remote adjustments.
- Regional traffic data to in-car traffic information provider: Road authorities want their regional traffic information included in in-car traffic information but the traffic information provider has limited interest to do so.
- Traffic data ownership of traffic control to vehicle communication: It is unclear who will own the data from traffic control to vehicle communication.
- Automation: Traffic control optimisation will be done with real-time traffic control optimisation software rather than by consultant time by time. This is likely to harm the economic interests of the consultants and benefit the traffic management providers.

Operation

- Automation: Traffic control optimisation will be done with real-time traffic control optimisation software. This is likely to reduce the work that has to be done in a traffic management centre. This may result in job loss.
- Traffic control data exchange: This data is valuable to traffic information providers but road authorities might want something in return.
- Aggregated route advice to traffic management authorities: Knowing where drivers are going to enables more accurate predictions of future traffic distribution. This data is however owned by traffic information providers that may not want to sell this data.
- Route guidance: is the driver supplied with the individual shortest route or with a route that is in the general interest.
- Privacy: The data has more value when it is not aggregated. But this poses a risk for privacy.

Not every actor is directly involved in each issue. Moreover, sometimes an actor is affected by (the outcome of) the issue or has resources that can help to resolve the issue without being directly involved. The table below has been created through induction to illustrate this (where full colour marks a direct involvement and half colour an possible involvement) for the previous described problems. This is done on the basis of the limited knowledge of the researcher but may serve a basis to form a process.

Table 9 - Actor issue involvement matrix

Stage	Dev.	Implementation				Operation				
Actor / issue	TM controlled vs. independent	Traffic control approach	Regional traffic data	Traffic data ownership I2V	Automisation	Automisation	Traffic data exchange	Aggregated route advice	Route guidance conflicts	Privacy
European Union										
Government of the Netherlands										
Rijkswaterstaat										
Province road authorities										
Municipality road authorities										
Water board road authorities										
Traffic manager										
Project contractor										
Traffic control providers										
Traffic management developers										
Consultancy firms										
Research institutions										
Navigation providers										
Automobile manufacturers										
Smartphone app providers										
Private data processor										

Stage / Actor / issue	Dev.	Implementation				Operation				
	TM controlled vs. independent	Traffic control approach	Regional traffic data	Traffic data ownership I2V	Automisation	Automisation	Traffic data exchange	Aggregated route advice	Route guidance conflicts	Privacy
Public data processor										
Drivers										
Locals										
Facilitating parties										
Interest groups										

From this can be noted that all issues involve the road authorities, none involve the contractors and research institutions, drivers and locals are only involved indirectly.

Sometimes, these parties are not able to reach an agreement about the nature of this problem, how to solve this problem or are unaware of the problem (assuming that a technological unsolvable problem seldom occurs). However, this may hinder the realisation of something bigger (in this case INTM). Then this can be the start for the process based strategy (to be discussed in Section 7.2).

5.6.5 Coalitions

In coalitions, actors may work together to increase their power and realise their goal. Coalitions are "semi-permanent arrangements among actors pursuing separate but, by and large, convergent or compatible purposes and using their separate action resources in coordinated strategies" (Scharpf, 1997). Although, these may come and go while the process moves on, one may try to estimate the formation of coalitions to detect shifts in the power balance. These may be based on with whom has similar interests or issues and with whom one usually interacts (see actor cluster Section 5.3). On the basis of this argumentation and previous sections the following coalitions are predicted:

1) Public proponents (societal orientated): Government, road authorities, Public Data Processor, Research Institutions and possibly European Union
2) Private proponents (market orientated): Traffic Management systems Developers, Navigation Providers, Smartphone App Providers and possibly Automobile Manufacturers
3) Private resistance: Traffic Control Providers, Consultancy Firms, Project Contractor, Private Data Processor
4) Under informed end users (theoretical proponent but perception dependent): Drivers, Locals and Interest Groups

The clusters of proponents can be used to realise the prescribed future and the formation of clusters of (possible) resistance can possibly be hindered. Moreover in Section 7.2.

5.7 Conclusion

This chapter has analysed how the prescribed future will affect the involved actors and how they are likely to respond. To analyse this, the proposed change was decomposed into elements that were categorised in: mandatory changes for ITNM, mandatory changes for OANM and optional changes. The effect of the mandatory changes could then be compared to the interests of actors. Because the number of actors involved with system is so huge, all actors were grouped on their basis of their function, in twenty-one actor groups. After analysing the actor network, the actor groups were clustered on the basis of relations and cluster characteristics into: public organisations, private firms and end users. Hereafter, their interests and perceptions were analysed from a theoretical perspective (backed by a limited set of interviews). This showed that the majority of actors and the subsequent interest and power allocation are predicted to be in favour of the prescribed future. Herein, the attitude among private parties varies considerably while the attitude of end users and public parties are almost all in favour. However, the changes identified can be incomplete due to the uncertainty and the dynamic nature of the network can cause strategic interests to change. Furthermore, due to the interaction of actors and the provision of new information perceptions may change. This may cause strategic problems and uncertainties that can hinder the realisation of the prescribed future and will require constant monitoring and a management approach that can cope this.

For the realisation of INTM and OANM specifically the resources required are scattered among almost all actor groups where the majority of them has production power (the means to contribute in the realisation). All these producing actors (except for the contractors) seem to become engaged in at least one of the identified issues spread over multiple stages. Characteristic from this is that all issues involve the road authorities and research institutions, drivers and locals are only involved indirectly. Furthermore, not every actor is active in every stage, causing some actors not to interact and the end users are only included in the operational stage.

A way to strategically influence the decision-making regarding these issues is by forming coalitions. By analysing the interests, issues and networks a prediction has been made about which coalitions may form. Regarding this, a coalition of private resistance (traffic control providers, consultancy firms, project contractor, and private data processor) or a coalition of under informed end users (drivers, locals and interest groups) that are theoretical proponent but perception dependent, may hinder the proposed change. Furthermore, it is predicted that if the coalition of 'public proponents' do not act, the independent traffic control scenario (of previous chapter) is more likely.

The aforementioned strategic problems and uncertainties may be caused by and reduced with institutional reform, thus this will be explained and investigated in the next chapter. To analyse the institutional environment, it will propose the partial separation of the traffic management development and infrastructure institutions because these take place in separate clusters of actors as found in this chapter. Hereafter, the network characteristics, actor's involvement per stage, engagement strategy, actor issue involvement matrix and the identified possible coalitions will be used in the process based strategy presented in Chapter 7. It will use this strategy because the resources to realise the prescribed future are scattered among many actors and the decision-making takes place between many different actors. An additional reason is that it seems societal undesirable that the end users are likely not to be involved in the decision-making while they are affected by the system.

6 Institutional analysis and design proposition

The government holds a special position in shaping the direction for the benefit of society. It has unique resources at its disposal that include budget allocation, legislative power and democratic legitimization (E. H. Klijn & Koppenjan, 2000, p. 151). These resources may be used to achieve changes in the institutional characteristics of a policy network. Although, institutions usually refer to an organisation founded for a religious, educational, professional, or social purpose (Oxford University Press, 2016), the definition of institutions in this research is more far-reaching than this. Of this far-reaching definition, a wide variety of definitions exist in the literature (Hodgson, 2006; Koppenjan & Groenewegen, 2005; McGinnis, 2011a; Ostrom, 2005, 2007; Scharpf, 1997). In this research one of the narrower definitions is chosen that is relatively concise and specific regarding the subject: "A set of rules that regulate the interaction between parties involved in the functioning of a (technological) system" (Koppenjan & Groenewegen, 2005, p. 244). According to this definition institutions may affect the functioning of the system (investigated in Chapter 3) and the actors involved (investigated in chapter 5). This statement is substantiated by Wallis and North (1986) that have shown transaction costs can become substantial if the institutions are not well in place. March & Olsen (1989) described this with a illustrative metaphor; if institutions are not tuned in to each other they can prevent or hinder interaction and make the problem solving process something like building the Tower of Babel. Alternatively, if the technology changes the institutions may need to change as well. Regarding this, Finger et al. (2005) state that the coherence between institutions and technology is an important factor for the technical performance of infrastructures.

Thus, this chapter will investigate the institutions of the INTM system. Specifically, it will focus on the road-bound subsystem with a similar reasoning as presented in Section 3.4. Moreover, institutions are usually formed in an incremental process of "muddling through" decision-making, as described by Nobel prize winner Charles Lindblom (1959). However, at intentionally changing institutions in an effort to realise a desired outcome (institutional design), is also possible. Thus to reduce the previous found problems and uncertainties options for institutional design will also investigated. Hence, this chapter will answer the following question: '*How do institutions play a role in current problems and how can they contribute in resolving the problems?*'.

To answer this question this chapter will first propose an institutional framework in Section 6.1. Inductive reasoning applied on this framework will then lead to a set of theoretical problems in Section 6.2. To resolve these, institutional design may be conducted but certain limitations and concerns regarding this are present that will be discussed in Section 6.3. Hereafter, set of institutional reforms are proposed in Section 6.4 that are discussed from a theoretical point of view in Section 6.5. Because the reforms discussed at that at that point are rather abstract and theoretical they will be further specified and evaluated with interviews in Section 6.6.

6.1 Institutional framework of road-bound network traffic management

This section will present an institutional framework for the evaluation of NTM because "without the capacity to undertake systematic, comparative institutional assessments, recommendations of reform may be based on naive ideas about which kinds of institutions are 'good' or 'bad' and not on an analysis of performance" (Ostrom & Ostrom, 2004). Frameworks organise diagnostic and prescriptive analysis by providing a general set of elements and general relationships between them, that can be used to analyse all types of institutional arrangements and a meta-theoretical language that can be used to compare theories (Ostrom, 2011, p. 8). Multiple institutional frameworks have been found in the scientific literature and are described and investigated in Appendix G. These are the four-layer framework of Williamson (1998), the four-layer framework of Koppenjan & Groenewegen (2005) and the institutional analysis, development framework (IAD) by Ostrom (2005). The framework of Künneke (2008) has also provided some valuable insights but has not been added to the review due to time research constraints. In order to describe ITNM this research proposes a new framework on the basis of these frameworks. The reasoning behind the creation of a new framework and the changes it has in comparison to the existing framework will be explained in the upcoming text.

Separation of traffic management development and institutions

Koppenjan & Groenewegen (2005) and Groenewegen (2005) have mentioned the interaction between technology and institutions. However, they were not explicit in how this interaction works. To make this explicit, the assumption is made that traffic management is the considered technology development. Hereafter, it is assumed that the development done by a separate entity other than the institutional entity. Previous chapter substantiates this separation with the found network clusters. The ratio behind this separation is that institutions and technologies form within clusters of actors. Regarding this, Klijn & Koppenjan (2006) argue that networks (in this research names network clusters) can be regarded as institutions (usually more informal) because they are patterns of social relationships between mutually dependent actors that have the same system of rules.

To capture this interaction between the two, the framework of Williamson (1998) is expanded with a technology development branch on the basis the four layer model of socio-technological systems of Groenewegen (2005) and Künneke (2008). This branch includes the following stages: technology, concept generation, product/service creation and production and sales. These are specific interpretations of the notions of technological paradigm, technological trajectories, routines, operation and management described by Künneke (2008). Each of these stages is aligned with an institutional stage forming tiers, while acknowledging that the stages in a tier may operate at a different pace. By creating a separate branch one is able to identify how and on what stage the technology development impacts institutions. For example, developments with limited impact (e.g. software updates) may be directly applied on operational stage, while technological innovations with high impact may cause changes in relationships, roles, power etc. that might require a change in the institutional environment.

Contextual stages

Relatively little theories focus on changing the embeddedness tier. Probably this is because it long time scale and its relative robustness to change. However, this tier remains vital as input for the other stages. Therefore, they will be seen as contextual tier (marked in light blue in the following figure) which includes layers that provide input or feedback but are assumed not to be directly changeable in relation to this research.

System feedback

While acknowledging the possible direct interaction that possibly skips stages (as suggested by Koppenjan & Groenewegen, 2005) the framework of Williamson (1998) is used as the basis, because it is predicted that direct interaction that skips stages occurs only limited in the current realisation of traffic management. However, in reality all actors involved in the realisation process most likely use the road infrastructure on a daily basis or know someone that does. So they will have some experience that will influence (i.e. provide feedback) the formation of institutions and technology. Therefore, this research suggests the addition of a system stage as contextual layer that provides feedback to all stages in addition to the feedback that Williamson (1998) proposed. Although, it can be influenced it is added as a contextual layer because many other factors may influence in stage simultaneously.

Naming of institutional stages

Finally, the names of stages are adjusted to terms used in previous chapters.

Institutional framework of road-bound network traffic management

The previous changes resulted in the following framework of road-bound network traffic management (see figure below). It is specifically for the road-bound subsystem because here the clustering between actors exists, which seems to be more integrated for the in-car subsystem. In this framework, the blocks will be called stages, a collection of stages in a vertical way a branch and a collection of stages in a horizontal way a tier. Similar to the framework of Williamson (1998) and Koppenjan & Groenewegen (2005) each tier operates at its own pace. This pace is slowest at the top and fastest at the bottom.

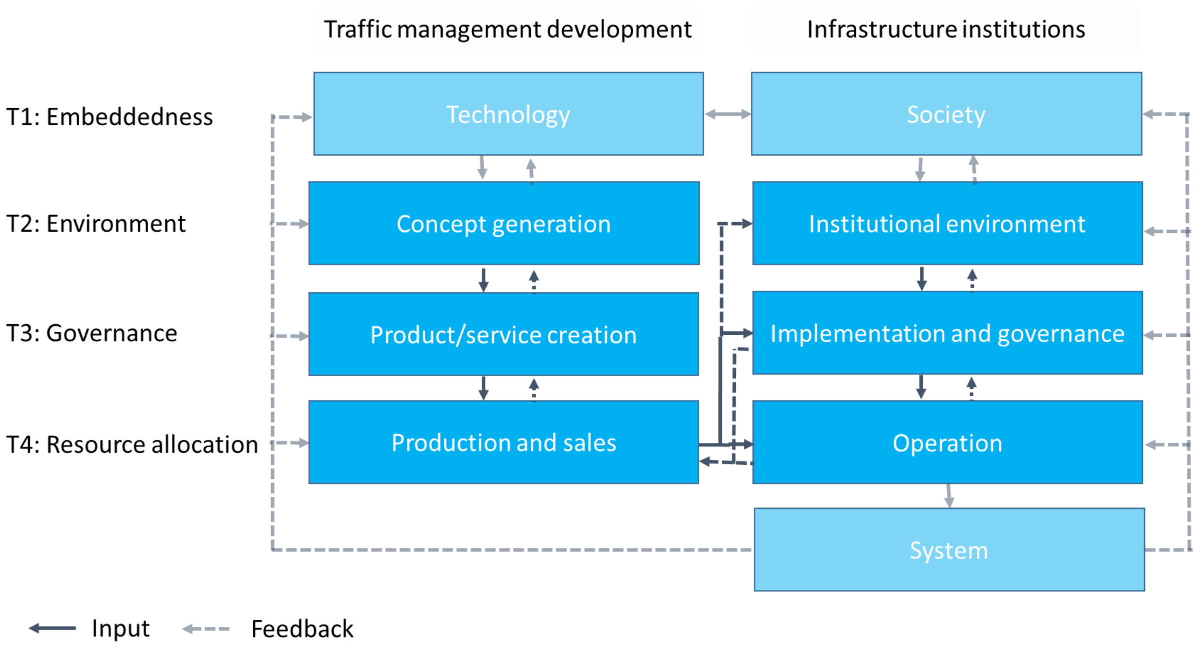


Figure 20 - Institutional framework of road-bound network traffic management

The proposed stages in this framework are:

- **Technology:** is a broad spectrum of technological knowledge upon which new concepts can be formed
- **Concept generation:** this stage uses identifies a technological possibility to address a certain problem in the system.
- **Product/service creation:** This stage develops the previous concept into one or more products or services.
- **Production and sales:** This stage produces, sells and personalises the previous created products or services.
- **Society:** This stage consists of norms, values and culture.
- **Institutional environment:** This stage sets the more formal boundary conditions to prevent undesirable societal outcomes that would otherwise not be resolved. To do so, assessments of the impact of new developments can be made or feedback of the governance stage or the system can be used.
- **Implementation and governance:** This stage involves the implementation and governance of an approach (for a specific location or region). With contracts a certain approach can be acquired and its operation can be influenced.

- **Operation:** This stage involves preserving the functioning of and proving service for the implemented approach with the allocation of resources. This stage presents the benefits as a result of the efforts made in previous stages.

Finally, some remarks are made regarding the previous presented framework:

- The levels of institution and technological development can partly be seen in the differentiation of actors in the Netherlands; within the government and between companies (i.e. institutional environment is usually done by the (supra)national government, implementation and governance by the road authority and the operation by the traffic manager). Although many exceptions exist.
- Up to now, product and service creation has been presented as one. However, there is a sharp differentiation between them. It varies on right of ownership of the product. Furubotn and Richter (1991, p. 6) state that the right of ownership consists of the right to use an asset, the right to appropriate the returns from an asset, and the right to change its form, substance, or location. When it is a service, the ownership is not transferred and the operation is usually done by the selling company who is often rewarded on its achieved result.
- Some of the blocks presented do not include all tasks preformed at that stage, but only the to INTM directly related tasks (e.g. the production and sales could be adapted to include research or marketing but then its interaction with the other tier would be incorrect).

6.2 Institutional problems

Inductive reasoning has been applied on the framework which was created in the previous section (Figure 20). From this some insights are gained that describe institutional problems that theoretically may occur. The following institutional problems were found:

Disalignment of supply and demand

The development of traffic management is separated of its application. Now governments acquire a product that is usually developed by private party. Assuming this is the case, then there interaction between the two, causing a private parties to make an estimate of the demands and vice versa. Here, there seem to be two strategies to acquire traffic management. The first strategy is market push, where the private (or private-public) traffic management development is followed by an implementation request whereafter the operation is possible. The second strategy is market pull where one may focus on operation and the required performance. From this one may order (the development of) the demanded approach. There is a risk involved with market push because firms might develop something that is not bought. Alternatively, market pull may lead to specific non-uniform demands that are costly and not easy to apply elsewhere. So a combination of the strategies seems to be preferable but this requires interaction that seems limited due to transaction costs. If the production, implementation and operation would be done by the same party the transaction costs would be limited there.

Time dynamic conflicts

The proposed framework may indicate why tension exists between development firms and governmental institutions. If there is a problem in the system, the detection of it may occur simultaneous for both parties. Hereafter the development firms may start developing but the infrastructure institutions cannot yet solve the problem. When the product is developed, the development firms want to apply it but then need to wait for the implementation to be done (if necessary). Meanwhile the production is at a lower tier than the implementation, thus it will have faster pace (although the speeds of the two branches do not have to be equal). This may cause (the impression) that an old system was implemented/embedded by the time it is realised. Furthermore, development firms often have high development costs that may span a long period while they are dependent on implementation to regain their investments. This emphasises a difficult environment for innovation.

Technology change and slow institutional environment

When the technology changes their (societal) effects are often unknown to actors. The institutional environment stage may try to predict the effect, receive feedback from the governance level or might notice the effects in the system (this is depicted in the figure with a feedback link). The first is rather difficult and requires lots of expertise, the second usually can originate form a trend in multiple contracts in the governance tier and the third from direct observation (but then it is usually too late). This uncertainty can cause the institutional environment to lag behind (this seems to be the case with e.g. automated cars, Airbnb etc.). This environment supplies rules to enable actors to depart from minimal institutional agreements in their interaction. This reduces transaction costs and simplifies collaboration (Hindmoor, 1998; Scharpf, 1997). A lack of this, can be circumvented with contracts in the governance tier. However, it can cause governments to struggle to incorporate these uncertainties in their agreements (transaction costs), were a uniform solution is less likely to emerge. Furthermore, the amount of feedback (that may lead to more formal institutions) can depend on the amount of actors involved and the frequency of the occurring event (actors usually form a certain habit over time). In traffic management there are many regional authorities. These authorities have relatively little experience (in comparison with larger authorities) which limits habits formation and enables thus flexible arrangements. This may explain why the Netherlands is a good testing country. However, these flexible arrangements may lead to high transaction costs (to deal with the uncertainty) and customized products. This in term may hinder the creation uniform solutions and thus the creation of institutional environment.

An example of a slow institutional environment would be that traffic management has developed NTM products that can span multiple road authorities. These are however fixed in their institutional environment that may change gradually. As long as this has not changed the traffic management approach may not be realised (stagnation) or may function less. This seems to be related to the concept of critical alignment of Künneke (2008)

Selective system perception

Every actor may participate in and observe the system. This can lead to personal and local observations that may influence their perception and the creation of institutions that vary geographically. E.g. a certain situation that is dangerous or a certain area that must be kept traffic jam free in the morning because a government official passes that area on his way to work.

The previous described problems are rather abstract and theoretical. However, they have led to insights for this research to come up with institutional directions in Section 6.4. Specifically, the first to 'Public vs private operation of traffic management' and the third to 'central vs decentral organisation of traffic management'.

6.3 Limitations and concerns of intentional institutional reform

The previous institutional problems may be reduced with institutional reform. However, reshaping institutions has a number of problems and limitations.

One of the problems is that while institutions may provide stability and certainty for actors to interact, they may 'codify' previous (unequal) power relations and hinder reforms (March & Olsen, 1989; Ostrom, 1990). Furthermore, companies active in the field of interest can give vital input for reform. However, there is a strong incentive to try to influence the design and redesign of institutions in order to create distributive advantages (Knight, 1992; Moe, 1990). This can also been seen in practice currently with the determination of the traffic control standards of the future (iVRI project of Beter Benutten), where parties try to gain a strategic advantage by trying to change the standard to gain a strategic advantage.

One of the limitation is that institutional design assumes that the government has the power to influence the rules, norms etc. However, this is not always the case because some actors that have a negative perception towards the proposed measures may try to block it (e.g. Bruijn & Heuvelhof (2008, p. 18) describe how closedness may limit the success of interventions) or may decide to no longer participate in the innovation process. Especially in a system of many interdependencies (network rather than hierarchy) this may pose a risk because the government may lose or oppose a vital actor by trying to impose institutional measures. This may block or hinder innovation and should therefore be used with caution. Therefore such institutional measures will not be proposed.

These concerns show why it is difficult to change institutions. Koppenjan & Groenewegen (2005) stress the need for correct and extensive argumentation and a widely supported solution that obviates unequal power relations. However, designs for reshaping institutions are by definition imperfect because "the complex and multi-level character of the institutional design game implies that both the way design processes evolve and their impacts are highly uncertain" (E.-H. Klijn & Koppenjan, 2006). During the process of reshaping the institutions, strategic behaviour of parties to institutional design strategies may become visible. These may result in unexpected and undesirable outcomes that may require further adaptation and thus for new decisions on institutional design. But according to Klijn & Koppenjan (2006) these adaptations may have shortcomings, which have to be addressed resulting in a process of institutional change. As a result, institutional design should be considered as direction for institutional change than as a definitive design. Finally, formal institutional design takes time to implement. So should only be pursued if less formal institutions do not or will not function as desired. So this research will propose directions that are mainly focused on the resources and organisation of the government.

6.4 Shaping institutional direction

This section will try to identify institutional directions that may resolve the problems, given the previous institutional design limitations. The list of proposed institutional directions can be grouped into three categories according to Klijn & Koppenjan (E.-H. Klijn & Koppenjan, 2006; Koppenjan & Klijn, 2004) namely strategies aimed at altering the network composition, network outcomes and network interactions. For each of these categories institutional directions have been devised that could resolve the problems of the system (technological, institutional and strategic). This has been composed with analytical reasoning based on the abstract strategies formulated by Klijn & Koppenjan (E.-H. Klijn & Koppenjan, 2006; Koppenjan & Klijn, 2004) because experts on institutional design to assist in this process were not available for this research. This led to the following institutional directions:

- Network composition
    - Central vs decentral organisation of traffic management implementation and governance
    - Public vs private operation of traffic management
- Network outcomes
    - Set performance goals and their measurement
- Network interactions
    - Set interoperability requirements
    - Facilitate timely data exchange

Eventually, this list is by no means complete, so this research may be repeated afterwards to include additional measures.

6.5 Evaluating institutional directions

Previous section has proposed an institutional directions. This section will evaluate these directions. that are ought to change the positions of actors in the network in order to reduce the hinder the realisation of (network) traffic management approaches. These are mere directions because "in view of the complexity and multi-actor nature of technologically complex systems, a design cannot be a 'blueprint' created through an intellectual process by a designer behind a desk. In as far as systems are created in such a manner, they are often adapted (beyond recognition) in the processes by which they are decided upon and implemented." (Koppenjan & Groenewegen, 2005).

6.5.1 Public versus private operation of traffic management

There exist proponents of privatisation in the literature regarding infrastructure (called new public management) and in practice regarding traffic management (e.g. Ottenhof, 2015). They propose separation of policy making and execution. For NTM this means, to grant a concession of the operation to private party that also (often) develops its own traffic management approaches. At the end or during the concession the performance is evaluated and the party is potentially reward on functional criteria. In the latter, private parties will have the incentive to improve the system and to develop or invest into new traffic management approaches. The idea behind this is that the hand-on experience of the development is beneficial with the selection of proper traffic management product and that operating the product themselves may provide for more direct feedback to the development.

However there are concerns regarding this direction. Koppenjan & Klijn (2004, p. 112) state that 'these types of steering are useful for situations in which objectives and products are clearly defined and monitoring can be arranged properly'. However, objectively measuring performance continuously is a requirement which still poses a challenge (see Subsection 6.5.4). Furthermore, more private involvement likely reduces governmental involvement which is predicted to result in the independent scenario that hinders OANM (see Subsection 4.4.2). Aside from this, privatisation may potentially interfere with protecting public interest (e.g. guarantee universal service obligation in case of bankruptcy and prevent infrastructure lock-ins and maintain availability during transition after concession period) and give rise to strategic behaviour (e.g. interaction between traffic management zones). Therefore, this direction is not further investigated in this research.

6.5.2 Set interoperability requirements

To create interoperability that is required for communication between regions, traffic management approaches, hardware etcetera standards may be determined. However, this is vital for the market position of involved companies thus the strategic interests are high. Determining standards, is assumed to require in-depth knowledge. Since the government usually lacks hands-on experience in the development, standards should be collectively decided upon in a process whenever possible. Moreover, an interview respondent (#4 in Appendix D) has stated that there has been made quite some progress on this field. Seen the strategic interests involved and the progress made, this direction is not further investigated in this research.

6.5.3 Stimulation of timely data exchange

Currently both traffic data (vehicle counts and FCD) as traffic control data is most often not timely and efficiently shared. Road bound traffic data (vehicle counts) is scattered amongst many road authorities or even not collected and stored at all. Although, quite recently the National Data Warehouse (NDW) was created, a lot of information is not shared due to strategic interests or because of limited incentive (not every road authority stands to gain equally as discussed in the background) or budget to do so.

Private traffic data (mainly FCD) is sold (see market for traffic data discussion at the end of Subsection 2.3.1) but usually only for a high price.

Sharing is beneficial because it is not only important to adjust traffic control to current traffic conditions but may be used to determine traffic management performance (see Subsection 6.5.4), to inform drivers and may facilitate in the development of new traffic management related product and services. Furthermore, the gathering costs may be shared among many parties (economy of scales), the same traffic data may be used to determine traffic in multiple zones and FCD (or similar sources) data are not geographically confined. Finally, when traffic data is shared it can cover a larger area that increases its value for parties that operate on a larger geographical scale, because adapting (inter)national products for the data of a small region is costly and has little impact. This does not mean that it directly becomes of real value but it may allow for the exchange of emergency data for example. This can also explain why road authorities fail to cooperate with large traffic information providers in the facilitation of local traffic information (e.g. road works) and start developing their own local in-car traffic information service

6.5.4 Set performance goals and their measurement

Currently, there is a large variance among road authorities in the factors used in their performance goals and in the way they are measured and interpreted (described in Section 3.3). This makes comparison of performance (over time, between regions and between products) difficult and may result in different types of control optimisation that may counteract each other (e.g. sources of traffic information that contradict) and impact driver experience when going from the one zone to the other (determining the extent of this is left for further research). However, drivers expect a certain consistency of the road infrastructure and a lack of consistency could affect traffic safety according to Wegman (2005). Furthermore, every road authority has to go through the effort of defining its own performance goals and a unity in performance goals may reduce the uncertainty in the development because then the demand is clear. Finally, a set of uniform performance goal may allow for a type of benchmarking to be conducted. This may increase incentive for road authorities to perform better, enable them to consult the better performing road authorities for advice and it may potentially be used to evaluate a private traffic manager or a traffic management approach.

The problems with performance goals and their measurements were described in Section 3.3. These have a technological but also an institutional side. The technological challenge, i.e. how to measure (most of) them uniformly, is likely to be (partly) solved in the future with developments as SimSmartMobility (TNO, 2016). However, institutionally one might want to determine the factors that should be measured, standardise how to measure them and possibly to supply road authorities with preferred values, scales and weights for the factors.

6.5.5 Central versus decentral organisation

Currently, (network) traffic management is organised quite similar to or together with the planning of physical road infrastructure as it was done last decades. This concerns a decentral approach were road authorities have lots of responsibility. This decentral approach originates from the reasoning that a local road authorities know local traffic problems better or as a result of muddling through. However, (network) traffic management is also quite different than the other task of a road authority. First, the costs, life expectancy and (positive/negative) impact to its surrounding of the physical infrastructure is a lot greater than with traffic management. Therefore, the physical infrastructure requires more careful planning, consultation of local parties and local financing is a more logical choice since local parties will experience the effect the most (in contrast to network traffic management). Secondly, it has well defined standards and interoperability is less of an issue, which is not the case for (network) traffic management. However, this decentral organisation has negative implications for NTM that will be discussed in this subsection.

As the road infrastructure is used more intensively (to acquire better return on investment), it requires more NTM that exceeds the geographical boundaries of road authorities. In order to do this efficiently, the traffic control that drivers encounter during their route options (that may cross numerous multiple of the current traffic management zones), need to be optimised together to give maximal influence. For this, multiple zones must interact. This means that a more central organisation or closely collaborating road authorities is required to implement (and operate) such an approach. If not, then the strategies, input a techniques of neighbouring zones might not be compatible to form a connected traffic management zone with a subsequent loss of performance as a result.

The gathering of traffic data from the zones of numerous road authorities is difficult to organise. Its sharing requires investment that only contributes to neighbouring road authorities (i.e. they gain the traffic data that the region itself already had). A more central organisation could increase the sharing of data and allow for the advantages described in Subsection 6.5.3.

Less governmental parties because of centralisation could bundle the of expertise and experience of road authorities. Furthermore, it may influence the strategic interests of private parties. Because with less parties, companies will probably be more focus on long term relationship building because they are more dependent on individual parties.

Finally, this research states that less parties involved with the implementation of traffic management (to be called traffic management authorities) could improve the formation of standards (feedback governance stage to institutional environment stage). With a reduction of traffic management authorities, they are responsible for a larger area so are likely to be involved in more projects. Probably this will involve similar approaches and agreements because of their experience (unless it was negative) and because of the benefits of having a single system. Then when the traffic management authorities with firms together have to decide the standard, the variance between the already chosen approaches is likely to be lower and a choice more easily made.

Thus NTM has economies of scales, requires interoperability but has limited standardisation and its effects and traffic data have implications beyond their zones. Furthermore, standards may arise quicker when less parties are involved. This advocates for a more central organisation of traffic management. This conclusion is also in line with other researches: in general with a report by Raad voor Verkeer en Waterstaat (2007), a case study of ITS policy in Japan by Ministerie van Verkeer en Waterstaat (2007a). However, centralisation goes against current governance trend (see Subsection 4.1.1) and there are nuances to be made to the statement of more central organisation. Besides the fact that centralisation could raise opposition of actors, it could limit ad hoc decisions, reduce attention to local fine tuning, raise the chance of global lock-in, cause for bureaucracy and there remain interdependencies with other decentralised activities (e.g. strategic development planning and infrastructure management) that may conflict or cause transaction costs. Second, there may be other ways to improve the problems stated above (e.g. centrally measure and publish results of different TM approaches so that certain approaches can be copied to other areas). Third, the more central organisations still knows many gradations and types of applications.

This section has theoretically evaluated five institutional directions and will analyse three of them in the next section.

6.6 Institutional direction scenario's

The remaining created and evaluated institutional directions up to now are rather theoretical ad abstract. To further specify the institutional directions and test their practical endurance they are presented as scenarios in interviews to various actors (results presented in Appendix D).

To do so, the institutional directions are introduced as an dilemma showing the pros and cons and decomposed (by induction) into several dimensions, to stimulate interview respondents to voice their opinion. These are constructed with simple linear scales with the according values on the axel such that it is easy to interpret. The values per dimension are constructed to show the extreme and possible middle values. Hereafter, interview respondents are asked to point out 1) what they think the current situation is; 2) What their preferred future situation is; 3) and what the expected future situation is. The first is a baseline to possibly assess whether the dimensions and values are clear or to establish that there is uncertainty in the current situation. The second could be used as a sort of normative policy scenario, where they can express their ideal situation. This is however not free of strategic interest (as described in Section 6.3). The third is a more realistic scenario and could possibly account for the strategic interest and/or could account for the amount of influence they think their (assuming similar opinion within one group) or other actor groups has on the creation of institutions. Thus it is difficult to draw a direct conclusion form the quantitative statements alone. Therefore, actors will be asked to provide a qualitative reasoning with their quantitative answer.

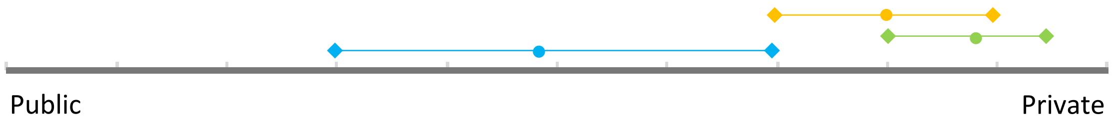
The following sections will present the scenarios of the three remaining institutional directions. Each direction is decomposed in the previous mentioned dimensions. Each dimension is simultaneously presented (in the figure) with the score of the interview respondents per dimension. At the end of each institutional directions (subsection) the results are discussed.

6.6.1 Stimulation of timely data exchange

Traffic data (road bound or FCD) remains scattered amongst many actors or even not collected and stored at all. This offers a commercial interest for various private parties but can also hinder the development and operation of societal beneficial products and services. To allow for the timely data exchange, the exchange may be centralised (e.g. NDW), but technically this is not a requirement. To review this institutional direction four dimensions have been devised.

Traffic data source

Currently the public authorities have road-bound sensors that can be used to measure intensity on individual location. These sensors often do not (yet) transmit their data to a central accessible database. Alternatively, private firms have FCD that measures only a percentage of the intensity but that can be used to determine speed relatively accurate. Thus this dimension describes the mixture of traffic data as input for traffic management, ranging from public to private.

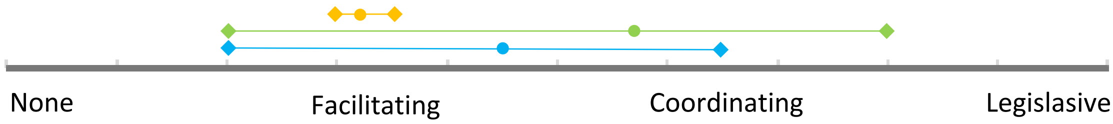


Legend respondents quantitative answer							
●	Average	◆—◆	Range current	◆—◆	Range preferred	◆—◆	Range expected

Figure 21 - Traffic data source scenario

Data gathering role

Offering traffic data could assist in determining traffic conditions in the neighbouring traffic zones, assist in the development of a range of new products and services, be used for research. Although the gathering of data will cost money, collecting data centrally will offer scales of economy. Alternatively, it could damage the business model of data gatherers (e.g. traffic information providers). Thus, this dimension describes the data gathering role of the national government (e.g. NDW). It varies from no role to a role that is forces parties to share data with legislation. In between the gathering of data can be facilitated (passive) or coordinated by actively involving parties.

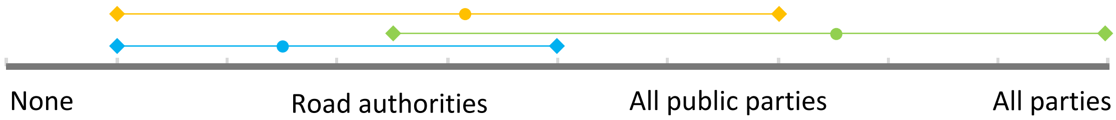


Legend respondents quantitative answer							
●	Average	◆—◆	Range current	◆—◆	Range preferred	◆—◆	Range expected

Figure 22 - Data gathering role scenario

Data sharing

This dimension describes to whom should the previous collected traffic data be dispatched. It varies from no one to all parties with a selection of public parties in between.

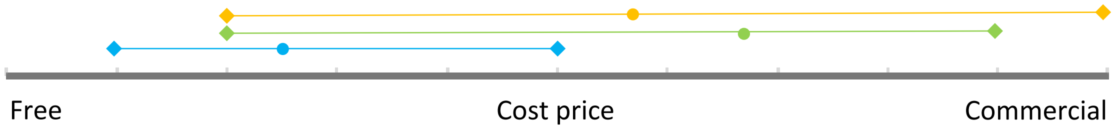


Legend respondents quantitative answer							
●	Average	◆—◆	Range current	◆—◆	Range preferred	◆—◆	Range expected

Figure 23 - Data sharing scenario

Sharing fee

This dimension describes at what price the previous collected traffic data be dispatched. It varies from free to a commercial price with a cost price in between.



Legend respondents quantitative answer							
●	Average	◆—◆	Range current	◆—◆	Range preferred	◆—◆	Range expected

Figure 24 - Sharing fee scenario

Discussion of interview results

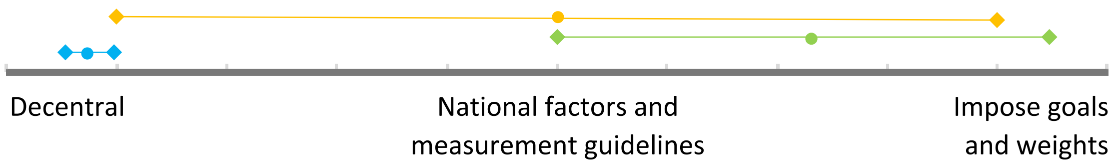
This dimension shows a rather scattered quantitative preferred outcome in the interviews (in the current, ideal and expected situation). The only respondents seem to agree on is that the future will utilise more private traffic data and that they expect a facilitating government regarding traffic data for the future. Further questioning lead to the conclusion that this had two causes. First, there are strong strategic interest involved in this dimension because it affects the profitability of some actors. More specific, traffic information providers and data distributors see non-commercial traffic data as a threat, whereas traffic management developers see it as opportunity as indicated by the qualitative responses that ranged from *"If data of high quality is gathered and offered to the public, it will empower companies (especially small ones) to develop a wide range of traffic services/products"* to *"Data is the currency of the future. If a government intervenes in this process they disrupt the market"*. Second, some respondents stated that there was a sharp difference between the governmental role regarding public and private traffic data. Open source traffic data of road-bound infrastructure seemed to receive less resistance than open source FCD.

6.6.2 Performance goals and their measurement

Performance goals and their measurement could help to compare products and providers and uniformalise the demand for traffic management products. It could therefore assist in a competitive market. Furthermore, it could increase public accountability and provide for incentives. However, it limits decentral freedom and the measuring of goals will cost money. Furthermore, translating quality into key performance indicators allows for performance related pay but might this might also induce perverse incentives. To review this institutional direction two dimensions have been devised.

Performance goals

If performance goals are not the same in every region, it will make comparing difficult, it might result in non-uniform traffic management products and (unwanted) changes in traffic experience between traffic management zones. Thus, this dimension describes the extent to which the performance goals should be uniformalised. It varies from decentral (local autonomy) to imposed goals and weights (national autonomy) with guidelines in between.

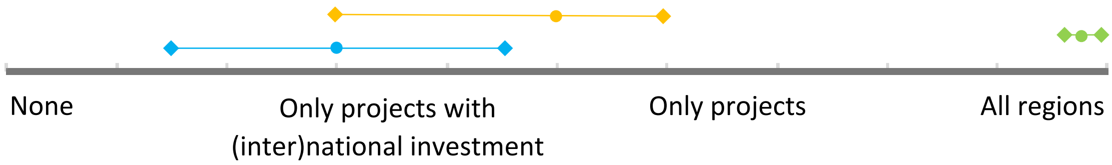


Legend respondents quantitative answer							
●	Average	◆—◆	Range current	◆—◆	Range preferred	◆—◆	Range expected

Figure 25 - Performance goals scenario

Active and publish measuring (benchmarking)

Measuring of goals will cost money but allows for the comparison of traffic management product and providers and/or stimulates public accountability. Thus this dimension describes the amount of benchmarking that has to be conducted. It varies from none to all regions (the whole of the Netherlands) with a selection of traffic management project in between.



Legend respondents quantitative answer							
●	Average	◆—◆	Range current	◆—◆	Range preferred	◆—◆	Range expected

Figure 26 - Benchmarking scenario

Discussion of interview results

In the interviews actors seem to agree that relatively little performance goals and benchmarking is used for operational traffic management and that creating a list of factors and benchmarking regions would improve the system. However, some state that road authorities should have to be able to determine their of weights between the factors used for local policies, warn that uniform factors may limit local exceptions (e.g. in situations where the normal factors lead to dangerous situations) and state that it may lead to create tunnel vision (i.e. other non-measured quality factors are neglected). Furthermore, the perception whether the current technology is able to measure actual traffic management performance varies among respondents.

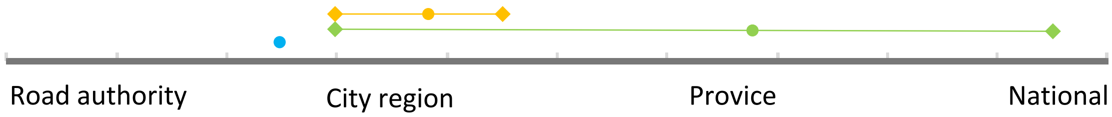
6.6.3 Central coordination of traffic management

The organisation of the implementation and operation of traffic management is dispersed on the basis of geography and infrastructure function. The technical optimal network traffic management zone may be rather different and it may change in size due to the computational possibilities and technical complexity of the chosen approach. Furthermore, zones will need traffic data and are affected by neighbouring zones. Incompatibilities can potentially be overcome through collaboration. These collaborations may also be beneficial for implementation by creating scales of economies, bundling expertise and more uniformalised traffic management zones. However, they may conflict with local policy, may prevent local detailing. The amount of actors involved and the variety in demand may make it difficult for companies to create uniformalised products and expect the future demand. To review this institutional direction four dimensions have been devised.

Figure 27 - Example of traffic management authority decomposition

Size traffic management authority

Currently there exist a patchwork of road authorities (illustrated in the figure above in orange), where some of them have formed collaborations with the surrounding zones, forming a traffic management authority (illustrated in the figure above in blue). This dimension describes the size of a traffic management authority and its values represent (former) existing governmental structures.



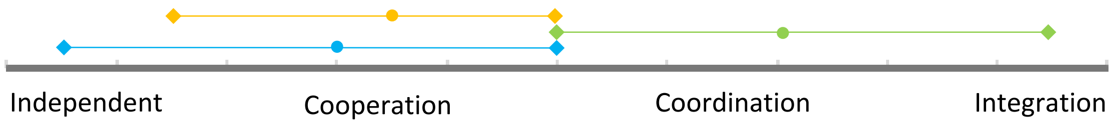
Legend respondents quantitative answer							
●	Average	◆—◆	Range current	◆—◆	Range preferred	◆—◆	Range expected

Figure 28 - Traffic management authority size scenario

Interdependence between road authorities within traffic management authorities

This dimension describes how road authorities work together within a traffic management zone (illustrated by multiple orange entities within a blue zone). On the basis of Raad voor Verkeer en Waterstaat (2007) three forms of collaboration have been distinguished (supplemented with independent as an extreme), these are:

- Cooperation: agreements of voluntary and informal basis without any juridical obligation or forming an juridical entity
- Coordination: agreements where parts of the autonomy is transferred to the traffic management authority
- Integration: the autonomy of the road authorities regarding traffic management is transferred to the new traffic management authority.

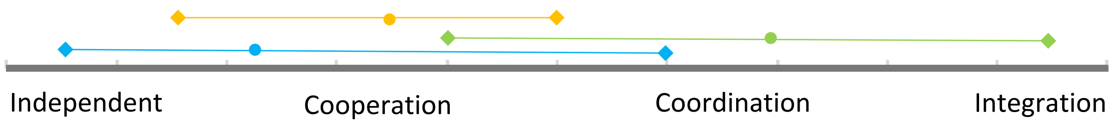


Legend respondents quantitative answer							
●	Average	◆—◆	Range current	◆—◆	Range preferred	◆—◆	Range expected

Figure 29 - Interdependence between road authorities in a traffic management authority scenario

Interdependence between traffic management authority regions

This dimension describes how traffic management authorities (illustrated by multiple blue entities) work together. Its values are the same as in previous dimension.

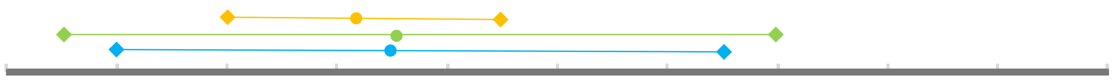


Legend respondents quantitative answer							
●	Average	◆—◆	Range current	◆—◆	Range preferred	◆—◆	Range expected

Figure 30 - Interdependence between traffic management authority regions scenario

Central supervision

Aside for the traffic management authorities there may be a central authority that assist or supervises the traffic management authorities (e.g. Beter Benutten). This dimension describes the role that the national government should fulfil and may vary from non-existent to enforcing with facilitating (passive) and coordinated (active) in between.



Legend respondents quantitative answer							
●	Average	◆—◆	Range current	◆—◆	Range preferred	◆—◆	Range expected

Figure 31 - Central supervision scenario

Discussion of interview results

In the interviews actors seem to agree that the ideal size for a traffic management zone should be bigger than it is now (ranging from city region to national). However, their ideal size varies from a city region to national. Furthermore, most respondents would like to see more cooperation between road authorities and traffic management authorities (consisting of multiple road authorities), but do not expect this to change much. Finally, they do not seem to agree whether or not additional national supervision is required.

But maybe more importantly the current voluntary collaboration seems to result in non-committal behaviour of same road authorities that 'wait and see' what the other do. Since most road authorities stands to gain, maybe all if you take into account pollution etc., this seems under desirable. It seems to result in 'a game of chicken' where the one stands gain the most if he can postpone his investment long enough to finally be invited to participate in a neighbouring authorities system. This is strengthened by the fact that road authorities sometimes have old traffic control systems that are incompatible and thus already require an initial investment. This voluntary collaboration also leads to a patchwork of collaborating regions and incompatible systems.

6.7 Conclusion

Previous chapters have described strategic and technological problems and opportunities. These problems may be caused by and/or reduced with institutional reform. Moreover, technological opportunities may require institutional reform and institutional reform may realise real structural improvements that lower transaction costs to stimulate the realisation of traffic management developments.

Institutional design (i.e. intentional institutional reform) is a nontrivial task and strong limitations and concerns to institutional reform in this context exist. Thus, only directions that are mainly focused on the resources and organisation of the government were proposed. This led to the selection of three institutional directions:

1) The stimulation of timely data exchange is expected to lower the data acquisition costs for road authorities, the bundling of data makes the sharing easier and the shared traffic data can be used to determine traffic management performance, inform drivers and stimulate development of new traffic management related product and services.
2) The performance goals and their measurement is expected to enable the objective comparison of performance (over time, between regions and between products). This is expected to increase incentive for road authorities and traffic management parties and may improve driver experience.
3) The central coordination of traffic management is expected to improve the operation of NTM, increase data sharing, bundle expertise and experience, enable economies of scale and stimulate the creation of an interoperable road network.

For these directions a number of scenarios were created and evaluated with the use of interviews. This led to the conclusion that:

1) No clear strategy regarding stimulation of timely data exchange dimension emerges from the interviews;
2) relatively little performance goals and benchmarking is used for operational traffic management and that creating a list of factors and benchmarking regions would improve the system;
3) the ideal size for a traffic management zone should be between city region to national and more cooperation between road authorities and traffic management authorities (consisting of multiple road authorities) would be beneficial but is ought not to change much.

These institutional directions and their evaluation by the interview respondents will be used in the formation of the strategy in the upcoming chapter.

7 Strategy design to manage complex interactions

Previous chapter have described a system with many problems and uncertainties regarding the system itself but also regarding the future, the strategic behaviour of actors and the institutions. But it also found (in Chapter 4) that INTM and OANM specifically are a great opportunity to improve network distribution and reduce the related negative effects. However, the various problems and uncertainties (substantive, strategic and institutional) and the large numbers of interdependent actors (as shown in Chapter 5) lead to complex interaction processes that could hinder this potential future. In this chapter this the remaining uncertainty is accepted and a proposition is made to act consciously in its presence by managing the complex interactions in various ways. Thus the following research question will be answered: "*How could the national government cope with complex interaction processes?".*

The. The literature describes two main approaches to manage the complex interaction processes in policymaking, these are the network constitution approach and the process management approach (Kickert, Klijn, & Koppenjan, 1997; E. H. Klijn, Koppenjan, & Termeer, 1994). "The network constitution approach is focused on achieving changes in the institutional characteristics of a policy network" (van de Riet, 2003, p. 3). The process management approach sets out the process agreements (the rules of the game that the actors involved must obey during the decision-making process) that can facilitate the cooperation and to manage distrust needed to realise policy progress (De Bruijn and Ten Heuvelhof, 1999; Klijn and Koppenjan, 2000). In preparation of these strategies an effort to create negotiated knowledge has been made in Chapter 3. This may reduce the substance uncertainty when discussing the need for or goals of such a strategy.

7.1 Institutional strategy

Section 6.6 has identified numerous institutional directions. With these directions, it is attempted to the institutional characteristics of the network such that the cooperation opportunities of actors improve. So, it can reduce the problems and uncertainties in the NTM system and assist the future application of the process management approach.

7.1.1 Stimulation of timely data exchange

The first proposed dimension was 'stimulation of timely data exchange'. No clear strategy regarding this dimension emerges from the interviews (see Subsection 6.6.1) because of the strategic interests involved. However, it is an enabler for performance measurement and allows for the prediction of traffic even beyond the traffic manager's own region. Thus, prudent strategies are created. First, buy and share FCD collectively with as many road authorities as possible because it allows for economy of scales. By only sharing this information with road authorities the data market is less 'disturbed'. Second, stimulate the sharing of traffic data among road authorities. Third, investigate the potential ownership and value of dynamically changing traffic control settings and the impact of future vehicle-infrastructure communication on this. Potentially, this data belongs to the road authorities, is of value to the traffic information providers and may be traded for other traffic data (e.g. FCD), although this may be in conflict with the government's open data policy.

It has to be noticed however that the prudent strategies mentioned above already seem part of current policy. Since further institutional change regarding this dimension brings about a dilemma among actors, it is advised to this include this dimension as a dilemma in the process design (see Section 7.2).

7.1.2 Performance goals and their measurement

The second proposed dimension was 'performance goals and their measurement'. Form the interviews and the theory it appears to be beneficial to nationally determine a list of factors (for example see Subsection 3.3.2). The factors that are to be included and how these should be measured may be determined in the process to create support for the concept (simple command and control may fail), use the knowledge of the involved parties (e.g. consultants and research institutions) and gain an accepted validity. Additionally, an advised factor weight range could be given to partly uniformalise policy among traffic management regions.

Finally, benchmarking should be considered. Although the costs are unknown to this research it is expect that it will become relatively less expensive when it is done on a regular basis for the whole of the Netherlands and that it would reduce a substantial amount of uncertainty.

7.1.3 Central coordination of traffic management

The third proposed dimension was 'central coordination of traffic management'. From operational technical point of view, covering grid of interconnected traffic management zones for the Netherlands with boundaries in non-urban areas would be preferred. The technical size of these zones would fluctuate per approach and over time due to scientific and technology developments and is thus not considered to be a determining factor. This assumes however that the zones are interconnected, able to share information and collectively optimize their traffic control. But this becomes increasingly difficult with smaller zones and larger zones can benefit from scales of economy regarding its implementation. Therefore, it is advised that the optimal size of these zones seems to be between a city region and a province. This research estimates that it should not be bigger because of its link with infrastructure management and strategic development planning. The formation of the exact zones and their level of independence should once again be determined in the process. It seems logic to use the boundaries of other public bodies as point of reference (e.g. city regions, provinces, Beter Benutten regions or maybe even bus consortia regions).

Regarding the interdependency within and between traffic authorities it is advised to strive for coordination (although the interview respondents varied in opinion) because it would enable for efficient agreements with private parties, i.e. limited dissension and more uniformity in demand. To simulate collaboration at this level, it is suggested to transfer (a part of) the budget of and authority of road authorities to this new traffic management authority.

Regarding the 'central supervision' a facilitating role is advised. It is expected that a central coordinator is needed to reform the institutions as the technology evolves and to act as a process manager to stimulate cooperation.

7.2 Process strategy

Chapter 5 has shown that the system is composed of actors that are mutually dependent and that the proposed change involves actions that transcends the boundaries of one actor. In this multi-actor environment actors are often not able achieve their objectives without resources that are possessed by other actors. This seems to be the case for the proposed change (see Subsection 5.6.2). So these actors will have veto opportunities that they can use if they do not like the expected outcome. Trying to achieve a certain result in a go-alone strategy can thus lead to blockades and stagnation and hence to inefficient and ineffective decision-making (Koppenjan & Klijn, 2004). Command and control is also not the way to go, because of the mutually dependency actors are most often not able to unilaterally impose their desired solution on other. So at least some cooperation is required.

However, establishing cooperation is troublesome because of different interests, uncertainties and the risks and costs involved with complex policy games (Koppenjan & Klijn, 2004, p. 118). Increasingly so, when it involves multiple institutional networks where shared institutions are not present (Koppenjan

& Klijn, 2004, p. 118). This seems to be the case for traffic management. Here, multiple actor network clusters and people of multidiciplinair environments come together and shared institutions are limited because the system is constantly evolving due actor interaction, external input and policy input. Especially here, perceptions, rules and languages of actors may differ and thus causing actors not know what to expect of others. The problems within this dynamic system are subject to the perception of actors whom may perceive them at different moments and under different conditions. The possible solutions for these problems are also constantly evolving and are subject to the perception of actors and to their strategic interest. So, there may be numerous problems and solutions that vary over time and in the perception per actor.

Since actors are dependent on each other within the system, strategic and institutional uncertainty will be present, in addition to technological uncertainty and external input uncertainty. Although institutional reform may reduce some uncertainty, eliminating all uncertainty is impossible. Therefore, it has been chosen to accept this uncertainty and act consciously in its presence. The chosen way to do this is by assisting actor cooperation via a process based strategy. Here, one or multiple actors function as facilitator, conflict manager or arbiter (called process manager). This reduces the chances influence of deadlock and enables realising breakthroughs and decision-making (Kickert et al., 1997). A process based strategy combats issues and uncertainties in environment of trust as a way to reduce negotiation transaction cost. Finally, a package deal is formed where actors give and take on numerous issues resulting in pareto-optimal outcomes that are higher than the cost of collaboration (else actors will not join the interaction process or will feel betrayed ex-ante which can compromise future collaboration). According to de Bruijn et al. (2010) the advantage of this approach is that: 1) The information of the various actors can help in the reduction of substantive uncertainty and acquiring a better (multi perspective) solution; 2) different perceptions of and (normative) beliefs about problems and solutions are brought together which may improve the outcome and allow parties to acquire a better understanding of each other which can increase support; 3) it can cope with dynamically changing problem definitions and solutions; 4) create transparency in decision-making; 5) de-politicizing decision-making and 6) create support. But there are risks involved with a process management strategy, the transaction costs of cooperation can be high and it is susceptible for conflicts and delay.

To specify the process based strategy further, this section will describe (parts of the process design that is to be presented in Subsection 7.2.3 that include) the following:

- Common goals: What will be the result of the process and added value of participation?
- Process manager: Who will initiate and guide the process?
- Process design: Which steps will be included in the process and its preparation?
- Actor involvement strategy: How and when will each actor be involved?
- Issue grouping and coupling: How can issues be coupled to improve decision-making?

7.2.1 Common goals

The goal is to create a pareto-optimal outcome where collaboration between actors leads to a situation where they stand more to gain by collaborating then by pursuing their individual path. To prevent this a process based strategy is proposed. But actors must be convinced to join the process. They must be convinced that there is an issue that needs to be solved and that it can only (or this research states more effectively) be solved through cooperation in a process (de Bruijn et al., 2010, p. 61).

The issues have been identified (and aligned to the views of actors) in Chapter 3 and the start of this section has explained why cooperation is needed. Furthermore, actors must be offered prospects of gain (i.e. an expected outcome that is higher than the cost of collaboration) if they are to join the process. In this process an actor might lose on an individual issue, but because multiple issues are bundled he might gain on another issue. In doing so a potential win-win scenario can be created. Section 4.3 describes exactly that, where OANM could cost efficiently increase the network efficiency and lead to a product that can be exported to foreign countries. “A major risk of process management is that it leads to slow and sluggish decision-making ” (de Bruijn et al., 2010, p. 25). Therefore, it can only succeed if a sense of urgency is present among the main actors (Kotter, 1995).

For the governments and the public OANM can become a way to improve liability, environment and safety, since it may redistribute traffic more efficiently and away from residential zones. If we wait longer more people will be harmed and climate agreements may not be met! Furthermore, Section 5.7 predicted that if the coalition of ‘public proponents’ do not act, an independent traffic control scenario is more likely and OANM or similar approach is unlikely to be realised.

Private parties stand to gain from the public investment for OANM and their services or products may increase in value. But by entering the process, new products may be developed and tested that can later be used and exported to other locations. Here, waiting too long leads in a reduction of competitive advantage. Furthermore, if the Netherlands is progressive in this field it may have a greater influence in the formation of European standards such that conversion costs are limited for both parties.

Finally, it may not be possible to achieve a direct gain for every actors. When this occurs and there are unequal costs for some actors, compensation by other actors could offer enough incentive to proceed. The expected process gain per actor is formulated in the table below.

Table 10 - Actor expected process gain

Actor group (function)	Expected process gain
European union	Increase road network performance in the EU
Government of the Netherlands	Increase road network performance with limited investment and positive contribution to climate targets
Rijkswaterstaat	Increase road network performance with limited investment
Province road authorities	Increase road network performance with limited investment
Municipality road authorities	Increase road network performance and liability with limited investment
Water board road authorities	Increase road network performance with limited investment
Traffic manager	Compensation for potential loss
Project contractor	Compensation projects
Traffic control providers	Traffic control adjustment orders and a bigger market
Traffic management developers	More demand
Consultancy firms	Income from advising during the process
Research institutions	Applied research
Navigation providers	Increased service of products
Automobile manufacturers	Increased service of products
Smartphone app providers	Increased service of products
Private data processor	Increased data demand
Public data processor	Role becomes more important
Drivers	Reduction of average travel time and increase of traffic information quality
Locals	Improved access time, reduced noise, air and aesthetic pollution and reduced traffic accidents

Facilitating parties	More users
Interest groups	Improved or preserved interests

7.2.2 Process manager

The process approach requires a mediator and/or stimulator of interaction and not as a central director, i.e. a process manager. He or she ensures that the parties comply with the rules, communication is effective et cetera. Without a process manager, individual issue can potentially not be bundled and thus potentially not resolved.

In theory anyone can be the process manager but any road authority probably has limited incentive to do so nationwide. Private parties are often not interested, influential enough or trusted enough to take upon this role. Therefore, it is advised that the national government should compose this role. They some (but fairly limited) hierarchical power, resources and the creation of formal institutions at its disposal that can be used (with care) to accelerate the process (de Bruijn & ten Heuvelhof, 2008, p. 115). Furthermore, they have reason to intervene since it is found to be a public interest (see Subsection 3.3.1) that exceeds the boundaries of road authorities. Additionally, they may use this role to create awareness for societal beneficial INTM approaches such as OANM.

The exact formation of this is left to people with more field experience. But the advice is given that a process management group consist (at least partially) from governmental representatives. By making a separate group the representatives, they can refrain them from making substantive choices for the government. To make this more credible non-governmental representatives can be added to the process management team. As a suggestion to fill the vacancies of this position representatives of e.g. Beter Benutten or Connekt could be considered because of their experience and position.

7.2.3 Conceptual process design

Apart from a common goal and a process manger, the process will need a design. De Bruijn et al. (2010) recommends process design as a result of negotiation to give actors a fair chance of influencing this such that the process itself will not harm their core values. Nevertheless, this research wants to provide hand-hold for the national government to initiate the process and to serve as a concept that may be adjusted in collaboration with the involved actors. To do so, the literature of De Bruijn et al. (2010) was used. They provide an overview of possible activities for making process design and describe the four core elements of a process design (openness, protection of core values, progress and substance). The overview has been used to formulate the step and the core elements (listed and applied on this case in Appendix F) have been used specify this further for the case at hand.

Preparation: a first exploration

1) Initial problem exploration (see Chapter 3)
2) Draw up an initial list of relevant actors (see Chapter 5)
3) Actor scan: collect information about views, interests and core values; about risks and opportunities they may identify once the process is started; about incentives and disincentives; and about pluriformity (see Chapter 5)
4) Identify issues (see Chapter 5)
5) Map common goal and sense of urgency of the process (Subsection 7.2.1)
6) Form process management team (Subsection 7.2.2)
7) Scan of the substantive couplings, and the initial agenda (see Subsection 7.2.5)
8) Create concept of rules
9) Testing the process design
10) Gathering participants

Process initialisation: create commitment

11) Initiate process: Actors should be convinced of common issue/goal that can only be solved together (Subsection 7.2.1). An opening workshop or serious game might be used to let them realise this. At the end of this workshop all actors can join the process by signing a declaration of intent
12) Share process dilemmas (e.g. core values like public accountability, confidentiality of corporate information)
13) Establish rules of interaction
14) Determine & share substantial dilemmas
15) Agenda setting

Actual process: sharing views

16) Negotiation blocks
    a. Development
    b. Implementation
    c. Operation
17) Possible trails: a lot of the uncertainty can be removed with a trail

Process conclusion: a package of shared benefits

18) Proposition of package deal
19) Negotiated approval of all parties

The specification of the intuitional reform dimensions will be done in the operation negotiation block (timely data exchange) and the implementation negotiation block (performance goals & central coordination).

7.2.4 Actor involvement

Actor analysis has identified a huge amount of actors and has shown risks and opportunities regarding those actors. This subsection will try to create a strategy to utilise and cope with that.

Simply including everyone will lead to lengthy procedures and high transaction costs, but a failure of including them can lead to opposition, blockades and a suboptimal result. Therefore, the process design can specify who is involved when and it what way. Bryson (2004a) proposed a participation planning matrix to show the involvement of actors per stage and knows the following values:

- Inform: We will keep you informed
- Consult: We will keep you informed, listen to you, and provide feedback on how your input influenced the decision.
- Involve: We will work with you to ensure your concerns are considered and reflected in the alternatives considered, and provide feedback on how your input influenced the decision.
- Collaborate: We will incorporate your advice and recommendations to the maximum extent possible.
- Empower: We will implement what you decide.

The table below shows the participation planning matrix. This is constructed with induction on the basis of the general actor engagement strategy presented in Table 8 and then spread over the stages according to the actor group involvement per stage presented in Table 6 (both of Chapter 5). For example, involve of Table 8 usually equals to collaborate or involve in the table below (because the scales of the different methodologies are not exactly equal) but may be adjusted if an actor is not active in that stage. Empower is intentionally not used in the participation planning matrix to stimulate cooperation, although individual exceptions for issues that can potentially harm an actor's core values can be made.

Table 11 - Participation planning matrix

Actor groups\Stage	Initialisation	Development	Implement.	Operation
European Union	Consult	Involve	Consult	Inform
Gov. of the Netherlands	Collaborate	Collaborate	Involve	Involve
Rijkswaterstaat	Collaborate	Collaborate	Collaborate	Collaborate
Province road authorities	Collaborate	Collaborate	Collaborate	Collaborate
Municipality road authorities	Collaborate	Collaborate	Collaborate	Collaborate
Water board road authorities	Collaborate	Involve	Involve	Involve
Traffic manager	Collaborate	Consult	Consult	Consult
Project contractor	Consult	Inform	Consult	Inform
Traffic control providers	Collaborate	Collaborate	Collaborate	Consult
Traffic management developers	Collaborate	Collaborate	Collaborate	Collaborate
Consultancy firms	Consult	Consult	Consult	Inform
Research institutions	Involve	Consult	Inform	Inform
Navigation providers	Collaborate	Collaborate	Collaborate	Collaborate
Automobile manufacturers	Collaborate	Collaborate	Collaborate	Collaborate
Smartphone app providers	Consult	Consult	Consult	Consult
Private data processor	Consult	Consult	Consult	Consult
Public data processor	Collaborate	Collaborate	Collaborate	Collaborate
Drivers	Consult	Consult	Collaborate	Consult
Locals	Consult	Consult	Collaborate	Consult
Facilitating parties	Collaborate	Collaborate	Consult	Consult
Interest groups	Consult	Inform	Consult	Inform

In the table above special attention is paid to drivers, traffic information users, locals and society, as they are only included in the last stage, with only limited power and limited information. Here, the government has the task to represent their demands. So they have been empowered in the process (also because of ethical considerations). However, due to the sheer size of this group makes it difficult to reach them. Therefore, only a select group will be included in the process and the rest has to be informed via media. Here, it is proposed to engage the interest groups. They will offered additional influence if they commit themselves to inform the public. In doing so, 1) any opposition by interest groups is reduced seen that they are involved, 2) they may additionally look after the societal interest and reinforce the position of the government in the negotiation, 3) are able to communicate via other networks then the governments network, 4) allows for management of the information and 5) incentification of regional governments.

However, the participation planning matrix only shows a general guideline. Further detailing per issue should be done. For this step it is advised to limit the interaction of actors that can potentially form the private resistance coalition (traffic control providers, consultancy firms, project contractor, and private data processor).

Since the table above speaks of actor groups, it is still specific who should participate. De Bruijn et al. (de Bruijn et al., 2010) states that the process should be heavily staffed. This means that people with high authority should be invited. This can be problematic with actor groups that consists of many actors or in groups where there is no direct authority (e.g. drivers). For this representatives (with a degree of authority) can be appointed during the initialisation stage. This allows a party to be represented on (for them) less important issues.

7.2.5 Issue grouping and coupling

The process manager does not make substantive choices but presents dilemmas (neutral point of view) to the actors. But he can determine the order and timing of issues and which issues are coupled. This gives the process manager a lot of possibilities to steer the process. In general the more issues there are the better it works to get actors aligned because: 1) if their issues are on the table they have incentive to enter the process of cooperation; 2) a trade-off between extremes can be made which is an incentive for unfreezing; 3) multiple interactions can be incentives for coalition and trust; 4) It puts actors' views into perspective and allow him to learn.

When the more difficult issues are on the table diverse techniques can be used to manage the negotiation that are described in the literature (e.g. de Bruijn & ten Heuvelhof, 2008). This includes the decoupling of the creation of negotiated knowledge and the decision-making and the usage of hierarchical power (threatening unilateral action).

The exact grouping and coupling of issues is left for further research when more issues are found and actor perception regarding these issues has been validated.

7.3 Conclusion

This chapter proposes to manage the complex interactions of the NTM system with the network constitution approach and the process management approach.

The network constitution approach created a strategy regarding the three investigated institutional directions proposed in Section 6.6. Only partial strategies originate from the "stimulation of timely data exchange" direction. First, buy and share FCD collectively with as many road authorities as possible because it allows for economy of scales. Second, stimulate the sharing of traffic data among road authorities. Third, investigate the potential ownership and value of dynamically changing traffic control settings and the impact of future vehicle-infrastructure communication on this. But the first two and possibly the third is already being done, although it remains on a voluntarily basis where not all road authorities contribute. Regarding the "performance goals and their measurement", it is advised to nationally determine a list of factors (and how they are measured) with an advised weight range and benchmarking should be considered. Regarding the "central coordination of traffic management" it is advised to create a covering grid of traffic management zones with boundaries in non-urban areas. The size of the zones is advised to be between a city region and a province. Although this still leaves some variance, it is suggested to use the boundaries of other public bodies as point of reference (e.g. city regions, provinces, Beter Benutten regions or maybe even bus consortia regions).

The network constitution approach still allows for some further specification. This is done intentionally because "in view of the complexity and multi-actor nature of technologically complex systems, a design cannot be a 'blueprint' created through an intellectual process by a designer behind a desk. In as far as systems are created in such a manner, they are often adapted (beyond recognition) in the processes by which they are decided upon and implemented." (Koppenjan & Groenewegen, 2005, p. 242). Alternatively, it is proposed to allow for the formation of the specifics in a process to create support for the concept (simple command and control may fail), use the knowledge of the involved parties and gain an accepted validity.

The process management approach describes how to create a win-win strategy for the involved actors. The actor analysis showed that interests are relatively in line but resources are scattered between actors and network clusters. Using the technical complexity and uncertainty to creatively shape the future, the realisation of OANM is proposed. Such an approach can create benefits for both the public as the private cluster. If a cooperation is established both parties have to contribute as both stand to gain. Important in this is that there is a sense of urgency, on the one hand there is the pressure of reducing environmental impact, government spending and increase liveability and on the other private firm may want to export the developed product. By entering and facilitating a process of interaction numerous issues may be identified that hinder the realisation of the approach. By creating a package deal with give and take on multiple issues a compromise can be made that is expected to result in pareto-optimal outcomes that is higher than the cost of collaboration. This package deal gives an incentive to enter the process of cooperation, for unfreezing, for coalitions and for learning (de Bruijn et al., 2010). In theory anyone can be the facilitator of this process (process manager) but it is advised that the national government should compose this role with (at least) some governmental representatives.

8 Conclusion and discussion

Based on the research conducted the research question can be answered. This will be done on the basis of the answers to the sub-questions. Their findings are presented in upcoming section, whereafter the main conclusion is presented. A discussion of the research follows thereafter.

8.1 Findings

This section presents the answers to the sub-questions. These and their answers are listed below:

How do the governance of the road infrastructure and network traffic management in the Netherlands function and how did these evolve?

The governance of the public road infrastructure in the Netherlands is done by road authorities. These road authorities form a geographical patchwork of zones, divided over more than 400 entities. Nowadays, an increasing number of them continuously steer traffic conditions with traffic control and traffic information. Meanwhile, the developments in traffic management and the advent of private traffic information parties gave way to numerous traffic influencing parties and approaches that do not have to cooperate. This results in a situation where traffic across the network is managed by various parties and approaches, often simultaneously, while theoretically (from a societal perspective) there is much to gain by an approach that aligns the diverse zones and types of traffic management (Integrated Network Traffic Management).

What are the problems and uncertainties of current network traffic management system that hinder its development, implementation and operation?

The previous complex situation extends beyond the operation because part of the problem is caused by and possibly resolved with technological development and its implementation. Herein, the operation of system is affected by the previous mentioned parties that have various interests, geographical boundaries and means of optimising their traffic management, while they steer a system that has difficult management characteristics (non-linear etc.). This causes for road network inefficiencies and unpredictable traffic behaviour. The implementation of the traffic management approaches on the road bound infrastructure is affected by case by case decision-making of many authorities that limits scales of economy when purchasing, limit interoperability and induce procurement inefficiencies. The development is characterised as a market of demand and supply of technological complex and multidisciplinary products between private firms and road authorities. Herein, the complexity of products increases the information asymmetry and the risk of the supply while the previous mentioned case-by-case decision-making of numerous road authorities cause for a variety and uncertainty in the resources limited demand. All three levels are affected by limited incentive because the quality of traffic management is often not specified and measured. Thus the system is characterised by various problems and uncertainties between various actors. Resolving these can only be a collaborative effort. Essential in this, is a shared problem perception. Therefore, the identified problems were aligned with the views of diverse actors by conducting interviewing with them.

In what direction is network traffic management and its governance expected to go and how can this direction be realistically shaped for the benefit of society?

The previous system is constantly evolving, in part because of the technological developments and implementations. The future of the system is therefore characterised by many uncertainties. In this uncertainty, this suggested the possibility to realise a specific INTM approach: Online Anticipatory

Network Management (OANM). This approach is expected to improve road network distribution and allow road authorities to regain partial steering control of the network that they have lost with the advent of private traffic information providers. Analysis has shown the realisation of this approach is possible in the future but requires a collaboration of a range of actors and the involvement of the national government. Furthermore, its realisation is hindered by the aforementioned problems. However, the future of the system remains rather uncertain thus the final strategy must cope with and possibly even utilise (by suggesting OANM) the uncertainty of the future.

Who are the actors involved and how will they perceive, respond to and interact regarding to the prescribed future?

To realise the prescribed future and to mitigate the identified problems, a range of actors has to cooperate. Among the range of actors, the resources that are required to realise, or able to block, the prescribed future are scattered and the decision-making takes place between many different actor groups. The majority of actor groups and the subsequent interest and power allocation are predicted to be in favour of the prescribed future. Within this, several issues between actors and potential coalitions were predicted that may affect progress. However, the changes identified to describe and the issues regarding the prescribed future can be incomplete due to the uncertainty, the dynamic nature of the network and the provision of new information that can cause strategic interests and perceptions to change. This may cause yet unforeseen strategic problems and uncertainties that can hinder the realisation of the prescribed future and will require constant monitoring and a strategy that can cope this.

How do institutions play a role in current problems and how can they contribute in resolving the problems?

The aforementioned strategic and technological problems and uncertainties may be caused by and may be reduced with institutional reform. To reduce these problems institutional reforms proposed, investigated and evaluated that are mainly focused on the resources and organisation of the government, because strong limitations and concerns to institutional reform in a multi-actor environment exist. This led to the selection of three institutional directions that could theoretically improve the INTM system: 1) The stimulation of timely data exchange is expected to lower the data acquisition costs for road authorities, the bundling of data makes the sharing easier and the shared traffic data can improve various parts of the INTM system. 2) The performance goals and their measurement is expected to enable the objective comparison of performance (over time, between regions and between products) to increase incentive for road authorities and traffic management parties. 3) The central coordination of traffic management is expected to improve the operation of NTM, increase data sharing, bundle expertise and experience, enable economies of scale and stimulate the creation of an interoperable road network. To test the theory, a number of scenarios was created and evaluated with the use of interviews. This led to the conclusion that: 1) strong strategic interests were involved with timely data exchange that resulted in a scattered opinion; 2) creating a list of factors and benchmarking regions would improve the system; 3) the ideal size for a traffic management zone should be between city region to national and more cooperation between road authorities and traffic management authorities (consisting of multiple road authorities) would be beneficial.

How could the national government cope with complex interaction processes?

The various problems and uncertainties (substantive, strategic and institutional) and the large numbers of interdependent actors (as described before) lead to complex interaction processes that could hinder the prescribed future and the development, implementation and operation of INTM. To cope with this two approaches were proposed: the network constitution approach (institutional strategy) and process management approach (process strategy).

The network constitution approach created a strategy regarding the three aforementioned institutional dimensions based on interview results and induction. Only partial strategies originate from the ‘stimulation of timely data exchange’ dimension that prescribed collective traffic data acquisition and sharing among traffic authorities, which is already being done. Regarding the ‘performance goals and their measurement’ , it is prescribed to compose a national list of performance factors (possibly with weights and target values) and define their measurement approach. Finally, it advised to investigate the possibility of national benchmarking and to investigate the potential ownership and value of dynamically changing traffic control settings and the impact of future vehicle-infrastructure communication on this. Regarding the ‘central coordination of traffic management’, a covering grid of interconnected traffic management zones with boundaries in non-urban areas for the Netherlands, is prescribed. The optimal size of this zone is predicted to be between a city region and a province. The institutional dimensions intentionally still allow for some further specification. It is proposed to formulate this in a process to create support and to use the knowledge of the involved parties.

The process management approach sets out the process agreements that can facilitate the cooperation and to manage distrust needed to realise progress. In this process, the realisation of OANM is proposed that can create benefits for both the public as the private cluster. This also creates the required sense of urgency. On the one hand there is the pressure of reducing environmental impact and government spending, and on the other hand private firms may be motivated by the prospect of gain by exporting the developed product (if it is still competitive by then). By entering and facilitating a process of interaction numerous issues may be identified that hinder the system and realisation of OANM. By creating a package deal in the end, with give and take on multiple issues, a compromise can be made that is expected to result in (pareto-optimal) outcomes that are higher than the cost of collaboration. Finally, it is advised that the national government should compose the role of process manager.

8.2 Main conclusion

This section presents the main conclusion by answering the research question and by fulfilling the goal of this research. This strongly build upon the answer of the last
The research question and its answer are:

How should the national government of the Netherlands cope with the strategic behaviour and uncertainties in the socio-technological environment of Integrated Network Traffic Management (INTM) to stimulate its development, implementation and operation, taking Online Anticipatory Network Management (OANM) as case study?.

By investigating its technological, process and institutional aspects, it is concluded that the various problems and uncertainties (substantive, strategic and institutional) and the large number of interdependent actors lead to complex interaction processes. These require a combination of an institutional strategy and a process strategy.

The institutional strategy prescribed a list of performance factors (possibly with weights and target values) and their measurement approach that should be applied on a national level. Furthermore, it prescribed a covering grid of interconnected traffic management zones with boundaries in non-urban areas for the Netherlands, where coordination exists with the road authorities that make up this traffic authority and between traffic authorities. Finally, it advised to investigate the possibility of national benchmarking and to investigate the potential ownership and value of dynamically changing traffic control settings and the impact of future vehicle-infrastructure communication on this.

The process strategy employs process management to facilitate the process of cooperation. It eventually makes a package deal of many separate dilemmas that should allow for actors to give and take on individual issues that could otherwise hinder progress. Although the case study (OANM) increased the complexity of this research, it also increased the benefit for the national government to intervene and offers additional opportunity in the process management approach to reach a pareto optimal outcome. Finally, it is advised that the national government should compose the role of process manager.

A combination of strategies is concluded because of the differences and complementarities between them. The differences between strategies is that process strategy is dynamic and thus flexible to unforeseen developments. Furthermore, the risks of a process strategy are smaller that institutional reform; the government can always withdraw itself from participation of the process when the expected result is insufficient but institutions take time to change in case of unforeseen consequences. However, the process strategy only reaches the actors that have joined the process.

The strategies can also function complementary. Currently, there are so many parties involved that process management may be difficult to realise. To reduce this, the institutional dimension of central coordination could help. Similarly, the timely data exchange could affect strategic interests and performance goals could clarify and align the position of the road authorities and benchmarking could incentify them and reduce uncertainty. Alternatively, by including the institutional reform in the process approach, it could allow for a discussion that is able to use the expertise of the various parties, bring more choices to the negotiation table that may increases the success of the negotiation and lead to better public-private understanding. However, since there are strategic advantages involved with institutional reform, the final decision for institutional reform remains the decision of the government.

For the realisation of the case study (OANM) the process strategy is better suited because it is more direct rather than setting the conditions right for OANM to emerge. At this point is seems unlikely that OANM will be realised without either of the two strategies.

Applying the strategies will be a non-trivial exercise. The process strategy is more dynamic but it will require constant monitoring and management. The institutional strategy however has an uncertain impact that is able to create distributive advantages and the strategy in this research consists of a set of directions that require further specification. Its formulation also neglected any potential legal implications, the cost involved and in part the repercussions for infrastructure management and strategic development planning and the actors attitude towards reform (only measured in a couple of interviews). Thus, these are the main suggestions for further research.

Hereto, the government of the Netherlands is recommended to go forward with both strategies. Although their application will not be an easy task, more efficient development, implementation and operation of INTM and the realisation of OANM could be achieved that is expected to reduce road congestion and its impact, reduce government spending and increase liveability. Furthermore, it could contribute in sustaining and improving the leading role for the Netherlands in traffic management.

Hereby, the goal of this research ‘to create a strategy…’ is accomplished (in a sense, because it did not create ‘a strategy’ but a set of two strategies).

8.3 Discussion

The result of this research is no quick solution but rather a strategy to deal with a complex socio-technological system. To deal with the complexity some assumptions and simplifications have been made. Some of them may be naïve, theoretical and/or too simplistic. Furthermore, the complex reality may be perceived in many ways and although the researcher attempts to remain objective, he himself has limited information and bounded rationality. Thus, the limitations and possible biases are and will be made explicit to allow for evaluation and discussion, which in term may be input to improve the research and/or policy. Therefore, these biases and limitations will be discussed. Hereafter, the contribution, the feasibility and uniqueness of this research is discussed.

8.3.1 Research objectivity and integrity

The objectivity of this research is important as it is ought to be the start of an actor interaction process. If actors do not experience this research to be objective it may be contested or worse it may lead to dialogues of the deaf (Koppenjan & Klijn, 2004, p. 26). However, there is a natural tendency for anyone (actors and researchers) who has investigated policy problems to assume that he has the facts and that what he perceives is the real situation but these perceptions of are always incomplete and necessarily subjective (Radford, 1984; Thomas & Janowitz, 1966).

It is attempted to specify the sources that could have influenced the perception of the research:

- **Bias researcher:** The technical traffic management background of the researcher there may be an unintentional bias towards using (a particular) and in the perceived gain of traffic management. The proposed OANM approach is a means to an end but alternatives are not considered.
- **Bias in research position:** On the one hand this research attempt to supply the government with strategic advise (see Subsection 1.4.2) while it proposes a process management approach that requires negotiated knowledge. Where the first tries to improve the interests of the government, the latter requires information that is impartial.
- **Bias problem orientation:** This research had a focus upon the road-bound subsystem rather than on the in-car subsystem (see Subsection 1.4.2). However, if the focus was placed on the in-car subsystem more traffic information related problems could have been found. Alternatively, interview respondent 2 (Appendix D) already stated that some of the problems found were not applicable on the in-car subsystem.
- **Bias interview respondents:** An actor that want to be interviewed is most likely in favour of the INTM developments. Furthermore, actors are asked in interviews about perceptions, problems and institutions. They however, can have strategic interested which may have incorporated in their answer. Knight and Moe (1992; 1990) state that there is a strong incentive to try to influence the design and redesign of institutions in order to create distributive advantages.

The biases, assumptions and methodology have been made explicit, such that its objectivity and integrity can be investigated if it is questioned. If It is, it suggested to discuss it in a workshop with experts which will be recommended in the next subsection to test the validity.

8.3.2 Research validity and limitations

The complexity and uncertainty of the subject together with the research time available has led to limitations that may affect the validity of this research. Therefore these will be discussed after which recommendations are made for further research. The following limitations, sorted per topic, may affect the validity of the research:

General

- There are currently so many ongoing developments (probably because of the amount of actors involved and the rate of technology development) that it is impossible to acquire a complete image of current developments. Therefore it is possible that some problems and solutions are neglected or introduced while already resolved.
- The scope of the research was the Netherlands while lots of traffic management interactions and regulations occur on a European or even international level.

- TIP approach has overlap but has been discussed sequentially. Although interactions have been included in the research the iterations may continuous indefinitely. This is of course outside of the scope of this research.

Interviews

- The validation of the problems and reflection on the institutional directions is done with a rather limited set of interviews and which contained limited government respondents and not all actor groups.
- The dimensions regarding 'stimulation of timely data exchange' shown to the respondents did not include the possibility to quantitatively differentiate per traffic data source although actors qualitatively stated that this differentiation was important.
- One respondent (#3) find the question hard to answer because their abstractness. This is likely a result of the chosen 'unravelling' approach to reduce the influence of the interviewer on the respondent.

System analysis

- The problems described in the system analysis may already to acted upon as this research did not investigate all ongoing projects.

Future analysis

- The scenarios are composed with external factors identified, grouped and sorted on uncertainty and impact by induction of the researcher. Although this has been done in a methodological way and its result is used in combination with trends from the literature, no validation of this has been conducted.
- The identification of trend disruptions and their effects is conducted in a fairly limited way. This may lead to an unexpected future.

Actor analysis

- The stakeholder analysis is practical to apply but its analytic quality not strong because it has limited specificity and logical interconnectedness (Hermans & Thissen, 2009).
- The stakeholder analysis was originally developed for project design and implementation (Enserink et al., 2010). However, policy problems include a range of solutions, rather than a specific project. Therefore, the attitude is conditional on the specific types of solutions one has in mind or may overlook specific implications of a certain solution. Initially, everyone seems to agree until the solution becomes more specific. To reduce this the proposed changed has been decomposed into smaller elements but this is expected not to be complete due to the uncertainty of the system (see Section 5.1).
- Functional generalisation or actors neglects two important aspects. First, there are possibly large differences between actors of an actor group. This can be caused by the dynamic positions of actors that can drastically affect the way an individual actor behaves. Second, actors can be position themselves in multiple actor groups with the activities they engage in. Any issues between the two actor groups can be affected by this because that actor may solve the problem internally.
- Cooperation groups have not been included and interest groups as one while they represent a range of interests. Feitelson & Salomon (2004, p. 13) states that interest group can be powerful because their relatively small size they can organize themselves effectively and devote their often-considerable resources to very concrete issues.

- The actor analysis has a lack of empirical data. Stated and/or perceived interests and problems or theoretical assumed (and verified by other actors in the field) perceived interests and problems (for the less relevant actor).
- An actor analysis can result in polarisation (it focuses on the differences but not on the resolution of these differences) and can induce the risk of a self-fulfilling prophecy (Enserink et al., 2010).
- Hidden agendas and ambiguous power structures may not be found in an actor analysis and remain a worrying factor (Hermans & Thissen, 2009).
- Rational decision-making based on maximal utility: humans often lack information, the cognitive resources or the required aspiration level to maximize their utility. They have bounded rationality (they may perceive information different), may not act directly in self-interest (example long term commitment) and this research only perceives a static situation.

Institutional analysis

- Institutional framework (presented in Section 6.1) is based on sets of rather heuristical frameworks without any empirical substantiation or external validation. Although it was only used as an analysis tool, its validity is questionable at this stage.
- Institutional directions found are based on a structured way of induction that generated an incomplete set of alternatives.
- The interaction between institutional directions, its link with infrastructure management and strategic development has not directly been investigated and the legal implications of these directions were neglected.

The main limitation that affects the validity of the result is estimated to be the lack of empirical data. Although interviews were conducted, the number of interviews and the available time in such an interview is rather limited. It is suggested to assess the validity in a workshop with experts (possibly the same workshop as mentioned in previous subsection). This should allow for a discussion that could potentially provoke more feedback and lead to convergence of ideas, rather than an argued (dis)agreement on a specific subject which is more the result of an interview. A survey could also be useful for gathering more empirical data on certain subjects (e.g. for actors analysis) but is expected to be less capable to assess the more complicated problems. Finally, it is suggested to use chosen process approach to reduce the remaining limitations.

8.3.3 Research contribution

The main research contribution is a methodical way to analyse the INTM as a complex socio-technological system from a technological, institutional and process perspective. Secondary contributions are of scientific nature which are the proposed system description and institutional framework for road-bound traffic management. Tertiary contributions are the practical contributions which includes: the problem description, the created scenarios, the results from the actor analysis (including the actor decomposition) and the design of the process management approach.

8.3.4 Research feasibility and triviality

The problem owner in this research is the national government of the Netherlands. They were chosen and did not request this research. They therefore may need to be convinced to follow the advice of this report. This is likely to be a tough task since this research identified the national government of the Netherlands as a fence sitter while the independent traffic control scenario is more likely without government involvement. In order to convince them there has to be a potential gain (costs versus benefits) which seems to be the case but is yet to be proven and there has to be an opportunity. Concerning the latter, the national government consists of multiple decision-makers where probably at least several of them have to be convinced. So there has to be a political window as described by Kingdons streams model (Kingdon, 1984) in order to realise the strategy of this research. Within this strategy institutional design will be the most difficult to achieve because institutions naturally difficult to change (as described by Koppenjan & Groenewegen, 2005). Potentially, a policy window can be created with the assistance of lobby groups, interest groups or media. It is however doubtful whether the rather decentralised government is willing to take on the prescribed role. Part of the initiative also may originate from private companies and parties outside of the Netherlands. The first may however steer towards a different direction and the latter probably means a loss of the competitive advantage (because it has been or is being done elsewhere). Thus there are doubts regarding this research realism and triviality. However, there is a change that it will inspire the right people to act and/or assist further research.

8.3.5 Research uniqueness

A final remark is made regarding the uniqueness of this research. Because it was the follow-up research more in-depth (network) traffic management knowledge be included. Additionally, the case study of OANM was found to be a solution to the decreasing steering capacity of the government and it offered additional gains to realise the win-win situation of the process management approach.

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Appendix A Future analysis

To assess the future of INTM the literature was evaluated for suitable candidates (step 1). After this was not found, the methodologies described by Enserink et al. (2010) were evaluated to analyse the future (step 2). Hereafter, the by Enserink et al. (2010) suggested steps were used to create contextual scenarios (step 3 till 7).

1. Existing future analysis

The following related external input analysis were found:

- Samenspel Informeren en Sturen van verkeer : een gemeenschappelijk toekomstbeeld (Technische Universiteit Delft et al., 2010)
- Trends in Mobiliteit (RAI Vereniging, 2013)
- Chaffeur aan het stuur? (Kennisinstituut voor Mobiliteitsbeleid, 2015)

After evaluation they were found not to be suitable for this research.

2. Method of analysis

Since no existing external input analysis could be used, the following options of Enserink et al. (2010) were considered to create a new external input analysis:

- Formal
    - Trend extrapolation and regression analysis
    - Analogies
    - Causal modelling
    - Trend impact assessment
- Consulting experts
- Scenarios

A combination between trend extrapolation, trend impact assessment and analogies has been done in more qualitative way (using trend from the literature) to tunnel the future (described in Section 4.1). Causal modelling was not feasible due to the complexity of the system (described in Section 3.1). Thus both consulting experts as the creation of scenarios remained as options. Since experts were already used for other parts of the research and since the creation of scenarios was thought to be faster to achieve, the creation of scenarios was chosen.

To specify this further Enserink et al. (2010) identified multiple dimensions to distinguish types of scenarios. These include: explorative or normative scenarios that a possible versus a desired image of the future; and context, policy or strategic scenarios that are based on external input, policy input or both. In respect to previous dimension it was chosen to construct a explorative context scenario. Whereafter, the explorative context scenarios was evaluated regarding the INTM proposition, its social benefit and likeliness in the current trends, making it more like normative strategic scenarios.

The contextual scenarios are created according to Enserink et al. (2010) in the following steps:

1) Formulate key question
2) Determine contextual factors
3) Cluster contextual factors into driving forces
4) Group driving forces into uncertainty and impact
5) Create and explain scenarios with high impact and high uncertainty
6) Evaluate the key question

3. Formulate key question

The trends of transport and smart mobility services and governance have already been evaluated. But this does not answer what the future of traffic management looks like. Thus the following question will be evaluated: *'What are plausible futures for traffic management in the Netherlands'.* The time scope of the upcoming analysis will be the same as the research, thus 20 years.

4. Determine contextual factors

External input identification is conducted by the researcher using DESTEP and decomposing this per stage. The word DESTEP is an acronym, within which D relates to demographic issues, E to economic issues, S to social issues, T to technological issues, E to ecological issues and P to political issues.

Table 12 - Contextual factors per type and stage

DESTEP\Stage	Development	Implementation	Operation
Demographic	-Available expertise	-Population growth	-Urbanisation -Aging population -Population growth
Economic	-Economic growth -Globalisation -Private funding -Export potential -New type of clients/markets -European funding	-Economic growth -European funding	-Economic growth
Social/cultural	-Globalisation	-Publicity (for problems or measures) -International traffic management performance	-Social events -Car usage & modality choice -Follow-up traffic information -Car sharing
Technological	-Automated/ cooperative driving - Development computation power (e.g. quantum computing) -Traffic model development -IT development	-Automated/ cooperative driving - Vehicle infrastructure communication	-Automated/ cooperative driving -New modalities -Satellite positioning methods - Vehicle infrastructure communication
Ecological	-Resource scarcity	-Climate change -Pollution of vehicles	-Weather
Political/judicial	-Jurisprudence -International/European standards -Patents	-Jurisprudence -European regulation	-Jurisprudence

5. Cluster external input into driving forces

The following grouping of external input has been made by the researcher:

- Traffic pressure

    - Urbanisation +
    - Transportation taxation ?
    - Economic growth +
    - Car usage +
    - Climate change (pollution prevention measures & weather affecting traffic) +
    - Aging population +/-
    - Car sharing -
    - Automated driving –
    - Weather +
- Effect of private traffic information
    - Aging population -
    - Follow-up traffic information +
    - Usage of connected navigation devices +
    - Automated driving +
    - Development satellite positioning +
    - Vehicle infrastructure communication -
- International TM development (de)stimulation
    - Jurisprudence -/+
    - International/European standards -/+
    - Patents -/+
    - Globalisation -/+
    - New type of clients/markets +
    - European funding +
    - Resource scarcity -/+
- Technological development speed
    - Private funding +
    - Economic growth +
    - Available expertise +
    - Development computation power (e.g. quantum computing) +
    - Traffic model development +
    - IT development +
- Technological development direction
    - Development computation power (e.g. quantum computing) +
    - Vehicle development +
    - New modalities -/+
    - Satellite positioning methods +
    - Traffic model development +
    - IT development +

Although external influences are external, the driving forces may be susceptible for policy input.

6. Classify driving forces into uncertainty and impact

The previous found driving forces are now classified on the basis of impact and uncertainty by the researcher.

Table 13 - Ordering of driving forces

	High uncertainty	**Low uncertainty**

High impact	-Technological direction	-Technological development speed
Low impact	-Traffic pressure -International traffic management development (de)stimulation	-Effect traffic information

7. Create and explain scenarios with high impact and high uncertainty

Two scenarios are created based upon the fact that the vehicles and the infrastructure become more connected due to IT development. There is however a third mixed scenario possible that could be preferable. The scenarios are defined as follows:

- **Independent scenario:** Up to now vehicle to vehicle and vehicle to infrastructure communication went via the driver but technology increasing allows for the automation of this. It allows for a digitalised way of agent based interaction that enable a safe and locally efficient interaction environment.
- **Controlled scenario:** Simultaneously, developments of computation power and traffic models allow for more central control of vehicle to infrastructure and infrastructure to infrastructure communication that would otherwise be too complex to achieve. This would allow for a system wide optimisation of the network.
- **Coordinated scenario:** Both scenarios could in theory lead to better network performance. The independent scenario would allow for fast adjustments to local conditions and the controlled scenario allows for the network traffic management. A combination between the both would probably be technical superior to the other scenarios but also the most difficult to achieve.

Figure 32 - Scenarios for the technological development direction

8. Evaluate the key question

The key question is answered and useful scenarios are created. The validity of the analysis could however be improved by using experts to repeat the steps. This is left for further research.

Appendix B Actor analysis

This appendix will present the actor analysis. It will start by exploring the approaches and choosing one whereafter numerous steps of that approach are taken.

Conceptual approach

An actor analysis usually includes three dimensions: perceptions, values and resources (Mitroff, 1983; Sabatier, 1988; Scharpf, 1997) but Hermans & Thissen (2009) have proposed a fourth dimension: networks. These are defined as follows:

1) Perceptions: The image that actors have of the other actors and the networks and the substantive characteristics of a policy problem (Bots et al., 2000; Scharpf, 1997).
2) Values: "These provide the directions in which actors would like to move; they describe the internal motivations of actors" (Hermans & Thissen, 2009, p. 809).
3) Resources: "*The practical means or instruments that actors have to realise their objectives*" (Hermans & Thissen, 2009, p. 809).
4) Networks: ''More or less stable patterns of social relations between interdependent actors, which take shape around policy problems and/or policy programmes" (E. H. Klijn, 1997, p. 30).

From these dimensions resources is expected to be the most important one for the realisation of ITNM because it shows which actors have to be involved. Hereafter, the values are second in importance because shows which actors are willing to cooperate and willing to use their resources. The networks are third in importance because they can show how the resulting decision-making will take place and because of its link with institutional design (discussed in Chapter 6). Finally, the perceptions are also important but difficult to analyse with substantively more interviews or questionnaires. Due to limited time this is only described to a conceptual level (Section 5.5) and empirical evidence is left for further research. This prioritisation helps to select a method in the next section.

Method

Hermans & Thissen (2009) have presented an overview of actor analysis methods partly grouped according the four dimensions previously mentioned. From this the stakeholder analysis (Bryson, 2004b; Freeman, 2010) is chosen. This method is practical to apply but its analytic quality not strong because it has limited specificity and logical interconnectedness (Hermans & Thissen, 2009). However, because of the system complexity and the huge number of actors involved this method is chosen due to its practical applicability. Moreover, it can be made with the use of key informants and documents. This allows for its creation before the interviews (Appendix D), such that more in-depth questions can be asked at the interviews where they can validate the outcomes of the analysis. To overcome some of the limitations of the stakeholder analysis, it will be expanded with a few steps in the next section

Steps

Stakeholder analysis methods typically focuses on the dimensions resources and values. It collects and structures information regarding stakeholders, resulting in specific participation strategies for each group. The remaining gap of the networks and perceptions dimensions will be covered in the main report. The stakeholder analysis will consists of the following steps (based on de Bruijn et al., 2010):

1) formulation of a problem as a point of departure;
2) inventory of the actors involved and the grouping of them (the grouping is added);
3) actor filtering (added step)
4) formal chart: the formal tasks, authorities, and relations of actors and the current legislation;
5) determining the interests, objectives and problem perceptions of actors;
6) the interdependencies: between actors by making inventories of resources;

7) the interdependencies: subjective involvement of actors with the problem (this step is separated from step 6);
8) determining the consequences.

These steps will conducted in the next sections.

1. Problem formulation

The problem formulation used in this actor analysis is:

Strategic behaviour and uncertainties hinder development, implementation and operation in the complex socio-technological environment of Integrated Network Traffic Management from a societal perspective.

This involves a set of changes that may impact the involved actors. This includes:

Mandatory changes with INTM

- **Traffic control settings to traffic information providers**: this allows navigation to include the travel time change of traffic control.
- **Improved network distribution and travel time prediction**: the previous data exchange supplies drivers (or their devices) with more information which allows them to better choose routes.
- **Automation of traffic management (assumed)**: It is assumed that traffic management can be more dynamic with INTM and will therefore require automation to determine and execute traffic control changes.
- **Software steering of traffic control (assumed)**: It is assumed that the previous automation is mainly software driven. In practice this means less hardware programmed interactions (i.e. the shift from a smart traffic control installation to server based optimisation)
- **Requires FCD (assumed)**: It is assumed that in order to make better traffic conditions predictions (especially for areas with intersections but without traffic control loop detectors) more traffic data and especially a mixture of traffic data sources is required.
- **Investment of governments, traffic management providers, traffic control providers, traffic information providers** (transition cost): the proposed change will require an investment of diverse parties that they may later earn back.
- **Costs of change** (transition cost)**:** any change to the infrastructure or information service may cause temporal disutility and/or discomfort for drivers and traffic information users.

Additional mandatory changes with OANM

- **Central steering of traffic control**: OANM will require some form of network wide optimisation as described in the controlled and coordinated scenario (Section 4.2).
- **Additional improved network distribution**: OANM will improve traffic distribution (towards Stackelberg optimum as described in Section 2.3.4). It will affect highly used and congested roads of meshed networks with lots of traffic control the most.
- **Steering for societal goals**: By imposing longer travel times with traffic control for e.g. residential areas, drivers can be motivated to drive around them.

2. Identification and grouping of actors

The step will identify the actor of the INTM system. For this, this research adopts the definition of an actor of Enserink et al. (2010) as “a social entity, person or organisation that has a certain interest in the system and/or is able to influence the system directly or indirectly”. This definition is wider than the definition of a stakeholder since it includes entities that do not have an interest but are able to influence the system and is chosen because it prevents the negligence of a possible reasonable impactful actor.

To identify actors Mitroff (1983) and Enserink et al. (2010) described several approaches. From these approaches a combination of the positional (review existing policy making structures) and reputational approach (ask key informants to identify important actors) are chosen for practical reasons, along with the system analysis made in Chapter 3. The first is conducted with desk research by reviewing legislation, tendering documents, policy pieces. Hereafter, the reputational approach is used by utilising the knowledge of the research supporting company to verify and complement the list. Then the result is a list of numerous actors that are, often 'composed' (i.e. involved in the problem(s) with more than one of its parts) and active in multiple functions. To structure them, two value chains have been constructed (listed in below) to identify and group actors on the basis of their function in the chain. The considered chains are "traffic management development & implementation" and "operational traffic management". At the end of both chains the public has a certain experience which is included although they do not have a direct function but they do have an interest. Hereafter, other parties are added that do not have a production influence but do have an interest.

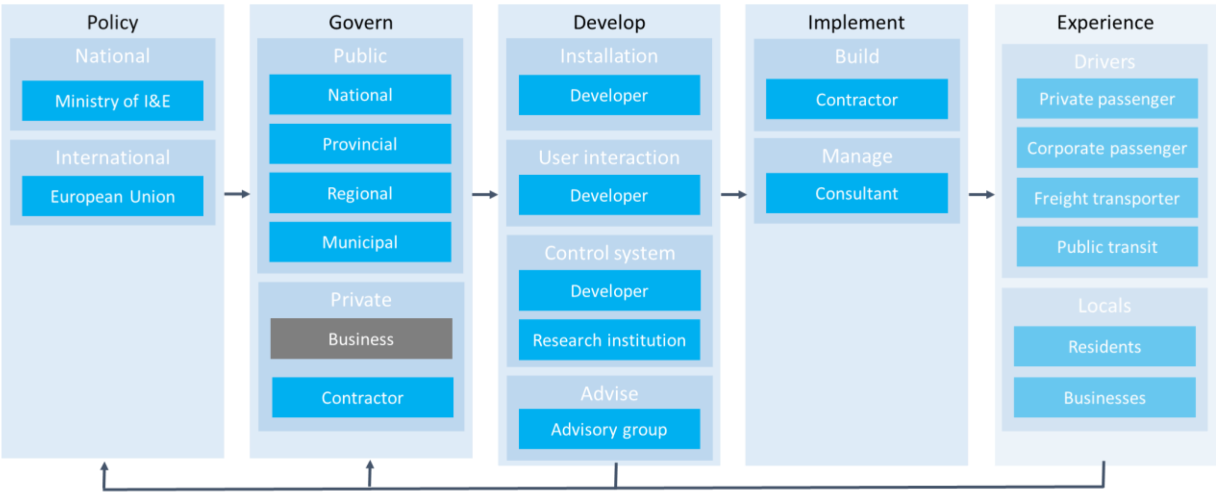


Figure 33 - Value chain Traffic management development & implementation

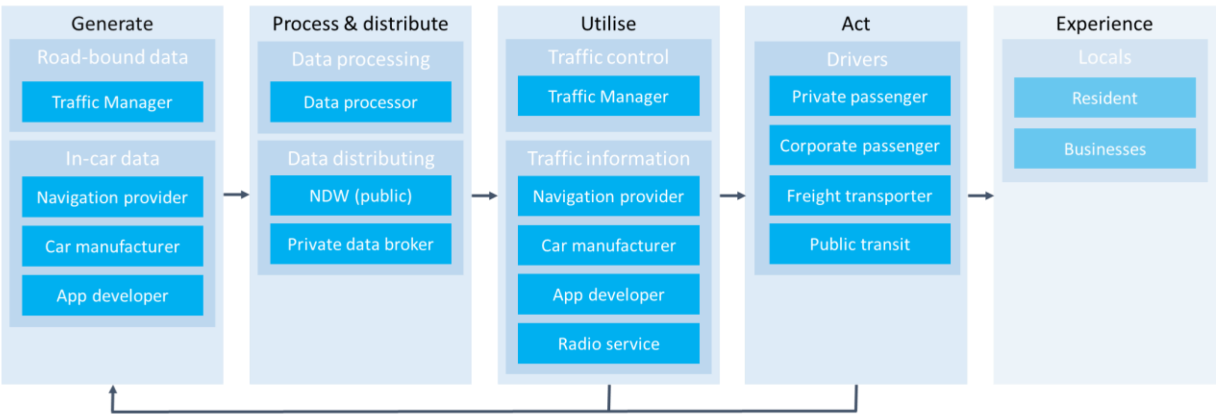


Figure 34 - Value chain operational traffic management

Actors in the value chain above are described and decomposed below on role (in blue), actor group (based on function). In this for example, the driver has the role of road user and traffic information user. Each actor group is subsequently decomposed into its actors or departments. Sometimes only an example of individual actors is given because there are too many actors to present and to be of practical use. If this is the case, several dots are presented to illustrate that it is an incomplete list. Finally, facilitating parties are added to group the parties that facilitate technical services vital to operational traffic management and interest groups are added to group the remaining actors with an interest.

Government policy developer

Responsible for the public infrastructure of the Netherlands.

- National government of the Netherlands
  - Ministry of infrastructure and the environment (Departments from Ministry of Infrastructure and the Environment, 2015)
    - Directoraat-generaal bereikbaarheid
      - Directorate roads and traffic safety
      - Program directorate Beter Benutten
- European Union (related departments according European Commission, 2016a)
  - Mobility and Transport (MOVE)
  - Environment (ENV)
  - Informatics (DIGIT)
  - Economic and Financial Affairs (ECFIN)

Road authorities

Governs a certain zone of the road network. According to Rijkswaterstaat (2016a) the following road authorities exist:

- Rijkswaterstaat (related departments from Rijkswaterstaat, 2015)
  - Water, traffic and living environment
  - Traffic and water management
  - Central information provision
  - Districts (16x)
- Provinces (12x) (generalised to following departments on the basis of Provincie Groningen, 2015; Provincie Noord-Brabant, 2016; Provincie Zuid-Holland, 2016)
  - Traffic & transport / Mobility
  - Infrastructure
  - Environment
  - Economy
  - Spatial planning
  - ICT
- Municipalities (389x although many of them have no traffic control see Section 2.1)
  - Variable departments
- Water board (29x)
  - Variable departments
- Private road authorities (outside of the scope)
- Regional cooperation groups: collaborations between road authorities
  - VERDER (Utrecht)
  - Bereik! (Zuid-Holland)
  - De Verkeersonderneming (Zuid-Holland)
  - Beter Bereikbaar Zuidoost-Brabant (Noord-Brabant)
  - BrabantStad (Noord-Brabant)
  - SLIM (Arnhem/Nijmegen)
  - Metropoolregio Amsterdam (Noord-Holland)
  - …

Traffic control facilitators
Design, build. Maintain (and operate) traffic control installations and other road bound infrastructure. (Companies from Platform Beter Benutten, 2016)

- Project contractor: advise/coordinate infrastructure adjustments
    - Technolution
    - Logica CMG
    - Cap Gemini
    - Imtech
    - …
- Traffic control providers: suppliers of traffic control hardware
    - Siemens Nederland
    - KoHartog Verkeerstechniek
    - Vialis
    - Heijmans Wegen
    - Ziut
    - Royal Haskoning DHV
    - Trinité Automatisering
    - Dynnyq
    - Technolution
    - Swarco Nederland
    - Sweco Nederland
    - Ars Traffic & Transport Technology
    - …
- Traffic management systems: suppliers of software systems that coordinate traffic control
    - Trinité
    - Technolution
    - …

Advisory development parties
Groups of experts that advice governmental bodies regarding traffic or infrastructure management.

- (Technical) consultancy firms
    - TNO
    - Witteveen & bos
    - ….
- Research institutions
    - Universities
    - ..
- Cooperation groups: collaborations between public and private parties
    - Strategisch Beraad Verkeersinformatie en Verkeersmanagement
    - MOGIN
    - Landelijke VM gremia
    - High Level Group (5 november groep)
    - Regiegroep Verkeersinformatie
    - Organisatiestructuur Incident management
    - IM-Beraad (strategic)

  - Landelijk Platform IM (tactical)
  - Programmabureau IM (operational)
  - Overige IM samenwerkingsvormen
  - Connekt
  - DITCM Innovations
  - Platform Marktversnelling Mobiliteitsinformatie (MMI)
  - VEMODIS
  - ASTRIN
  - CROW/KpVV
  - Wegbeheerders Ontmoeten Wegbeheerders
  - Innovatieberaad
  - Club van Maarssen
  - Ronde Tafel
  - Talking Traffic
  - Landelijk Verkeersmanagement Beraad
  - DVM Exchange
  - …

Traffic data collector

Collect traffic data from the network.

- In-car (Companies from Platform Beter Benutten, 2016)
  - Navigation service Providers
    - TomTom
    - …
  - Automobile Manufacturers
    - BMW
    - Opel
    - ..
  - Smartphone Application Providers
    - Innovactory International
    - ARS T&TT
    - Flitsmeister
    - Cygnify
    - Traxpert
    - …
- Road-bound
  - Road authorities/Traffic manager

Traffic data processor and/or (re)distributor

Merge and process traffic data for traffic management applications. (Companies from Platform Beter Benutten, 2016)

- Public
  - NDW (Nationale Databank Wegverkeersgegevens)
- Private
  - FileRadar
  - Siemens Nederland
  - HERE Europe

    - TomTom Global Content
    - Be-Mobile
    - PTV Nederland
    - Technolution
    - Ericsson Telecommunicatie
    - Alcatel-Lucent Nederland (NOKIA)
    - KPN
    - Vialis IT&M
    - Ars Traffic & Transport Technology
    - Simacan
    - Cisco Systems International
    - …

Traffic information provider

Supply the road users with information regarding traffic conditions and travel times.

- In-car
    - Navigation service Providers
        - TomTom
        - …
    - Automobile Manufacturers
        - BMW
        - Opel
        - ..
    - Smartphone Application Providers
        - Innovactory International
        - ARS T&TT
        - Flitsmeister
        - Cygnify
        - Traxpert
        - …
    - Radio traffic services
- Road-bound
    - Road authorities/Traffic manager

Traffic manager

Manage traffic with road bound traffic installations

Drivers

People that use the road and the road-bound infrastructure and traffic information separated on the basis their function (i.e. what they transport).

- Private passenger transport: People that use the road for a personal occasion
- Corporate passenger transport: People/businesses that use the road for a business related occasion
- Freight transport: Businesses that transport goods
- Public transit: shared passenger-transport service which is available for use by the general public

Locals
Experience the effect of traffic.

- Residents
- Businesses
- Visitors

Infrastructure Managers
Maintain the roads on behalf of the traffic authority

- Public
  - Department of road authority
- Private: project contractor that maintains the road in e.g. DBFM contract
  - BAM
  - Strabag
  - …

Facilitating parties
- Telecom
  - KPN
  - …
- Satelite positioning
  - GPS
  - Galeileo
  - ..
- Car manufacturing
  - BMW
  - Toyota
  - ….
- Map producers
  - tomtom
  - here
  - navteq
  - …

Collaboration groups
- Public groups
  - Interprovinciaal Overleg (IPO)
  - Vereniging van Nederlandse Gemeenten (VNG)
  - Samenwerkende Kaderwetgebieden Verkeer en Vervoer (SKVV).
  - WOW (wegbeheerders ontmoeten wegbeheerders) platform
  - ….
- Public-private
  - ….
- Private
  - ….
- International/european
  - ITS Europe
  - GS1 Germany

- International Road Federation (IRF)
- European its-platform
- …

Interest groups

Diverse national groups that may have an interest regarding the realisation of integrated traffic management.

- Mobility & transport
    - Vlaams Instituut voor de Logistiek (VIL)
    - Logistics in Wallonia
    - Platform Jong Logistiek Nederland
    - Programma Impuls Dynamisch Verkeersmanagement Vaarwegen (IDVV)
    - AutomotiveNL
    - Stichting Nederland is Logistiek
    - Topsector Logistiek – Strategisch Platform Logistiek
    - Branche-organisatie verkeersindustrie Astrin
    - Freight Leaders Council
    - ..
- Environmental parties
    - Green peace
    - …
- Traffic safety
    - SWOV
    - ….
- Technology
    - Platform BISON
    - GeoBusiness Nederland

Note on governmental parties

The governmental parties are composed. They have multiple directorates/departments (Ministry of Infrastructure and the Environment, 2015; Provincie Groningen, 2015; Provincie Noord-Brabant, 2016; Provincie Zuid-Holland, 2016; Rijkswaterstaat, 2015) that are involved with INTM. Since quite some variance exist between the different parties the following decomposition is suggested (see Figure 35). This is a simplification of reality but allows for the naming of groups of public parties. Some notes on the decomposition: it implicitly shows hierarchy although this is rather limited in reality; it decomposed operation is three agencies (traffic manager, infra manager and strategic development planner as discussed in Section 2.1) although this decommission will not exist in all road authorities.

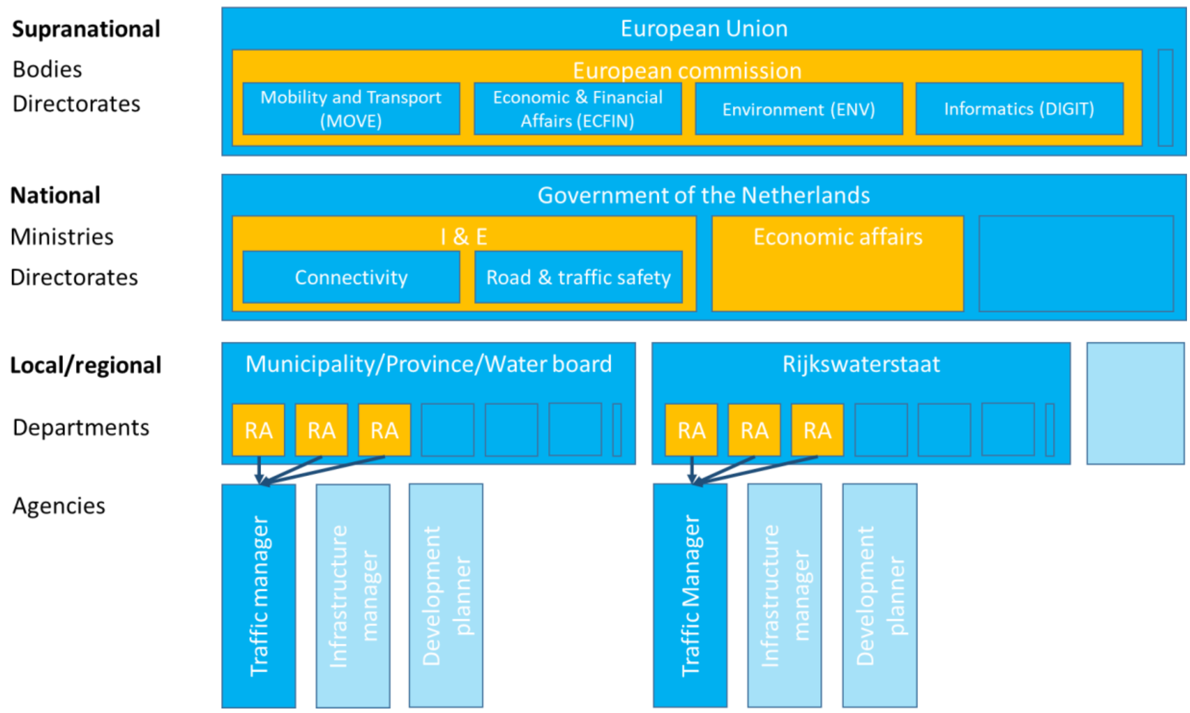


Figure 35 - Decomposition of governmental bodies

3. Actor filtering

Previous step has identified and grouped actors. The result is a large list of actors that is too numerous (35+) to present and analyse. Enserink et al. (2010) state that an actor analysis should contain between ten and twenty different actors as a rule of thumb. Therefore, the list of actors will merged where possible. By including these actors in the first place this research tries to prevent the exclusion of relevant actors, is required to substantiate the exclusion, and leaves the decision of exclusion open for comments. This step affects the following actors:

- Private road authorities are assumed to be outside the area of control of the government and/or has little impact on the outcome of the proposed solution.
- Infrastructure managers, strategic development planner are executive organs that have limited authority.
- Actors in group road users show little deviation in interest, power and perception and are therefore retroactively combined in one group.
- Actors in group locals show little deviation in interest, power and perception (except the visitor who has limited interest) and are therefore retroactively combined in one group.
- Actors in group facilitating parties have either (almost) no interest and/or power so their involvement will be limited and so will the impact of their mutual differences. Therefore they are retroactively combined in one group
- The actors within cooperation groups are usually also represented as individual. To limit the amount of actors in the analysis these groups will not be included which may cause a negligence to the effect of some coalitions.
- Interest groups have a combination of wide spread interests and their influence is limited and indirect. Although the diverging interest they are included as one group.

The resulting list of actors is shown in the table below.

Table 14 - Filtered actor groups

Actor group (function)	Role	Cluster
European Union (international government)	Government policy developer	Public organisations
government of the Netherlands	Government policy developer	Public organisations
Rijkswaterstaat (national road authorities)	Supervisor, Traffic information providers	Public organisations
Province Road Authorities	Supervisor, Traffic information providers	Public organisations
Municipality Road Authorities	Supervisor, Traffic information providers	Public organisations
Water board road authorities	Supervisor, Traffic information providers	Public organisations
Traffic manager	Traffic manager	Public/Private
Project contractor	Traffic control facilitators	Private firms
Traffic control providers	Traffic control facilitators	Private firms
Traffic Management systems Developers	Traffic control facilitators	Private firms
Consultancy firms	Advisory development parties	Private firms
Research institutions	Advisory development parties	Public organisations
Navigation providers	Traffic data collector, Traffic information providers	Private firms
Automobile manufacturers	Traffic data collector, Traffic information providers, Facilitating parties	Private firms
smartphone App Providers	Traffic data collector, Traffic information providers	Private firms
Private data processor and/or (re)distributor	Traffic data processor and/or (re)distributor	Private firms
Public data processor and/or (re)distributor (NDW)	Traffic data processor and/or (re)distributor	Public organisations
Drivers	Road users, Traffic information users	End user
Locals	Locals	End user
Facilitating parties	Facilitating parties	Public/Private
Interest groups	Interest groups	End user

4. Mapping formal relations

The positions of actors and their characteristics are formed by their relations. These relations have a formal and an informal side. This step maps out the formal positions and relations because these can be constructed on the basis of public documents. This step can subsequently be used to map all relations (formal and informal).

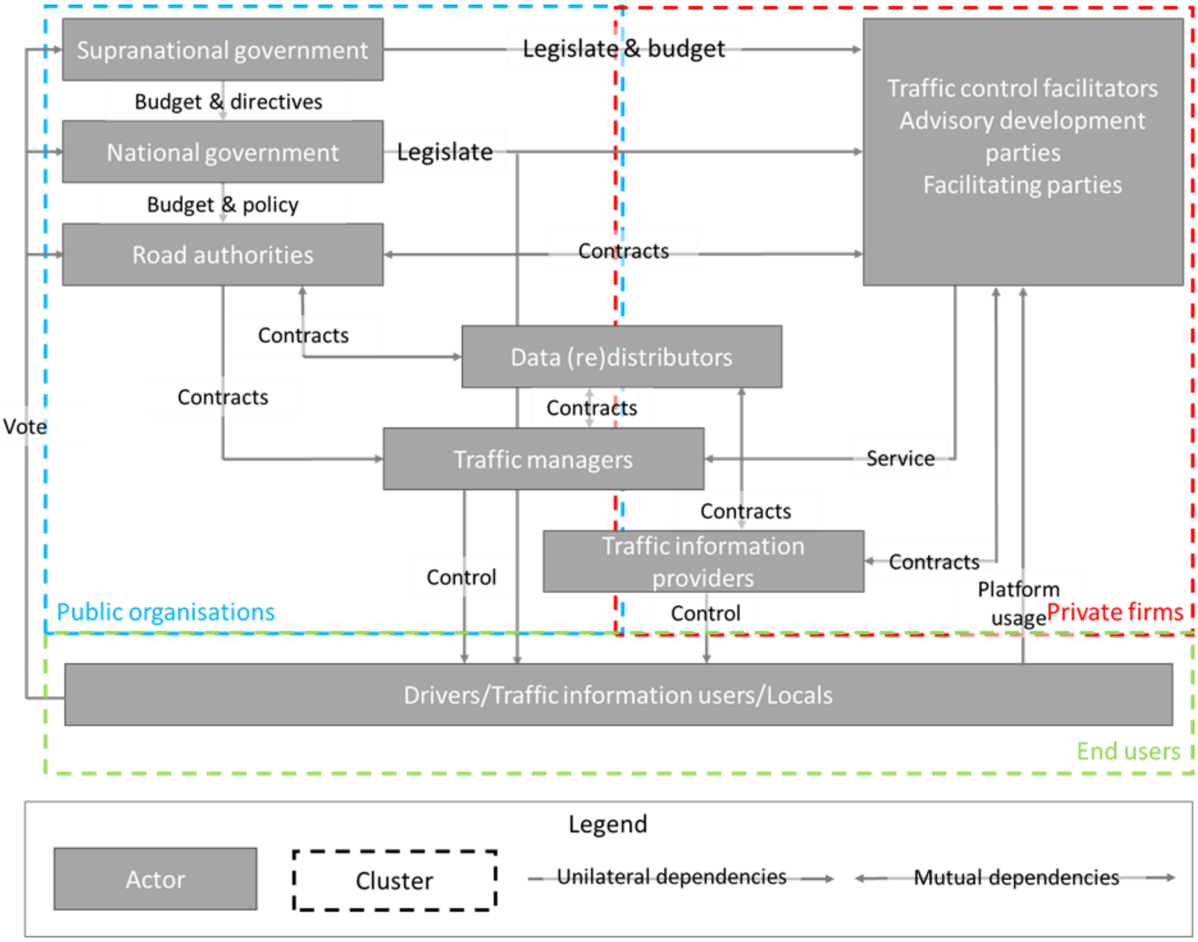


Figure 36 - Formal relations

Form the figure above can be deduced that the government formally holds an important, if not the most important, role. Private parties are most of the time dependant on contracts with mutual dependencies. Drivers, locals and society have a weak formal role. They may only vote each couple of years and choose which platform they use. Additionally, they may choose to move relocate but this is left out of the diagram. So the formal relations show a mixture between a hierarchy and a network characteristics (unilateral and bilateral dependencies.

5. Actor interests, objective and problem perception

The perception of an actor is crucial for how he or she will behave. To analyse this the following elements are being used:

- Interests are defined as "the total of values and desires that an actor finds important regardless of the specific situation" (Enserink et al., 2010, p. 54).
- Objectives are interests made concrete and only those that are directly related to the problem situation should be listed (Enserink et al., 2010, p. 93).
- Existing or expected situation and gap is the previous objective is compared with the future formulated in chapters 4 and 5 in contrast to the current situation.
- Causes list the cause for previous gap.
- The possible solutions is the solution from their viewpoint and determines which strategic direction they will want to go.

These elements should be written for the view of the actor as much as possible on the basis of documents or on the basis of the interviews (Appendix D). This because they may have different information and/or a different interpretation of this information than the researcher. However, since this analysis uses actor groups instead of actors specifically, the elements are of a higher aggregation level. To acquire the elements (e.g. interests) there are four options: use interviews, use public information one of the actors as example of the actor group, analyse public information numerous actors from the group and use average or use induction. It is chosen to use the interviews for the main actor groups and induction for the others (with some sources if possible). This because, public information is often subjected to framing and often not specifically applicable to INTM, one actor as example is rather a limited information source and analyse public information numerous actors requires a lot of effort without a lot of estimated increase of accuracy. The limitation of the chosen approach is that it is subjected to different interpretation of the researcher.

Table 15 - Actor perception matrix

Actor group (function)	Interests	Desired situation / Objective	Existing or expected situation and gap	Causes	Change (transition) cost/profit	Proposed change perception
European Union	Prosperity, mobility & liveability European Union	Increase road network performance in the EU	Limited road network performance increase	Numerous incompatible traffic management systems, limited innovation and sub optimal network steering		Positive
government of the Netherlands	Prosperity & liveability Netherlands	Increase road network performance with limited investment	Limited road network performance increase from their investments	Numerous incompatible traffic management systems, limited application of innovation and sub optimal network steering	Initial investment to facilitate change	Positive but reluctant to invest and facilitate active central coordination
Rijkswaterstaat	Mobility, liveability & safety Netherlands	Increase road network performance with limited investment	Limited road network performance increase from their investments	Numerous incompatible traffic management systems, limited application of innovation and sub optimal network steering	Initial investment to facilitate change, transition caused suboptimal system behaviour	Positive but hesitant to reduce control own and commit to data exchange given uncertainty and complexity
Province Road Authorities	Maintain or improve their road network and its performance	Increase road network performance with limited investment	Limited road network performance increase from their investments	Numerous incompatible traffic management systems, limited application of innovation and sub optimal network steering	Initial investment to facilitate change, transition caused suboptimal system behaviour	Positive but hesitant to reduce control own and commit to data exchange given uncertainty and complexity
Municipality Road Authorities	Maintain or improve their road network and its performance	Increase road network performance with limited investment	Limited road network performance increase from their investments	Numerous incompatible traffic management systems, limited application of innovation and sub	Initial investment to facilitate change, transition caused suboptimal	Positive but hesitant to reduce control own and commit to data exchange given uncertainty and complexity

				optimal network steering	system behaviour	
Water board road authorities	Maintain or improve their road network and its performance	Increase road network performance with limited investment	Limited road network performance increase from their investments	Numerous incompatible traffic management systems, limited application of innovation and sub optimal network steering	Initial investment to facilitate change, transition caused suboptimal system behaviour	Positive but limited benefits of proposed changes so reluctant to commit
Traffic manager	Maintain or improve performance road network	Fulfil/preserve job	Job might be at risk or might change	Automation	Job requirements change	Reluctant
Project contractor	Economic profit (& public image)	Income from infrastructure projects	Possible reduction of income	A shift from infrastructure building to traffic management and control		Reluctant
Traffic control providers	Economic profit (& public image)	Income from sales and maintenance traffic control systems	Income uncertain because traffic control installations may become more simple	Traffic management systems seem to take over some of the local hardware tasks	If standards are changed so does the infrastructure	Reluctant
Traffic Management systems Developers	Economic profit (& public image)	Income from sales and maintenance traffic management systems	Unsure future and better products often do not lead to more income	Technical complexity, uncertain demand and lack of performance incentives	Standards adaptation	Are likely to improve sales and the market position of TMD
Consultancy firms	Economic profit (& public image)	Income from infrastructure, traffic management or strategy projects	Many clients	Decentral approach enables the selling of similar advice		Services required more initially for transition but centralisation can impact future need
Research institutions	Scientific and technological research	Published research	Research is only limited applied	Multi actor environment and technological uncertainty		Positive
Navigation providers	Economic profit (& public image)	Preserve or improve profit and amount of their users	Amount of users is likely to increase if they cooperate (for a cost?)	Value of traffic information increases	Facilitate change, Co-invest?	Positive
Automobile manufacturers	Economic profit (& public image)	Preserve or improve profit of traffic information and car buyer satisfaction	Amount of users is likely to increase if they cooperate (for a cost?)	Value of traffic information increases	Facilitate change, Co-invest?	Positive
smartphone App Providers	Economic profit (& public image)	Preserve or improve profit and amount of users	Amount of users is likely to increase if they cooperate (for a cost?)	Value of traffic information increases	Facilitate change, Co-invest?	Positive

Private data processor and/or (re)distributor	Economic profit (& public image)	Improve profit	They could sell data but demand more money than the government is willing to pay for data	Data exchange is likely to improve system prediction		Sceptic
Public data processor and/or (re)distributor	Mobility in the Netherlands	Facilitate an efficient traffic data exchange	Potential more usage of NDW	INTM and OANM require traffic data exchange	Facilitate change	Positive
Drivers	Mobility	Improve quality of transportation and traffic information	Unreliable and longer travel times and contradicting traffic information	Suboptimal network distribution and multiple traffic information providers	Traffic information switching costs, transition caused delay	Under informed
Locals	Accessibility, safety & environment	Improve access time, reduce noise, air and aesthetic pollution and reduce traffic accidents	Limited accessibility, safety and too much pollution	Traffic through area of interest	Transition caused congestion	Under informed
Facilitating parties	Providing service	Improve profit or amount of users	More users	Value of traffic information increases so the usage of (and commercial interests along with) traffic information increases		Neglect
Interest groups	Protect interests	Improve or preserve interests	Likely to improve but rather uncertain	Technical complexity and uncertainty and limited information about this	Create awareness if needed	Under informed

6. Resource dependency and actor criticality

This step identities which actors are critical in the process because they have to contribute a certain resource. Herein, resources are "*the practical means or instruments that actors have to realize their objectives*" (Hermans, 2005). The following types of resources can be distinguished according to Kok (1981) although this list is assumed to be incomplete:

- information
- knowledge (and skills)
- manpower
- money
- authority/formal power
- position in the network (support from or access to other actors)
- legitimacy
- organisation (ability to mobilize and use resources effectively and efficiently

The resources that the actor has, may result in a dependency (described by Hanf & Scharpf, 1978). In this research this is defined by the resource importance (limited, medium or great) and the resource replicability (easy, average, difficult), which are estimated by the researcher. Hereafter the following rule is applied to determine actor dependency (Resource importance & Resource replicability = dependency):

- Limited & easy = no
- Limited & average = no
- Limited & difficult = no
- Medium & easy = no
- Medium & average = no
- Medium & difficult = yes
- Great & easy = no
- Great & average = yes
- Great + difficult = yes

The given definitions result in the following table.

Table 16 - Actor resources

Actor group (function)	Resource type	Resource importance	Resource replicability	Actor production dependency
European Union	Money, authority, position	Great	Average	Yes
government of the Netherlands	Money, authority, position	Great	Difficult	Yes
Rijkswaterstaat	Money, legitimacy, position	Medium	Difficult	Yes
Province Road Authorities	Money, authority, position	Great	Average	Yes
Municipality Road Authorities	Money, authority, organisation	Great	Average	Yes
Water board Road Authorities	Money, authority	Great	Easy	No
Traffic Manager	Knowledge	Limited	Easy	No
Project Contractor	Lobby	Limited	Easy	No
Traffic Control Providers	Organisation	Great	Average	Yes
Traffic Management Developers	Knowledge, manpower, position	Great	Average	Yes
Consultancy Firms	Knowledge, manpower	Medium	Easy	No
Research Institutions	Knowledge	Medium	Average	No
Navigation Providers	Knowledge, money, Information	Great	Average	Yes
Automobile Manufacturers	Knowledge, money, position, Information	Great	Average	Yes
Smartphone App Providers	Knowledge, Information	Great	Easy	No
Private Data Processor	Knowledge, information	Medium	Average	No
Public Data Processor	information	Medium	Difficult	Yes
Drivers	Lobby, voting, moving, usage	Limited	Easy	No
Locals	Lobby, voting, moving, usage	Limited	Easy	No

Facilitating Parties	Service	Great	Average	No
Interest Groups	Position	Medium	Easy	No

A limitation to this analysis is that it does not yet consider the not interchangeability or the amount of a certain resource (the latter maybe partially in the replicability). E.g. with enough money, knowledge or manpower may be developed or bought. Further research could expand on this. Furthermore, one exception has been made for the facilitating parties, they have not been marked as a production power but rather as a diffuse power.

7. Involvement of actors with the problem

The problem can be resolved if multiple issues are resolved. This research will attempt to identify issues that are or could be games along with the actors involved. Games between actors can originate from the technological problems (from Section 3.5), strategic problems and institutional problems (to be described in Section 6.2). In these games an actor strategically interacts with another actor in an effort to resolve the problem. If actors start to interact (possibly indirect) about this issue it can be seen as a game. The following issues are found:

Development

- Traffic management steering controlled versus independent: Both approaches have their advantages but may be incompatible.

Implementation

- Traffic control hardware versus software: Traffic control can be steered via primarily via hardware or via software. The first may be more robust and the latter more flexible to remote adjustments.
- Regional traffic data to in-car traffic information provider: Road authorities want their regional traffic information included in in-car traffic information but the traffic information provider has limited interest to do so.
- Traffic data ownership of traffic control to vehicle communication: It is unclear who will own the data from traffic control to vehicle communication.
- Automation: Traffic control optimisation will be done with real-time traffic control optimisation software rather than by consultant time by time. This is likely to harm the economic interests of the consultants and benefit the traffic management providers.

Operation

- Automation: Traffic control optimisation will be done with real-time traffic control optimisation software. This is likely to reduce the work that has to be done in a traffic management centre. This may result in job loss.
- Traffic control data exchange: This data is valuable to traffic information providers but road authorities might want something in return.
- Aggregated route advice to traffic management authorities: Knowing where drivers are going to enables more accurate predictions of future traffic distribution. This data is however owned by traffic information providers that may not want to sell this data.
- Route guidance: is the driver supplied with the individual shortest route or with a route that is in the general interest.
- Privacy: The data has more value when it is not aggregated. But this poses a risk for privacy.

Not every actor is directly involved in each issue. Moreover, sometimes an actor is affected by (the outcome of) the issue or has resources that can help to resolve the issue without being directly involved. The table below has been created to illustrate this (where full colour marks a direct involvement and half colour an indirect involvement) for the previous described problems. This is done on the basis of the limited knowledge of the researcher but may serve a basis to form a process.

Table 17 - Actor issue involvement matrix

Stage	Dev.	Implmentation				Operation				
Actor\issue	TM controlled vs. independent	Traffic control approach	Regional traffic data	Traffic data ownership I2V	Automisation	Automisation	Traffic data exchange	Aggregated route advice	Route guidance conflicts	Privacy
European Union										
Government of the Netherlands										
Rijkswaterstaat										
Province road authorities										
Municipality road authorities										
Water board road authorities										
Traffic manager										
Project contractor										
Traffic control providers										
Traffic management developers										
Consultancy firms										
Research institutions										
Navigation providers										
Automobile manufacturers										
Smartphone app providers										
Private data processor										
Public data processor										
Drivers										
Locals										
Facilitating parties										
Interest groups										

8. Determining the consequences

On the basis of step 5 and 6 an quantitative assessment can be made of the level of interest power and attitude of an actor. This has been done in the table below.

Table 18 - Actor interest, power, attitude table

Abr.	Actor group (function)	Interest	Power	Attitude
EU	European Union	3	10	8
Nl	government of the Netherlands	4	9	7
Rws	Rijkswaterstaat	5	8	7
PRO	Province Road Authorities	6	6	7
MRO	Municipality Road Authorities	8	7	8
WRO	Water board Road Authorities	3	4	6
TM	Traffic Manager	6	3	3
PC	Project Contractor	4	3	2
TCP	Traffic Control Providers	8	6	3
TMD	Traffic Management Developers	10	8	9
CF	Consultancy Firms	6	4	4
RI	Research Institutions	7	4	10
NP	Navigation Providers	6	6	8
AM	Automobile Manufacturers	4	7	7
SAP	Smartphone App Providers	5	4	8
PriDP	Private Data Processor	5	4	4
PuDP	Public Data Processor	6	5	8
Dr	Drivers	4	3	8
Lo	Locals	6	4	9
FP	Facilitating Parties	2	4	6
IG	Interest Groups	5	5	8

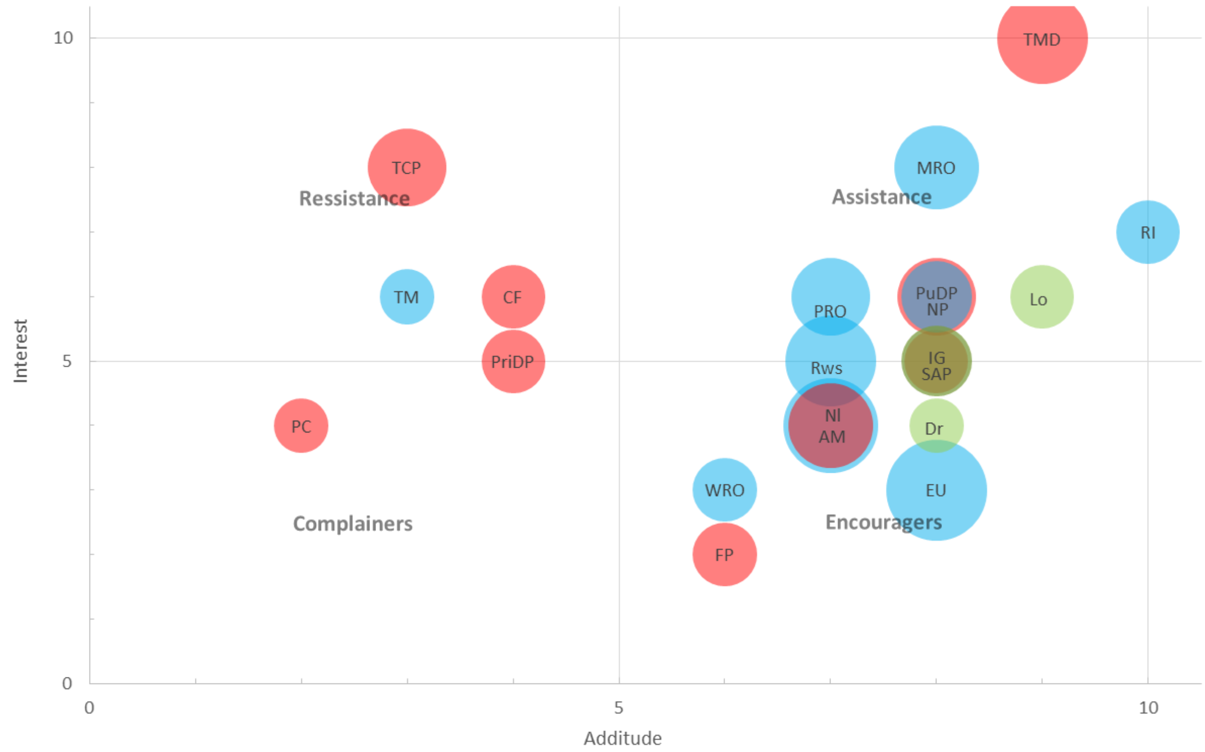
Graphically previous table can presented in a power interest grid as suggested by Eden & Ackermann (1998). This is presented in the following diagram (see previous table for abriviations).

Figure 37 - Power interest diagram

According to Johnson et al. (2005) the following response is required:

- Context setters: keep satisfied
- Key players: manage closely
- Crowd: monitor (minimum effort)
- Subjects: keep informed

An alternative presentation is proposed that also includes interest and is presented in the figure below.



Abr.	Actor group (function)
EU	European Union
Nl	government of the Netherlands
Rws	Rijkswaterstaat
PRO	Province Road Authorities
MRO	Municipality Road Authorities
WRO	Water board road authorities
TM	Traffic manager
PC	Project contractor
TCP	Traffic control providers
TMD	Traffic Management Developers
CF	Consultancy firms
RI	Research institutions
NP	Navigation providers
AM	Automobile manufacturers
SAD	smartphone App Providers
PriDP	Private data processor and/or (re)distributor
PuDP	Public data processor and/or (re)distributor
Dr	Drivers
Lo	Locals
FP	Facilitating parties
IG	Interest groups

Symbol	Meaning
	Power
	Public party
	Private party
	End user
	Public/private party

Figure 38 - Attitude, interest, power diagram

The interpretation of this diagram is that especially the larger bullets on the top left (e.g. TCP) are strong opponents and that especially the larger bullets on the top right are strong proponents.

The resources identified in step 6 determine the type of power that an actor has. According to de Bruijn & ten Heuvelhof (2008) this leads to three types of power positions:

- **Production power**: the power to can make a positive contribution towards the realisation of something.
- **Blocking power:** the power to (only) prevent something.
- **Diffuse power**: an power position that is (yet) unclear. This actor produce, block or it is unclear whether an actor wants to use his resources.

When the resources of the actors are categorised based on the differentiation of above, the following table can be constructed with this and the level of interest and attitude. Herein, a fence sitter has interest lower than 5 and if above the attitude higher or lower than 5 determines opponent vs proponent.

Table 19 – Actors' power type and attitude

Actors with power	Production	Blocking	Diffuse
Proponents	Rijkswaterstaat, Province Road Authorities, Municipality Road Authorities, Traffic Management Developers, Navigation Providers, Public Data Processor	Locals	Smartphone App Providers
Opponents	Traffic Control Providers	Traffic Manager	Private Data Processor
Fence sitters	European Union, government of the Netherlands, Automobile Manufacturers	Drivers	Facilitating Parties

Actors with one of the types of power described above are considered to be critical actors. In they have an interest level above 5 they are considered to be dedicated. This together with the attitude gives the following overview.

Table 20 - Classification of interdependencies

	Dedicated actors		Non-dedicated actors	
	Critical	**Non-critical**	**Critical**	**Non-critical**
Similar/Supportive interests	Rijkswaterstaat, Province Road Authorities, Municipality Road Authorities, Traffic Management Developers, Navigation Providers, Smartphone App Providers, Public Data Processor, Locals	Research Institutions, Interest Groups	European Union, government of the Netherlands, Automobile Manufacturers, Drivers, Facilitating Parties	Water board Road Authorities
Conflicting interests	Traffic Manager, Traffic Control Providers, Private Data Processor	Consultancy Firms		Project Contractor

Per cel the following action is advised:

- Dedicated, critical, similar interests: strong allies thus involve.
- Dedicated, critical, conflicting interests: strong opponents thus listen to them.
- Dedicated, non-critical, similar interests: weak allies thus inform.
- Dedicated, non-critical, conflicting interests: potential critics thus monitor them.
- Non-dedicated, critical, similar interests: indispensable allies thus try to engage them.
- Non-dedicated, critical, conflicting interests: potential strong opponents thus monitor them closely and sooth them.
- Non-dedicated, non-critical, similar interests: less relevant actors thus ignore them.
- Non-dedicated, non-critical, conflicting interests: less relevant actors thus ignore them.

This results in the following general engagement strategy.

Table 21 - General engagement strategy

Strategy	Actors
Involve	Rijkswaterstaat, Province Road Authorities, Municipality Road Authorities, Traffic Management Developers, Navigation Providers, Smartphone App Providers, Public Data Processor, Locals
Engage	European Union, government of the Netherlands, Automobile Manufacturers, Drivers, Facilitating Parties
Listen to	Traffic Manager, Traffic Control Providers, Private Data Processor

Strategy	Actors
Inform	Research Institutions, Interest Groups
Monitor	Consultancy Firms
Ignore	Water board Road Authorities, Project Contractor

Finally, an expectation is made on the basis of induction what the actors' behaviour will be if no intervention takes place. This is not directly used in the research but might offer insight in what will happen if no action is taken as a result of this research.

Table 22 - Actors' individual predicted behaviour without intervention

Actor group (function)	Their individual predicted behaviour without intervention
European Union	Coordination between EU countries
government of the Netherlands	Leaves responsibility with road authorities
Rijkswaterstaat	Muddling through
Province Road Authorities	Muddling through
Municipality Road Authorities	Muddling through
Water board road authorities	Muddling through
Traffic manager	Advice traffic authority to be conservative
Project contractor	Advice traffic authority to be conservative
Traffic control providers	Influence standard to become more hardware orientated
Traffic Management Developers	Wait for demand certainty or be bold and try to predict the demand
Consultancy firms	Resist change
Research institutions	Continue as usual
Navigation providers	Cooperate under the right conditions. Wait and see for now.
Automobile manufacturers	Cooperate under the right conditions. Wait and see for now.
smartphone App Providers	Cooperate under the right conditions. Wait and see for now.
Private data processor and/or (re)distributor	Hold on to resources until the right price is offered
Public data processor and/or (re)distributor	Cooperate
Drivers	Observe unless…
Locals	Observe unless…
Facilitating parties	Observe
Interest groups	Observe for now

Appendix C SWOT/TOWS analysis of OANM

A SWOT analysis is an established (and yet rather basic) method that can be used when formulating a strategy (Dyson, 2004). It originated in a publication of Learned et al. (1965) and aims to identify positive and negative factors of and organisation (internal) and its environment (external). This decomposes a grid which consists of the strengths, the weaknesses, the opportunities and threats. To systematically identify opportunities and threats acronyms exist like PEST and DESTEP to assist with the identification with factors is various dimensions like Political, Technical et cetera. On the basis of these methods the following table has been constructed.

Table 23 - SWOT analysis of OANM

	Internal	**External**
Positive	**Strength** - Cost efficient (in comparison to building more infrastructure)[3] - Driver comfort enhancing - Steering for public interests	**Opportunity** - Autonomous driving - GNSS development - Mobile telecom development - Computational development (e.g. quantum computing) - Traffic modelling techniques development - Possible export product
Negative	**Weakness** - Complexity - Scalability - Traffic data required - Conceptual development stage	**Threat** - Diverse involved parties - Public perception - Unclear product demand/supply

There is a strong overlap between the external factors and the factors found in external input analysis (see Appendix A). The factors in this appendix are however specific for OANM and not for INTM.

When the factors of this grid are found strategies can be developed that build on the strengths, eliminate the weaknesses, exploit the opportunities or counter the threats. However, a variation of the SWOT analysis, the TOWS Analysis (Weihrich, 1982), may assist in this process. In a TOWS analysis the previous identified internal and external factors are combined in pairs to create new strategies.

[3] More research needed to determine how cost efficient OANM is in comparison to other traffic management solutions

Table 24 - TOWS analysis of OANM

	Strength	Weakness
Opportunity	**SO** - Create a cost efficient product that can be exported	**WO** - Increase scalability and compensate for complexity with computational development and traffic modelling techniques - use autonomous driving, GNSS development and mobile telecom development as an opportunity to gain more and better traffic data.
Threat	**ST** **-** Convince the public how their interests are improved (reduced average travel time, increased comfort and maintained privacy) with the OANM approach in an easy understandable way.	**WT** - Use the knowledge of the many involved parties to combat the complexity. - Show an interest in ITM products to facilitate a stable product supply and get OANM out of the conceptual development stage.

It shows that the OANM approach offers the opportunity to cost efficiently increase the network efficiency and that the approach can be exported to foreign countries. Although the proposed approach is complex, its scalability issues and the technical complexity can be compensated with new computational developments, new traffic modelling techniques and by using the knowledge of the many involved parties. Traffic data is required for OANM but autonomous driving, GNSS development and mobile telecom development offer opportunities to gain more and better traffic data. Moreover, the public may oppose the implementation so they need to be convinced of how their interests are improved (reduced average travel time, increased comfort and maintained privacy) in an easy understandable way. So, if the collective of road authorities would show interest in OANM and a strategy is devised to bring the required parties together, it is likely it could be achieved.

Appendix D Interviews

Since information regarding the perceptions of actors regarding INTM is not published, this research will attempt to collect this by conducting a number of interviews. This appendix describes the setup and presents the results of these interviews.

Goal

The goal of the interview is to verify the theoretical found problems (in an attempt to create negotiated knowledge) and to acquire the perception of important actors on the problems and institutional direction.

Approach

The chosen interview approach is a semi-structured quantitative face-to-face interview. It is semi-structured because this approach is used when there is some knowledge about the topics or issues (from the theoretical analysis), but further details are still needed (C. Wilson, 2014). It allows for the gathering of facts, attitudes, and opinions on identified issues and goals, but provides users with the opportunity to raise new issues (C. Wilson, 2014). The semi-structured approach gives direction to the interview; it is a mechanism for redirecting conversations that deviate from the topic (C. Wilson, 2014) and provides some certainty that there is enough content to talk about and that certain topics are not forgotten. Furthermore the follow-up questions and probes can explore and clarify and complex topics (C. Wilson, 2014) and may lead to a better dialog that may enthuse respondents. It is achieved by preparing and using a set of questions (adaptable per type of actor) that are relatively simple open questions. In such questions respondents can answer in their own terms, give non contemplated responses, do not receive suggestions for certain kinds of answers and these questions are useful for exploring new areas or ones in which the researcher has limited knowledge (Bryman, 2012). In this process it is essential that the respondent can talk freely and is not hindered by upsetting or theoretical questions. Finally, it is preferred to be a face-to-face interview (although a video call also is amongst the possibilities) because by telephone an interviewer cannot engage in observation so this limits the response to e.g. signs of puzzlement and an interviewer cannot readily employ visual aids (Bryman, 2012). The downside of the chosen approach is that interviewers can give clues for a particular answer and may therefore affect the result, the findings might be hard to generalize and compare because of the flexibility in questions (C. Wilson, 2014). To compensate for this it is chosen to make the interview 'unravelling', meaning that actors will be first asked about their opinion than given more information to further specify the subject and then asked again. The interview is intended to be an in-depth interview so it might take a while. Bryson (2004b) states that with a long schedule, questions should be grouped into sections to maintain the flow of the interview.

Guidelines and remarks for chosen approach

- Recording interviews (using mobile phone) is essential for (re-)analysis. However the interviews are not fully transcripted to present compact information in the report and due to restricted research time. So the result will be a summary that will be sent for confirmation to the respondent (with deadline) after the interview.
- The list of questions may be adapted throughout the first interviews on the basis of new insights. Any important missing answers may have to be supplemented afterwards though.
- During the interview questions may be modified, questions may be added or deleted (with exception of core questions) and the order of questions may be changed to fit a particular context (C. Wilson, 2014, p. 39)
- The time spent on each question may be varied (C. Wilson, 2014, p. 39).

- Probe the respondent on a question until no new information emerges (Preece, Rogers, & Sharp, 2007).
- Prompt the respondent to assist with recall (Preece et al., 2007).Prompt the respondent to assist with recall (Preece et al., 2007).
- The following should be prevented: questions that are overly long or complex, a double question, obviously biased prompts (but provide some general reinforcement for the participant), interruption of answer (unless necessary) (C. Wilson, 2014).

Selection of respondents

The actor analysis (e.g. interest x power) showed that the following actors groups were most critical in the development and implementation of integrated traffic management solutions. Therefore these are selected for further analysis with the use of interviews. To conduct these interviews respondents are selected that are employees, preferably with a strategic vision, of companies within this group. These have been found using the contacts of this research supporting company. The amount of respondents per group is rather limited due to the research time available. It is chosen to acquire a 'wide picture' by interviewing different actor groups, rather than multiple actors per group and acquiring more empirically valid data. This allows to set a conceptual agenda of the process (Chapter 7). Furthermore, this will mean that the research is more focussed on creating a methodology rather and may need to be repeated to gain more validity. The selection of respondents with a strategic vision may lead to a bias (e.g. negligence of daily problems).

- Traffic authority/ Traffic manager
  - Lieke Berghout (Provincie Zuid-holland/Bereik!)
- Traffic management developer
  - Bas van der Bijl (Sweco)
- Traffic control providers
  - Willem Hartman (Vialis)
- Traffic information provider
  - Jeroen Brouwer (former TomTom)

Interview protocol

Steps on the basis of (Bryman, 2012, p. 219; C. Wilson, 2014)

Activity	Comments/Questions	Approximate time

Introduction	- Start meeting & recorder
	- Present interviewer (Jim)
	    - name
	    - education
	    - purpose of research
	    - facilitating company
	- Get acquainted with respondent
	    - name
	    - age (nr)
	    - gender (male, female)
	    - firm
	    - firm position (policy maker, road authority, traffic manager, consultant, researcher, traffic information provider, data processor, contractor, traffic management provider)
	    - function within firm
		10 m

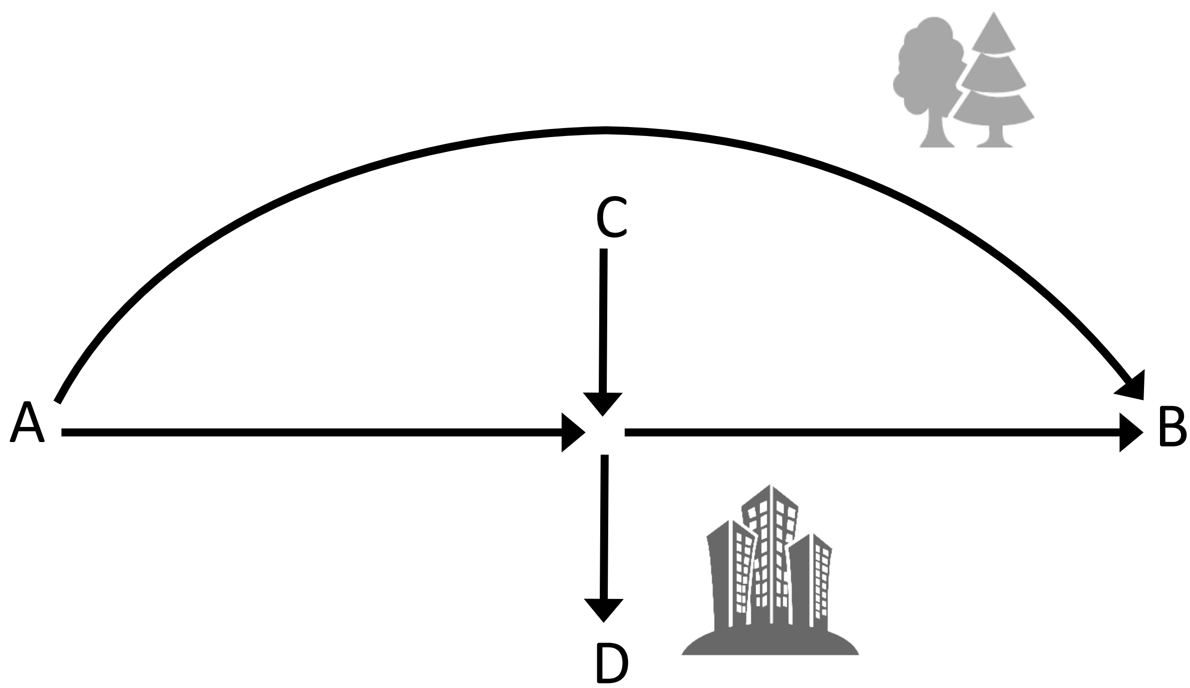
Activity	Comments/Questions	Approximate time
	- experience (0-2, 2-5, 5-10, 10-20, 20+ years) - education (level and direction) - General introduction - interview introduction - interview approach - present protocol - timeframe - interview reporting	
Topics	Repeat 5x - Introduce respondent into the topic - Question and probes	45 m
Closing comments	- Remaining comments and feedback interview - Thank respondent - Stop meeting & recorder	5 m
Process interview	- Summarize interview (disclosed with names and positions of respondents) - Concur summarisation by email (with deadline)	-
Conclude research	- Invite respondent to final presentation - Send copy of report	-

Actor introduction elements

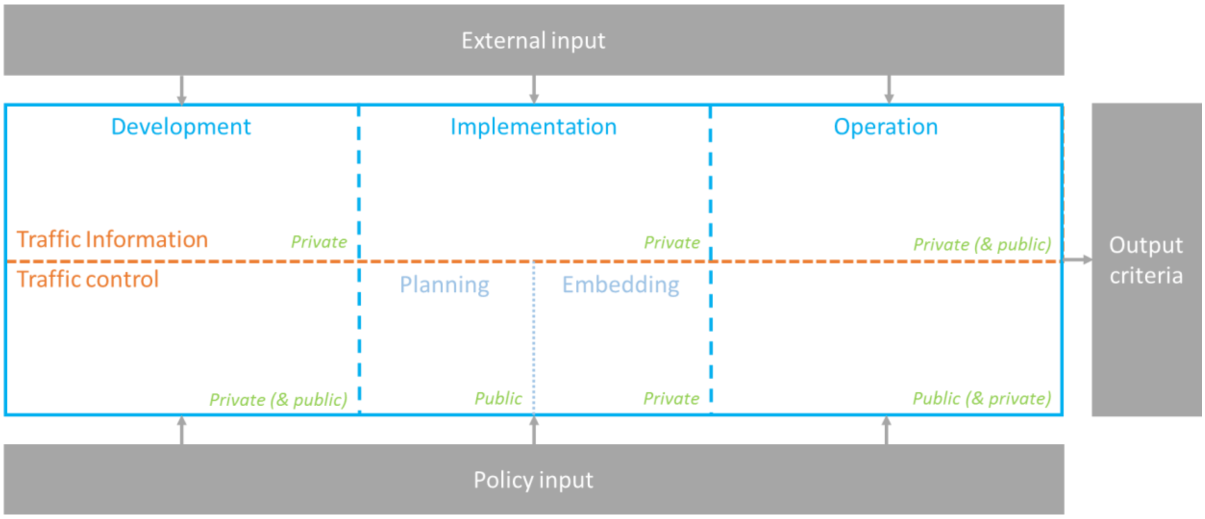
The text below is used to introduce topic by topic to the respondent. Although this is the full text, it serves as a guideline what to tell (not to read out loud) to the respondent, in order to make it personal and keep them engaged. This is written in Dutch, since this will be the language for the interview.

Visual aid for respondent

Example OANM



System diagram



Opinie meter

0 1 2 3 4 5 6 7 8 9 10

Probleem decompositie

Organ	Maats	Fase/Probleem
		Ontwikkeling
		Beperkingen op vraag/aanbod
		Implementatie
		Beperkte prikkeling voor wegbeheerders
		Versnipperde aanpak
		Aanbestedingsinefficiënties
		Trage procedures
		Concessie verantwoordelijkheden conflicten
		Operatie
		Sturingssystemen die niet samenwerken (data uitwisseling en sturingsvorm)
		Versnipperde sturing
		Beperkte prikkeling voor verkeersmanagers

Institutionele richtingen

Verkeersdata

Data bron:

Publiek Privaat

Data verzamelingsrol:

Geen Faciliterend interveniërend Wetgevend

Data openstellen aan

Niemand	Wegbeheerder	Alle publieke partijen	Alle partijen

Deel vraagprijs:

Gratis	Kostprijs	Commercieel

Prestatiedoelen en de bemeting hiervan

Prestatiedoelen

Decentraal	Nationale factoren en meetrichtlijnen	Opleggen van doelen

Actief bemeten end it publiceren (benchmarking)

Niet	Alleen voor projecten met (inter)nationale investering	Alleen projecten	Alle regios

Centrale coordinatie

Grootte traffic management beheerders

Wegbeheerder	Stadsregio	Provincie	Nationaal

Afhankelijkheid binnen traffic management beheerders

Onafhankelijk	Cooperatie	Coordinatie	Integratie

Afhankelijkheid tussen traffic management beheerders

Onafhankelijk	Cooperatie	Coordinatie	Integratie

Centrale supervisie

Geen	Facilitaterend	Stimulerend	Verplichtend

Figure 39 - Example of traffic management authority decomposition

General questions & respondent introduction (for eyes interviewer only)

The questions are designed to tunnel the subject trough the interview. This allows a respondent to first answer unbiased of the researcher's point of view. Hereafter the subject is given additional information (see actor introduction items above) which enables a more in-depth discussion. Finally, the solution direction is presented in a couple scenario's to trigger the respondent into stating his opinion. Each question below contributes to a specific item of the interview goal, namely the verification or actor analysis. The specific item is marked in green behind the question.

Algemene introductie

In de wereld van traffic management is er veel onzekerheid. Door de snelle technologische ontwikkelingen ontstaat er inhoudelijk veel onduidelijkheid maar ook ontstaat er onzekerheid door de strategische gedrag en benodigd het een verandering van normen, waarden en regels. Dit onderzoek richt zich daarop en zal zich focussen op de realisatie van een specifieke aanpak. Omdat strategische belangen een grote rol spelen is de perceptie van de verschillende actoren van groot belang. Daarom ben ik benieuwd naar jou perceptie hierop en zal daar gedurende dit interview achter proberen te komen.

De algemene gedachte gang is dat er veel z.g.n. transactiekosten (e.g. tijd die in onderhandeling/voorbereiding van samenwerkingen gaat zitten) zijn en strategische belangen die voorkomen dat het wegennetwerk optimaal wordt benut. Een betere organisatie van de samenwerking zou dit moet kunnen verbeteren.

Wat is INTM?

Zowel verkeersinformatie als verkeerslichtinstellingen kunnen de distributie van verkeer in het netwerk beïnvloeden. Maar ze kunnen ook elkaar beïnvloeden. Zo kunnen verkeerslichtinstellingen ervoor zorgen dat reistijden anders worden en daarmee reisinformatie beïnvloeden. Omgekeerd is het ook mogelijk, waarbij reisinformatie het routekeuzegedrag van weggebruikers stuurt wat ervoor zorgt dat verkeerslichten een andere instelling behoeven. We spreken van "Integrated Network Traffic Management" (INTM) wanneer deze twee onderdelen op een dynamische manier met elkaar rekening houden.

1) ITM & system overzicht

1.1) Denk je dat de term INTM zo helder en duidelijk is geformuleerd?

1.2) Denk je dat de systeemslayout zo helder en duidelijk is geformuleerd?

1.3) Wat is de ambitie van jou organisatie met betrekking tot INTM? =>desired situation

1.4) Wat is jouw persoonlijke visie op INTM?

a) Ben je verwachtingsvol? (schaal 1-10 met uitleg) => indication awareness of potential and strategic behaviour

b) Ben je gefrusteerd? (schaal 1-10 met uitleg) => indication of problems and transaction costs

Probleem

Strategisch gedrag van actoren en onzekerheden in de complexe sociaal technologische omgeving verhinderen efficiente ontwikkeling, implementatie en uitvoering van Integrated Network Traffic Management (INTM) vanuit een sociaal perspectief.

2) Probleemomschrijving

2.1) Denk je dat de probleem zo helder en duidelijk is geformuleerd?

2.2) Wat denk je dat dit problem bekent of zal gaan betekkenen voor je organisatie? =>interest proponent/opponent

2.3) Welke problemen zijn er nu of voorzie je in de toekomst (binnen dit systeem) die de ontwikkeling, implementatie en uitvoer van INTM kunnen verhinderen? =>additional problems

Probleem decompositie

Zie sectie 3.5.

3) Probleem decompositie

3.1) Denk je dat de probleem decompositie zo helder en duidelijk is geformuleerd?

3.2) Denk je dat ze kloppen? =>problem verification

a) Zo nee, waarom niet?

b) Zo nee, hoe zou je ze veranderen?

3.3) Kun je problemen toevoegen aan de lijst? =>additional problems

a) Conflicten tussen actoren

b) Technische uitdagingen

3.4) Was je je bewust van de problemen? =>interest

3.5) Welke problemen zijn van het grootste belang? (verdeel 15 puntent over de problemen) =>problem verification

(I) Voor de maatschgepij

(II) Voor je bedrijf

3.6) Welke oplossingen voor deze problemen zou je kunnen bedenken? => verification solution direction

3.7) Denk je dat jouw organisatie invloed kan uitoefenen op de toekomst van INTM? (slider 1-10 pluos explanation) =>power

Wat is OANM?
Een (vooralsnog theoretische) vorm van INTM is Online Anticipatory Network Management (OANM). Dit is een aanpak die ten doel heeft om de distributie van het verkeer te verbeteren door het bepalen en toepassen van verkeerslichtinstellingen die de reistijden en de daaruit volgende netwerkverdeling optimaliseren, terwijl weggebruikers (dynamisch) worden geinformeerd over reistijdveranderingen.

4) OANM

- **4.1)** Denk je dat de term OANM zo helder en duidelijk is geformuleerd?
- **4.2)** Zie je een rol weggelegd voor jou organisatie met betrekking tot OANM? =>interest
- **4.3)** Ben je voor op tegenstander tegen een degelijke ontwikkeling (schaal 1-10 met uitleg)? =>proponent/opponent
- **4.4)** Welke middelen kan je bedrijf aan de realisatie hiervan bijdragen? => resources
  a) Zijn dit belangrijke middelen? =>Resource importance

Regels van interactie
Het vorige concept was een technologisch concept. Het zou het systeem er beter op kunnen maken echter zouden lost het de eerder geschetste problemen niet op. Sterker nog, de eerder geschetste problemen kunnen de ontwikkeling, implementatie en operatie van een degelijk concept hinderen of zelfs tegenhouden.

Om de negatieve effecten van strategisch gedrag van actoren en de onzekerheden tegen te gaan, kan de overheid de regels van interactie beïnvloeden. Dit kunnen wetgevende regels zijn maar ook bijvoorbeeld minder formele afspraken met publieke en/of private partijen. Om dit te verkennen heeft dit onderzoek drie richtingen voorgesteld en deze uiteengezet in verschillende dimensies.

Verkeersdata
Verkeersdata (weggebonden of FCD) blijft (vooralsnog) versnipperd over veel verschillende actoren of wordt niet eens opgeslagen. Het biedt commerciële mogelijkheden voor bedrijven maar kan ook verhinderen dat er maatschappelijk wenselijke producten en services worden gerealiseerd. Deze richting bekijkt of en zo ja hoe de overheid hierbij moet ingrijpen. Dit kan centraal (zoals NDW) maar hoeft technisch gezien niet persee.

Prestatiedoelen en de bemeting hiervan
Uniforme prestatiedoelen en bemeting hiervan kunnen competitieve markt faciliteren (hierdoor kunnen producten beter worden vergeleken), zouden er meer uniforme producten kunnen worden ontwikkeld en zou het publieke verantwoordelijkheid kunnen stimuleren. Daarentegen zal het bemeten geld kosten en kunnen uniforme prestatiedoelen decentrale vrijheden verminderen. Daarnaast zou het bemeten (en evt. Een vergoeding op basis hiervan) kunnen leiden prestatiegerichte doch mogelijk perverse prikkels.

Centrale coördinatie
De organisatie van de implementatie en operatie is verspreid, geografisch en op de basis van infrastructuurfunctie. Operationeel vormt dit zones die anders kunnen zijn dan technisch optimale zones voor netwerk verkeersmanagement (wat weer afhankelijk kan zijn van computatie kracht en technische complexiteit van de aanpak). Verder hebben de zones verkeersdata nodig van buurzones en ondervinden ze effecten van de management van buurzones. Dit kan overwonnen worden door samenwerkingen. Deze samenwerkingen hebben ook voordelen voor de implementatie: schaalvergroting, kennis bundeling, en een meer uniforme aanpak. Maar dit kan wel ten kosten gaan

van lokale oplossingen en lokaal beleid. Ook zijn deze samenwerkingen nu op vrijwillige basis waardoor er een grote variëteit van verkeersmanagement autoriteiten zijn.

5) Regels van interactie

5.1) Kan je je vinden in deze oplossingsrichtingen? => verification solution direction

a) Zo nee, waarom niet?

(I) Zijn ze niet bruikbaar of onjuist?

b) Zo nee, hoe zou je ze veranderen?

c) Kun je oplossingen toevoegen aan de lijst? => verification solution direction

5.2) Waar bevinden we ons nu??

5.3) Waar zou je willen dat we naar toe gaan?

a) Kunnen deze oplossingen je organisatie negatief of positief beinvloeden? =>proposed change perception

5.4) Waar verwacht je dat we naar toe gaan?

5.5) Voor welke oplossingen is je organisatie een voorstander? (slider 1-10 plus explanation) =>interest proponent/opponent

a) Zijn er kosten/baten in de transitieperiode naar de oplossingen=>Transistion costs

b) Zul je je na toepassingen van deze oplossingen anders gaan gedragen?

5.6) Kunnen deze oplossingen jou zelf (professioneel) positief of negatief beinvloeden?

6) Zou je nog een van je eerdere antwoorden willen aanpassen?

Interview responses

Metadata	
Number	1
Date	16-02-2017
Time	14:00 - 15:00
Location	Sweco, de Bilt
Personal data	
Name	Bas van der Bijl
Age	31
Gender	Male
Position	Research Manager
Experience	5-10 year
Education	MSc. Traffic Engineering & Management
Firm data	
Name	Sweco
Firm position	Consultant, Traffic management provider
Questions answer summarisation	
1	Sweco has the ambition to fulfil a central role in the integrated traffic management market. They want to achieve this with alliances and a focus on traffic control management systems. Expectation 8 lots of technological opportunities; we're now at the beginning. Frustrated 5 the government is slow and reluctant with implementing these developments
2	-Road authorities are usually do not have the technical background and are therefore not convinced of TM potential

<table>
<tr><td></td><td>-Road authorities are often advised by their traffic managers. Since innovation concerns automation for a large part it might affect the position of the traffic manager. He has therefore incentive to block innovation.
-Consultants have an interest to block automation because they can earn money by advising on traffic control settings each couple of years that is likely to disappear with automation.
-Traffic control vendor lock-in
-There is a group of new market players that try to manage traffic control with a software rather than the original hardware approach
-Depreciation of traffic control systems are long (around 20 years), it may hinder intermediate change. Since the technological future is uncertain it causes road authorities to postpone changes. Furthermore, it causes the system to be less flexible to software innovation.</td></tr>
<tr><td>3</td><td>Problems seem valid and the list seems complete. Bas states that he was passively (not actively) aware of most problems since he is only confronted with a limited number of them on a daily basis.
<table>
<tr><th>Organ</th><th>Society</th><th>Phase/Problem</th></tr>
<tr><td></td><td></td><td>Development</td></tr>
<tr><td>4</td><td>4</td><td>Demand/supply restrictions</td></tr>
<tr><td></td><td></td><td>Implementation</td></tr>
<tr><td>0</td><td>0</td><td>Incentive limitation</td></tr>
<tr><td>1</td><td>1</td><td>Disperse implementation approach</td></tr>
<tr><td>0</td><td>0</td><td>procurement inefficiencies</td></tr>
<tr><td>0</td><td>0</td><td>Sluggish implementation</td></tr>
<tr><td>0</td><td>0</td><td>Concession responsibility conflicts</td></tr>
<tr><td></td><td></td><td>Operation</td></tr>
<tr><td>5</td><td>5</td><td>Incompatible steering</td></tr>
<tr><td>3</td><td>3</td><td>Disperse management</td></tr>
<tr><td>1</td><td>1</td><td>Incentive limitation</td></tr>
</table>

Companies that have invested, have high expectations and interests in their products. This is a strategic interest that may prohibit collaboration initially.

Proposed solutions
-Improve accessibility data
-Increase control areas
-Measure, set goals for (and possibly incentivise on) performance</td></tr>
<tr><td>4</td><td>Bas states that there are in general two approaches: a bottom-up and a top down approach. The first concerns an intersection that optimises traffic control locally whereafter it may interact with other traffic control installations. The second concerns a network optimisation that directs traffic control installation throughout the network whereafter local adaptations can be made. OANM is the latter and shows potential. But it is just one of the approaches and some networks may be better suited for the first and others for the second. Since, OANM involves informing the drivers and traffic information has to be reasonable stable, he states that the bottom-up approach is more dynamic. Eventually, a combination of the both may become possible. Seen the ambition of Sweco they have interest in the potential development of OANM</td></tr>
<tr><td>5</td><td>Institutional directions seem valid.

<table>
<tr><th>Institutional direction</th><th>Dimension\Respondent</th><th>Current</th><th>Ideal</th><th>Expected</th></tr>
</table></td></tr>
</table>

Data	Data source	3	8	8
	Governmental role	5	7	3
	Data sharing	9	10	1
	Sharing price	1	2	10
Goals	Performance goals	1	5	5
	Benchmarking	3	10	3
Centralisation	Size TA authority	2,5	3	3
	Interdependence within TA	6	4	4
	Interdependence between TA	5	5	5
	Central supervision	3	2	2

Data
If data of high quality is gathered and offered to the public, it will empower companies (especially small ones) to develop a wide range of service/products.

Goals
Setting performance goals is a difficult task but Bas thinks that it is a task that should be done by a traffic authority. However, creating a list of factors and benchmarking regions could give a certain transparency. Although this is desirable according to Bas, he doesn't think that it is a likely scenario because of the strategic interests involved.

Centralisation
Bas believes in road authorities with the size of a city region where there is some cooperation between them and within them. He doesn't think that more centralisation is needed because market dominance or agreement can come up with standardised products themselves.

Other
Collaboration between firms can lead to risk reduction and also to a reduction of niche products. It does not have to be promoted further.

Overall
All proposed solutions seem to work in the benefit of Sweco as a traffic management developer but more central organisation can negatively affect Sweco as a consultant role.
Proponent consultant:5
Proponent TDM: 9
Power: 6-10 (dependent of success of product development)

6	-

Comments
-Suggestion received to make problems list better visible

Metadata	
Number	2
Date	21-03-2017
Time	15:00 - 16:45
Location	Sweco, de Bilt
Personal data	
Name	Jeroen Brouwer

<table>
<tr><td>Age</td><td>29</td></tr>
<tr><td>Gender</td><td>Male</td></tr>
<tr><td>Position</td><td>Product manager (former)</td></tr>
<tr><td>Experience</td><td>5-10 year</td></tr>
<tr><td>Education</td><td>BSc. Traffic Engineering</td></tr>
<tr><td colspan="2">Firm data</td></tr>
<tr><td>Name</td><td>TomTom</td></tr>
<tr><td>Firm position</td><td>Traffic information provider (& data processor)</td></tr>
<tr><td colspan="2">Questions answer summarisation</td></tr>
<tr><td>1</td><td>INTM is currently a utopia according to Jeroen.
To describe the ambition of tomtom is important to know that the business model of TomTom has changed. Now they profit most from selling their systems in cooperation with car manufacturers (and not the individual devices or smartphone apps). Doing business with governments is difficult, labour intensive and not so profitable because they often have very specific and sometimes unachievable demands and expectations as well as conflicting interests (steering with a collective vs. individual goal). TomTom wants to contribute in INTM and steer towards a beneficial network distribution. However, the previous hinders its cooperation with governmental parties and may conflict with commercial interests. Thus, it hinders the realisation of INTM.
Personally, he is positive (7 out of 10) about the technological opportunities but sceptic (3 out of 10) about the realisation of INTM. There are lots of challenges that will not be resolved if there is no clear will to do so and the government doesn't invest. Furthermore, he states that he is experiencing frustration (7 out of 10), mainly in his interaction with governments.</td></tr>
<tr><td>2</td><td>Jeroen agrees on the presented problem formulation and system layout.
He believes that INTM is a "nice to have" for TomTom but its core business will remain to provide services for its users.</td></tr>
<tr><td>3</td><td>Generally, Jeroen acknowledges the list of problems and states that he was aware of them. But her remarks the following:

Privacy and traffic data exchange are no issue from his perspective
For traffic information, the following problems do not exist or are rather limited (they do exist for traffic control): lock-in effects, long procedures, dispersed management and concession conflicts
Tendering demands in the Netherlands are too (technically) specific which leads to excessive costs, long duration, limited international companies that compete and eventually incompatibility with the traffic information systems that operate internationally. Innovation of commercial parties should be leading.
Limited incentive for road authorities: some TA's only want to invest when they receive complaints of their inhabitants or companies (example of Haarlem given 1-29:30)
Incentive for the traffic manager seems to be focused to traffic safety and is throughput optimisation secondary. For traffic information providers, this is reversed.

Priority of problems
<table>
<tr><th>Organ</th><th>society</th><th>Phase/Problem</th></tr>
<tr><td></td><td></td><td>Development</td></tr>
<tr><td>10</td><td>2</td><td>Demand/supply restrictions</td></tr>
<tr><td></td><td></td><td>Implementation</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td></td><td>
<table>
<tr><td>1</td><td>0</td><td>Incentive limitation</td></tr>
<tr><td>2</td><td>5</td><td>Disperse implementation approach</td></tr>
<tr><td>0</td><td>0</td><td>Procurement inefficiencies</td></tr>
<tr><td>0</td><td>0</td><td>Sluggish implementation</td></tr>
<tr><td>0</td><td>0</td><td>Concession responsibility conflicts</td></tr>
<tr><td></td><td></td><td>Operation</td></tr>
<tr><td>0</td><td>0</td><td>Incompatible steering</td></tr>
<tr><td>0</td><td>0</td><td>Disperse management</td></tr>
<tr><td>2</td><td>8</td><td>Incentive limitation</td></tr>
</table>
To solve these problems Jeroen thinks that a lot of investment is required and that TomTom has influence (power 8 out of 10).
</td></tr>
<tr><td>4</td><td>
Jeroen sees a role for TomTom with OANM because the traffic control settings could improve the travel time predictions and thus the route advice. He even states that if TomTom would work together with a traffic management provider that a road authority would not have to do anything operational anymore (privatisation of traffic management)
Proponent (9 out of 10)
Resources that TomTom could contribute: Users (15/20% of the Netherlands), Aggregated traffic data, knowledge
</td></tr>
<tr><td>5</td><td>
Data
“Data is the currency of the future. If a government intervenes in this process they disrupt the market” (2-22:30) From this perspective Jeroen states that the governmental role in this should be minimized.
Goals
Jeroen believes in functional goals. The market should then be able to realise those. In order to prevent regional differences these goal factors and their weights should be enforced everywhere in the Netherlands. Measuring these goals would be ideal but it would also cost money and it may therefore not be a viable solution.
Centralisation
Currently there is a lot of variation in traffic management authority sizes. Ideally, this should be national or even international such that traffic data could be bought for a lot bigger area and transaction cost could be avoided. From the market perspective, the collaboration between traffic management zones would have more uniform demands with more cooperation but you would have less individual clients (i.e. they would share more information). Within the traffic management zones integration would be preferable such that they speak with one voice. Central supervision would only increase bureaucracy.
<table>
<tr><th>Institutional direction</th><th>Dimension\Respondent</th><th>Current</th><th>Ideal</th><th>Expected</th></tr>
<tr><td>Data</td><td>Data source</td><td>4</td><td>9,5</td><td>7</td></tr>
<tr><td></td><td>Governmental role</td><td>6,5</td><td>2</td><td>3,5</td></tr>
<tr><td></td><td>Data sharing</td><td>9</td><td>3,5</td><td>4,5</td></tr>
<tr><td></td><td>Sharing price</td><td>5</td><td>9</td><td>5</td></tr>
<tr><td>Goals</td><td>Performance goals</td><td>0,5</td><td>9,5</td><td>9</td></tr>
<tr><td></td><td>Benchmarking</td><td>1,5</td><td>9,5</td><td>6</td></tr>
<tr><td>Centralisation</td><td>Size TA authority</td><td>2,5</td><td>9,5</td><td>4,5</td></tr>
</table>
</td></tr>
</table>

		Interdependence within TA	3,5	9,5	4
		Interdependence between TA	0,5	9,5	2
		Central supervision	6,5	0,5	3,5

6	

Comments

Is there a market for traffic data?
Yes there is. There is B2G for FCD and some instances of road bound data (cameras, bluetooth etc.). Then there is B2G for road bound data gained from public infrastructures and emergency data. This is currently offered for free (according to their open data policy) and it is unclear if companies would be willing to pay for this data. Finally, there is B2C, where consumers pay for a subscription (like TomTom does) or pay indirectly via for example advertisements.

Who will own the data of future traffic control installations that can communicate with vehicles?
This is still unclear at this stage. But, Jeroen thinks this will end up in private hand because it is already happening with the iVRI project for Sweco.

Who are the buyers of FCD?
Diverse parties: governments, traffic information services, consultants, researchers

Metadata	
Number	3
Date	03-04-2017
Time	13:00 - 14:00
Location	Office Metropoolregio Rotterdam Den Haag, Den Haag
Personal data	
Name	Lieke Berghout
Age	43
Gender	Female
Position	Program manager
Experience	10-20
Education	MSc. Traffic Engineering
Organisation data	
Name	Bereik!
Organisation position	Road authority, traffic manager
Questions answer summarisation	
1	The ambition Bereik! has regarding Integrated Network Traffic Management (INTM) is to use it as a means to improve safety, accessibility and liveability. It is a way to distribute the available capacity over traffic equally and in a social preferable way. Lieke describes that there is quite some potential to improve the system. However, many of the development work well in test environments but are often not robust in reality. She states that the (future) operation of a development should be evaluated during the development phase. This may prevent unrealistic or unaffordable products.
2	She describes that the technology development will impact behaviour of the actors involved. As long as development goes slow people will have time to adjust their habits but changing this suddenly can invoke transition costs. Furthermore, there are companies that have interest to preserve current conditions (i.e. stagnate development because of vested interest) or have little benefit from cooperating with the products of other companies.

<table>
<tr><td></td><td>Finally, she described that if you are ahead with a certain system of the others around you, it might be difficult to let go of it once you have it (if you are content with it). However, this is sometimes necessary (e.g. with the arrival of a European standard).</td></tr>
<tr><td>3</td><td>-Budgets of infrastructure vs. traffic management mainly compete in the time (manpower) available. With all the tasks of a public authority there is often only limited attention for traffic management.
-She acknowledges that some road authorities have limited information regarding traffic management developments. Therefore, the larger road authorities that do have the ability to explore traffic management market should give the other road authorities an example to follow or the ability to join. Sunk cost may however limit a smaller road authority to join.
-'Perverse financial incentives exist when more budget is allocated to places with more congestion.' theoretically exist but she doubts if they occur in practice.
-She states that quality is indeed not always clearly defined and that it could be beneficial to do so. But it may limit local exceptions or lead to create tunnel vision (i.e. other non-measured quality factors are neglected).
-Disperse implementation approach is receiving attention in collaboration groups. However, the actions resulting from this are not binding for all road authorities.
-Sluggish procedures are not present. With the exception when it comes to safety.
-Incentive limitation is hard to combat because the external influences (e.g. accidents) that impact the system

Priority of problems
<table>
<tr><th>Organ</th><th>society</th><th>Phase/Problem</th></tr>
<tr><td></td><td></td><td>Development</td></tr>
<tr><td>0</td><td>0</td><td>Demand/supply restrictions</td></tr>
<tr><td></td><td></td><td>Implementation</td></tr>
<tr><td>0</td><td>0</td><td>Incentive limitation</td></tr>
<tr><td>5</td><td>5</td><td>Disperse implementation approach</td></tr>
<tr><td>0</td><td>0</td><td>Procurement inefficiencies</td></tr>
<tr><td>0</td><td>0</td><td>Sluggish implementation</td></tr>
<tr><td>0</td><td>0</td><td>Concession responsibility conflicts</td></tr>
<tr><td></td><td></td><td>Operation</td></tr>
<tr><td>5</td><td>5</td><td>Incompatible steering</td></tr>
<tr><td>5</td><td>5</td><td>Disperse management</td></tr>
<tr><td>0</td><td>0</td><td>Incentive limitation</td></tr>
</table>
*note only the three most important problems were chosen.</td></tr>
<tr><td>4</td><td>Skipped due to the time.</td></tr>
<tr><td>5</td><td>Data
Lieke empathises that traffic data collection gathering, distribution and price is rather different per source. The road bound data is distributed for free. However, the recently bought FCD (by NDW) is only sold to non-public parties to prevent 'market damage'. For the future she expects a combination of data sources. Regarding the road bound data, it should actively be collected, distributed to all (public) parties at a cost price.

Centralisation</td></tr>
</table>

	Traffic management zones should be the size of a province, while keeping in mind that is one of the layers (the road authorities should remain). Between those layers there should be coordination. Integration doesn’t match the Dutch way of governing

Institutional direction	**Dimension\Respondent**	**Ideal**
Centralisation	Size TA authority	6,5
	Interdependence within TA	6,5
	Interdependence between TA	6,5
	Central supervision	5

6	
Comments	
She finds some questions rather abstract. => less time will be spent on the general problem formulation in later interviews so that the respondent more content as guidance. She finds the term “intervenierend” not suited to describe the dimension. => This is adjusted for later interviews.	

Metadata	
Number	4
Date	04-04-2017
Time	11:00 - 12:00
Location	Vialis, Houten
Personal data	
Name	Willem Hartman
Age	49
Gender	Male
Position	Director software & product development
Experience	20+ years
Education	Technical Computer Science (BSc) & MBA
Firm data	
Name	Vialis
Firm position	Traffic control provider, traffic management provider, contractor, data processor, traffic information provider
Questions answer summarisation	
1	Vialis is part of VolkerWessels. They acquired Vialis amongst others to acquire a strategic position. One firm that is able to create every aspect of the infrastructure. In this the role of Vialis is also changing from a company that was only a traffic control provider to a provider of traffic services that offers much more. Their ambition regarding INTM on the short term is to provide more services to road authorities. But on the long-term Willem expects that they may take over the role of the traffic manager and start providing traffic flow/traffic management as a service. Expectation 8; Traffic management will not solve all problems but it will come a long way. Past decades there have been huge improvements (e.g. in the communication of traffic information:datex2 and between traffic centres: DVM exchange). Additionally, demand management (e.g. variable road pricing) is needed. Frustrated 9: He is frustrated about the lack of ambition and the conservatism that the government shows.
2	Skipped due to the time.
3	Willem was aware of the problems found in the research and stated the following.

<table>
<tr><td></td><td>Demand/supply restrictions: governments are sometimes obligated to use proven technology (risk aversion) which may limit the ability to select the best product/service available.
Sluggish implementation: if traffic management is included in an infrastructure tender, it may take years before it is realised. By that time the traffic management market has changed and a better product could have been selected. If traffic management is not included in an infrastructure tender, but handed separately the procedures are far less sluggish.
Incentive limitation for road authorities: In the past 20 years, there has been a huge overall increase of incentive where road authorities listen to public complaints. Furthermore, there are road authorities that do define their quality in factors. However, in both the incentive as with the definition of quality there is a large variance among road authorities.

Incompatible steering: The amount of FCD that can be used will increase and traffic control data will be published. This will improve the aligning.

An additional problem that Willem expects to occur is with the link between automotive and traffic management. As an example, he mentions the wifi-p protocol that will be included in all cars by 2018, where it is still not clear who will receive the data.

<table>
<tr><th>Organ</th><th>Society</th><th>Phase/Problem</th></tr>
<tr><td></td><td></td><td>Development</td></tr>
<tr><td>0</td><td>5</td><td>Demand/supply restrictions</td></tr>
<tr><td></td><td></td><td>Implementation</td></tr>
<tr><td>0</td><td>0</td><td>Incentive limitation for road authorities</td></tr>
<tr><td>5</td><td>5</td><td>Disperse implementation approach</td></tr>
<tr><td>5</td><td>0</td><td>procurement inefficiencies</td></tr>
<tr><td>5</td><td>0</td><td>Sluggish implementation</td></tr>
<tr><td>0</td><td>0</td><td>Concession responsibility conflicts</td></tr>
<tr><td></td><td></td><td>Operation</td></tr>
<tr><td>0</td><td>0</td><td>Incompatible steering</td></tr>
<tr><td>0</td><td>0</td><td>Disperse management</td></tr>
<tr><td>0</td><td>5</td><td>Incentive limitation for traffic managers</td></tr>
</table>
</td></tr>
<tr><td>4</td><td>Skipped due to the time.</td></tr>
<tr><td>5</td><td>Data
Willem believes that the road bound data should be actively collected and distributed to all for a commercial price. The bought FCD data should remain amongst road authorities to preserve market conditions.

Goals
Willem believes that the costs of measuring will be greatly reduced when measurement factors are uniformalised and the whole country is measured at once rather than in separated regions.

Centralisation
As a size for a Traffic Management authorities Willem recommends somewhere around the size of a province. Utrecht is too small (urbanism continues at its borders) as a traffic authority but Noord-Brabant maybe too big. Furthermore, he would like</td></tr>
</table>

	to see more coordination (towards integration) within and between traffic management authorities. **Institutional direction** / **Dimension\Respondent** / **Current** / **Ideal** / **Expected** Data / Data source / 7 / 9 / 9 / Governmental role / 2 / 8 / 3 / Data sharing / 2,5 / 9 / 7 / Sharing price / 1,5 / 9 / 2 Goals / Performance goals / 0,5 / 7,5 / 1 / Benchmarking / 4,5 / 9,5 / 6 Centralisation / Size TMA authority / 2,5 / 8 / 3,5 / Interdependence within TA / 0,5 / 7,5 / 1,5 / Interdependence between TA / 1 / 7,5 / 2,5 / Central supervision / 1 / 7 / 4,5
6	-
Comments	
The interview was well prepared.	

Institutional direction	Dimension\Respondent	Current	Ideal	Expected
Data	Data source	7	9	9
	Governmental role	2	8	3
	Data sharing	2,5	9	7
	Sharing price	1,5	9	2
Goals	Performance goals	0,5	7,5	1
	Benchmarking	4,5	9,5	6
Centralisation	Size TMA authority	2,5	8	3,5
	Interdependence within TA	0,5	7,5	1,5
	Interdependence between TA	1	7,5	2,5
	Central supervision	1	7	4,5

Interview quantitative results overview

Table 25 - Problem prioritisation of respondents

Phase/Problem	Organisation					Society				
Respondent	1	2	3	4	AVG	1	2	3	4	AVG
Development										
Demand/supply restrictions	4	10	0	0	3,5	4	2	0	5	2,75
Implementation										
Incentive limitation	0	1	0	0	0,25	0	0	0	0	0
Disperse implementation approach	1	2	5	5	3,25	1	5	5	5	4
Procurement inefficiencies	0	0	0	5	1,25	0	0	0	0	0
Sluggish implementation	0	0	0	5	1,25	0	0	0	0	0
Concession responsibility conflicts	0	0	0	0	0	0	0	0	0	0
Operation										
Incompatible steering	5	0	5	0	2,5	5	0	5	0	2,5
Disperse management	3	0	5	0	2	3	0	5	0	2
Incentive limitation	1	2	0	0	0,75	1	8	0	5	3,5

Table 26 - Institutional dimensions responses

Institutional direction	Dimension\Respondent	Current					Ideal					Expected				
		1	2	3	4	AVG	1	2	3	4	AVG	1	2	3	4	AVG
Data	Data source	3,0	4,0		7,0	4,7	8,0	9,5		9,0	8,8	8,0	7,0		9,0	8,0
	Governmental role	5,0	6,5		2,0	4,5	7,0	2,0		8,0	5,7	3,0	3,5		3,0	3,2
	Data sharing	9,0	9,0		2,5	6,8	10,0	3,5		9,0	7,5	1,0	4,5		7,0	4,2
	Sharing price	1,0	5,0		1,5	2,5	2,0	9,0		9,0	6,7	10,0	5,0		2,0	5,7
Goals	Performance goals	1,0	0,5		0,5	0,7	5,0	9,5		7,5	7,3	5,0	9,0		1,0	5,0
	Benchmarking	3,0	1,5		4,5	3,0	10,0	9,5		9,5	9,7	3,0	6,0		6,0	5,0
Centralisation	Size TA authority	2,5	2,5		2,5	2,5	3,0	9,5	6,5	8,0	6,8	3,0	4,5		3,5	3,7
	Interdependence between TA	6,0	0,5		1,0	2,5	4,0	9,5	6,5	7,5	6,9	4,0	2,0		2,5	2,8
	Interdependence within TA	5,0	3,5		0,5	3,0	5,0	9,5	6,5	7,5	7,1	5,0	4,0		1,5	3,5
	Central supervision	3,0	6,5		1,0	3,5	2,0	0,5	5,0	7,0	3,6	2,0	3,5		4,5	3,3

Appendix E Overview applied research

The following list of applied research has been used to substantiate the problems.

Table 27 - Applied research

Research group (year)	Title
DHV (2007 report was not available)	Vlottere doorstroming
TNO (2007)	Naar een vlottere doorstroming op het wegennet
Goudappel Coffeng	Verkeersmanagement bij Anders Organiseren Wegbeheer
Ecorys (2007)	Van wegbeheer ondernemen naar ondernemend wegbeheer
Ministerie van Verkeer en Waterstaat (2007a)	ITS-strategie: de Japanse succesformule
Berenschot	In dienst van doorstroming
Raad voor verkeer en waterstaat (2007)	Van wegbeheer naar netwerkbeheer: Advies over het anders organiseren van wegbeheer
Ministerie van Verkeer en Waterstaat (2007b)	Wegbeheer in Nederland feiten en ontwikkelingen
KiM (2007)	Publieke belangen en weginfrastructuur
SEO (2007)	Wegen van publieke belangen
Rijkswaterstaat(2007)	Ambitie Verkeersmanagement 2020
KiM (2008)	Wikken en wegen
Adviescommissie Verkeersinformatie (Commmissie Laan III) (2009)	eindrapport
Strategisch Beraad Verkeersinformatie en Verkeersmanagement (2010)	Samenspel Informeren en Sturen van verkeer: een gemeenschappelijk toekomstbeeld
Beraad Strategisch Verkeersinformatie en Verkeersmanagement (2011)	Eindadvies
Regiegroep Verkeersinformatie(2011)	Het Pact van Sint-Michielsgestel
Connekt (de Mooi, 2013)	Beter geïnformeerd op weg
TrafficQuest (2014)	Stedelijk verkeersmanagement
DITCM (2015)	Markt en overheid: wie geeft kleur aan ITS diensten?
Connecting Mobility (2016)	Precompetitieve samenwerking in het ITS domein

Appendix F Process design

De Bruijn et al. (2010, Chapter 3.3) describes four core elements of a process design, along with more specific recommendations. This appendix will cite the specific recommendations (marked by quotes) from pages 44 till 56, whereafter its application is discussed. Most of the discussed items have been used to formulate the process strategy in Section 7.2.

1. Openness

'Openness means that an initiator does not take unilateral decisions, but adopts an open attitude. Other parties are offered an opportunity to participate in steering the decision-making , and therefore also to highlight the issues they are interested in and that they feel should be placed on the agenda.'

All relevant parties are involved in the decision-making process

'There is a tendency to invite mostly large parties that have productive power and that support an initiative. The risk will be evident: such an invitation may be an incentive for the other parties to join forces in their resistance against this initiative. Does this mean that everyone should be invited? This will often be impossible, if only because it can stall the decision-making the process can result in utter indecision. '

'Accurate representation of the parties that have an interest in the decision-making'

→ Allow the formation of representative groups that speak on behalf a certain group. After each meeting all represented parties are informed. Furthermore the representative group advises on the final decision. This may reduce interaction costs for some parties and thus may allow them to participate in a less active way.

→ All parties (form actor analysis) are included in some way (also with limited power, blocking power and diffuse power)

'A process may, for instance, have several different phases; one may choose to invite fewer parties in the initial phase, and more parties later on.'

→ 4 phases included: Initialisation, Development, Implementation, Operation

'It is also possible to identify different roles: some parties are involved in the decision-making , while others provide obligatory advice or participate in the process as experts.'

→ See Participation Planning Matrix

'There may be important moral arguments to involve certain parties in the decision-making. '

→ The locals, drivers and traffic managers are included early on in the process.

Substantive choices are transformed into process-type agreements

'Minimization of the number of substantive choices made prior to the process. Although the substantive issues may be assessed, this merely leads to an indication of how the decision-making process will proceed. In other words, there is a transformation from substantive choices to process agreements. '

'It offers enough room to all of the parties when parties commit themselves to these agreements, they are sitting around the table the initiator also has a prospect of a result.'

→ Allow parties to influence the agenda

Both process and process management are transparent

'If a process lacks transparency and if parties are unaware of the process agreements, this will be a breeding ground for mutual distrust and, as a consequence, for conflict.'

→ Include all parties (in some way) in the initialization phase where they can have a saying in the agenda.

2. Protection of core values

'Every party will have its own interests, and runs the risk that these interests are not sufficiently addressed. At the end of the process one or several parties may therefore not be satisfied with the result, while it is difficult for them to withdraw from the process at that stage. They must be offered sufficient protection. How? They must be certain that their core values will not be harmed, regardless of the outcome of the process. '

The core values of parties are protected

'The core value transcends the level of the single process and the single point of view, and has a much more generic nature.'

→ Include a step in the process initialisation to determine core values. Whereafter parties can agree to a process where these remain unharmed.

Parties commit to the process rather than to the result

'Even though this result is yet unknown, it seems reasonable to ask parties to commit to it otherwise, after all, there is a chance that the initiator designs a time-consuming process only to conclude at the end of it that the parties remain divided. They are not asked to commit to any process result beforehand. They can only be asked to commit to the process.'

→ Declaration of intent at the end of process initialisation.

Parties may postpone their commitments

'Parties are not asked to commit to subdecisions during the process. Only at the end of the process will the parties be asked for their commitment to the final package of decisions.'

→ Last step is final package deal

The process has exit rules

'If there is no exit option, it will be inevitable that some parties will not join the process, or that there will be serious conflicts during the process.'

→ Define exit rules at declaration of intent

3. Progress (speed)

'Chances are that even if there is discussion and negotiation, still no decision is made. Perhaps the outcome will include nothing but sluggish processes that will never produce a clear result. A third category of design principles addresses the need for the process to show sufficient momentum and progress.'

Stimulate 'early participation'

'It is important that arrangements are introduced at the start of the process to stimulate parties to join and to make the waiting game a less appealing option. This will add momentum to the process.'

→ Stimulate early participation with research and trail investments to gather substantive data to create quick wins as well as agreement on starting conditions

→ Early participation allows the setting of the agenda

The process carries a prospect of gain

'As soon as a party has received its gain, it no longer has an incentive to be cooperative. At that point there is a risk of opportunistic behaviour: the party in question may withdraw from the process and cease to behave cooperatively. This implies that the process architect should ensure to maximize the chances of gain towards the end of the process.'

→ For private parties: Export potential. If we wait longer we lose our advantage!
→ For public: Improve liability, safety and environment. If we wait long people will be harmed!
→ Compensate 'losers' if they participate?
→ Try to influence the formation of European standards with the Dutch trails such that conversion costs are limited for both parties.
→ Place most governmental investment at (the start of or during) the operation

There are quick wins

'On the one hand the gain should not present itself too soon, for this would stimulate parties to leave the process. On the other hand there should be some pay-off—through quick wins— because parties may also leave the process if the gain is too far away.'

→ For consultants as experts (but with audit to prevent bias because of their own strategic involvement).
→ For traffic control providers: traffic control adjustments.
→ For traffic information providers: Traffic control data.
→ But leave main adjustment/investment until the end of the process.

The process is heavily staffed

'Heavy staff means that the participants in the process are the ones who hold high positions within their organizations, and/or have authority in these organizations.'

→ Invite people that hold high positions personally and require a level of authority of the representative of the actor in the declaration of intent.

Conflicts are addressed in the periphery of the process

'Process architects may utilize the fact that many processes have a layered organizational structure. There is a core that is enveloped by a number of shells. There may for instance be a structure that involves a steering group, a project group and a working group.'

→ Use layer approach in combination with command and control for difficult issues.

Tolerance towards ambiguity

"The use of ambiguous terms may stimulate progress in the negotiations. These ambiguous terms will often have a ''feel-good'' connotation. Examples include terms such as 'quality', 'future-proof', 'efficient', and so on. Leaving the exact meaning of these terms in the open may evoke criticism on the one side: they are vague and it remains unclear what will happen exactly. On the other hand, the use of such terms will allow parties to keep dreaming that their preferences are 'still on the table', which may be sufficient reason for them to keep participating in the process. Such 'constructive ambiguity' allows parties to portray agreements as a victory."

→ Start process with the use of ambiguous terms. Specify further when the specific issue is discussed.

Command and control are used to maintain momentum

'The next agreement may be that the minister will adopt any consensus reached by the parties, while he will follow his own discretion and make a unilateral decision if parties continue to disagree. In other words, in case of disagreement he will steer by command and control. The threat of command and control may be an incentive for parties to reach consensus.'

→ This can possibly applied later on for specific issues

4. Substance

'The progress should meet certain substantive quality standards. After all, there may be strongly conflicting interests that force parties to make decisions that are substantively poor and perhaps even incorrect. Therefore it is crucial that the process has a sufficient number of substantive elements.'

Substantive insights are used for facilitation. The roles of experts and stakeholders are both bundled and unbundled

'A process without substance is hollow. At the same time, though, substance can never determine the course of a decision-making process. After all, one of the justifications for a process design is that it is impossible to solve problems on the basis of objective information. There is another reason why expert involvement in the process may be important. It offers stakeholders the opportunity to question experts about the scientific level of their research results or beliefs: which assumptions are they based on, which data have been used, which system boundaries have been established, and so on.'

→ Enable participants access to experts facilitated by the process -> creates substance and enables weak parties to talk on an equal level.

The process proceeds from substantive variety to selection

'A large number of substantive insights and ideas may be introduced at the start of a process and that in the end, some of these insights and ideas will be selected from among this variety. If a variety of insights and ideas is taken into account, this makes it harder for parties to call into question the selection of insights and ideas at a later stage.'

→ Ask the issue involved actors to supply substantive content at the start of an issue and formulate steps per issue analyse problem (supply substantive content), generate alternatives, evaluate alternatives, result for final proposal.

→ enable dialogue between experts and audit if no consensus in reached.

Appendix G Review Institutional frameworks

To systematically make assessments and recommendations to facilitate a stable and yet technical flexible institution, a framework is needed. Frameworks organize diagnostic and prescriptive inquiry by providing a general set of elements and general relationships between them, that can be used to analyse all types of institutional arrangements and a meta-theoretical language that can be used to compare theories (Ostrom, 2011, p. 8).

The interest in institutions as shaping factors for economic performance of network industries has been renewed last decades as a follow-up of literature in the field of institutional economics (Jonker, 2010). Now, various institutional frameworks exist that are able to analyse the institutional environment for the purpose of implementing a traffic management approach. In this appendix multiple well-known institutional frameworks are presented. These are the four-layer framework of Williamson (1998), the four-layer framework of Koppenjan & Groenewegen (2005), the institutional analysis and development framework (IAD) by Ostrom (2005). The framework of Künneke (2008) has also provided some valuable insights but has not been added to the review due to time research constraints.

Four-level Framework Williamson

Williamson (1998) created a four level framework presented in Figure 40 that differentiated types of institutions to describe institutions in an integrated manner. In doing so, different theories can be applied to different levels for analysation and it shows that each level operates at its own pace (indicated with frequency).

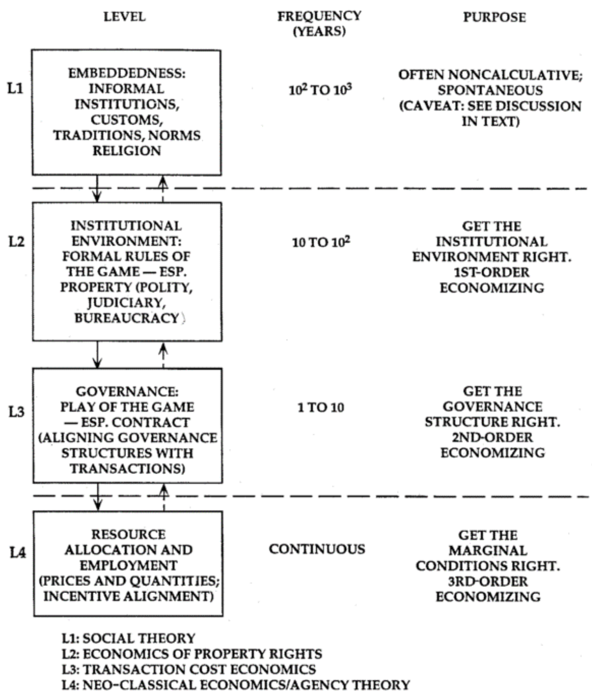


Figure 40 - Framework of economic institutional levels (Williamson, 1998)

At the first level (L1) the social embeddedness is described. This level represents the norms, customs and religion, which are often formed over a long period of time. Therefore, this level is analysed by economic historians and by social scientists. The second level (L2) describes the formal institutional environment, which are 'the product of politics and provide the rules of the game within which economic activity is organized' (Williamson, 1998). This level includes laws and formal regulation amongst others and is mainly analysed with modern institutional economics. The third level (L3) describes 'the play of the game'. This is where institutions of governance are located. These governance structures are institutions that may govern the interaction between actors. This level is usually analysed with transaction cost economic theories. The final level (L4) describes the resource allocation. This level is guided by market behaviour and therefor analysed in the field of neo-classical economics and agency.

The different levels of Williamson have bidirectional connections to show that each level is affected by the surrounding ones. This is indicated with solid arrows and dashed arrows. The first represent the imposed constraints on the level immediately below. The latter connect lower with higher levels are represent signal feedback. These connections cause the gradual change of frequency because the middle levels are constrained by a slower and a faster operating level.

Institutional Analysis Development (IAD) Framework (obsolete?)

The IAD framework is a multi-tier conceptual map that allows a policy analyst to generate and address key questions by organising diagnostic, analytical, and prescriptive capabilities (Ostrom, 2011). Its form has varied considerably over time (McGinnis, 2011b).

The main attribute in the IAD framework (presented in the figure below) are the action situations (previously named action arena). These are the social spaces where individuals (acting on their own or as agents of organizations) interact. How they interact may be affected by four clusters of variables: 1) the involved resources of an actor; 2) the valuation of actors to states and actions; 3) Actor information handling (acquire, process, retain, and use); and 4) the action selection processes of actors (Ostrom, 2011). In their interaction they may exchange goods and services, solve problems, dominate one another, or fight etc. This leads to certain patterns of interaction between actors and subsequently to (collective) outcomes. Hereafter, both aspects can be evaluated by a set of evaluative criteria. Prior to the action situations there are external variables that may influence the action situations. These are biophysical conditions (e.g. availability of natural resources), community attributes (e.g. norms) and rules and may be used to govern and guide the behaviour of the involved actors.

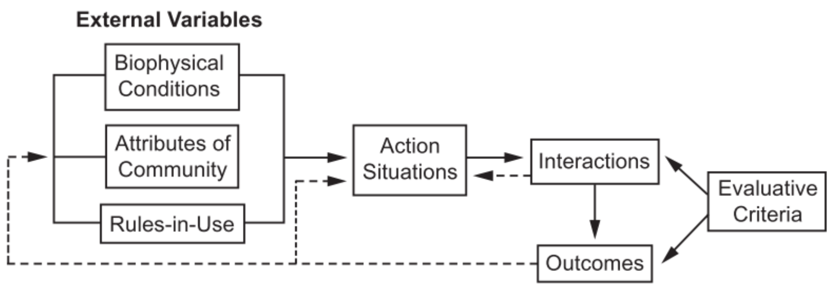


Figure 41 - IAD Framework (adapted from Ostrom, 2005, p. 15, 2011, p. 10)

The type of rules within the IAD can consist of boundary rules, position rules, scope rules, choice rules, aggregation rules, information rules, and payoff rules (Ostrom, 2011). These rules are decisive for the action situations (presented in more detail in the figure below). In this, a common set of variables used to describe the structure. This includes the set of actors, the specific positions, the set of allowable actions, the potential outcomes, the level of control each participant has over its choice, the information available and the costs and benefits assigned to actions and outcomes (Ostrom, 2011). Furthermore, the strategies of individuals may be affected by whether a situation will occur once, a known finite number of times, or indefinitely.

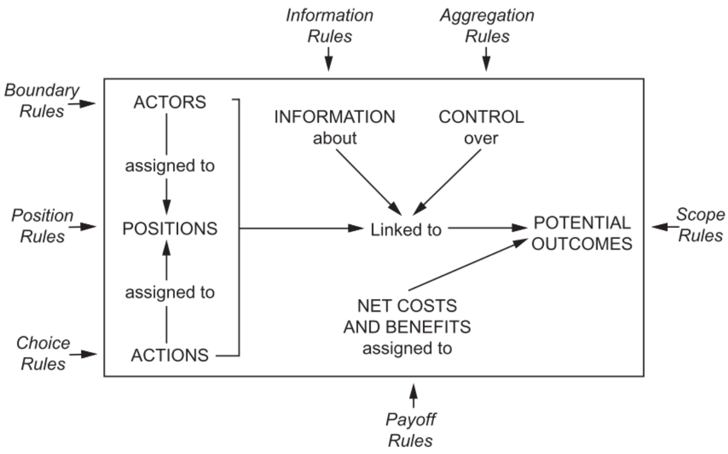


Figure 42 - Rules as exogenous variables directly affecting the elements of an action situation (adapted from Ostrom, 2005, p. 189, 2011, p. 10)

The previously described IAD framework can be applied on three tiers. The operational tier where actors interact in light of the incentives they face to generate outcomes directly in the world; the policy (or collective-choice) tier where decision makers repeatedly have to make policy decisions within the constraints of a set of collective-choice rules; and the constitutional tier where decisions are made about who is eligible to participate in policymaking and about the rules that will be used to undertake policymaking. These tiers appear to match to the levels of Williamson: the operational (Williamson L4), the collective choice (Williamson L3), and the constitutional choice levels (Williamson L2) (apart from L1 that matches the exogenous variables) (Stepney, Welch, & Andrews, 2010).

Four-Layer Framework of Koppenjan & Groenewegen

Koppenjan and Groenewegen (2005) state that some complex technological systems are 'unruly', where both technological aspects as the behaviour of actors matter for the functioning of the system. Usually there are many involved actors (multi actor environment) of which both public and private parties and the functioning of the system can be influenced by both market forces and government regulation. For these complex technological systems, it is often necessary to guide and coordinate the behaviour of actors. So, in addition to a substantive technological design, an institutional design is also needed (Goodin, 1996; Ostrom, 1990). These designs are however not created by a designer behind a desk but in interactive processes between stakeholders. So, as source of previous designs, the process design should also be included (presented in the figure below).

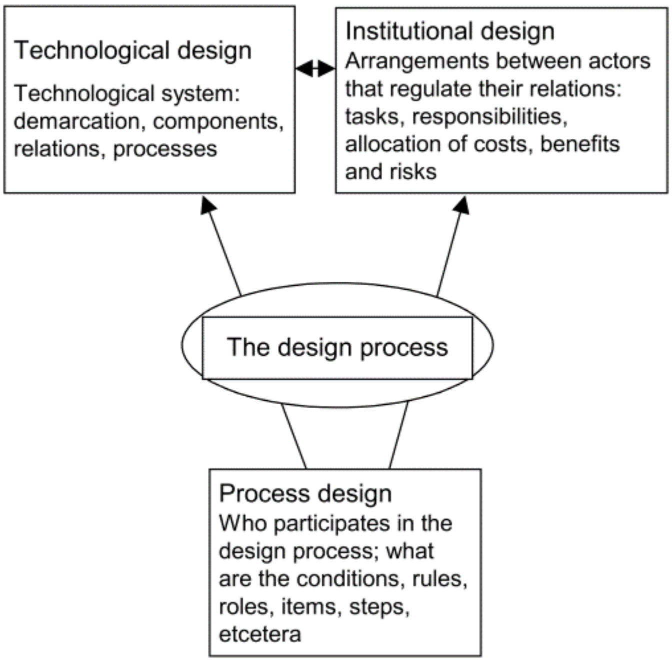


Figure 43 - The relation between technological, institutional and process design (Koppenjan & Groenewegen, 2005)

To describe the relation between these designs, Koppenjan and Groenewegen (2005) developed a framework for (re)designing complex technological systems. This is inspired on the four-layer framework of Williamson (1998) but differs from in two respects. First, the first layer is changed to the actors and games, which is somewhat similar to the IAD framework of Ostrom (2011). Second, this model explicitly allows for the direct interaction between the layers (see figure below). Furthermore, the indication of time seems less important.

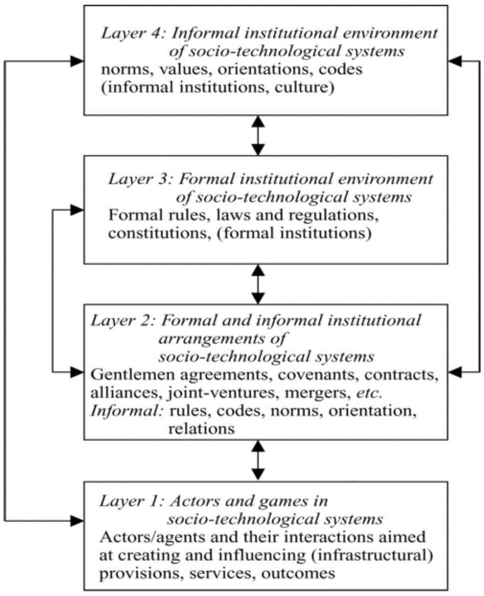


Figure 44 - The four levels of institutional analysis (Koppenjan & Groenewegen, 2005)

Finally, one of the two authors has published a similar framework with the slight adaptation (see figure below). This version embeds technology in the 4th layer and hereby specifies the interaction between technology and institutions.

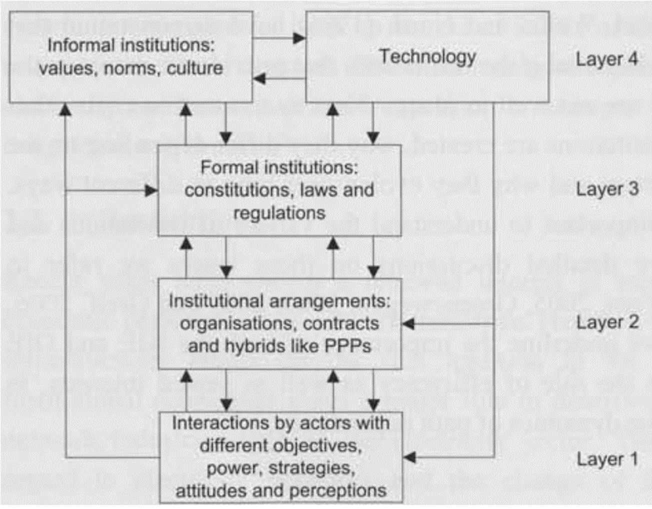


Figure 45 - Four layer model of socio-technological systems (Groenewegen, 2005) adapted from (Koppenjan & Groenewegen, 2005)

Similarities and limitations

All of the previous presented institutional frameworks have a similar function and are based upon similar concepts. However, the IAD framework is specified in more detail than the others that mainly look at the four separate layers; these are more heuristic (e.g. the time indications of Williamson are not empirically proved). It describes the process between the involved actors in institutional creation rather than just the institution(s), where Williamson's framework does not include this and the framework of Koppenjan & Groenewegen includes it with less detail. Finally, although all the researchers, except Williamson's, include the impact of technology on institutions, a large part of this remains neglected.

For the INTM system the IAD framework seems to specific. The INTM system is too complex and uncertain to analyse it in such a way. So the remaining two will be used as a starting point. However, this research stated that traffic management development is partly separated from the infrastructure institutions. Thus, a framework will be proposed that partly separates the two.