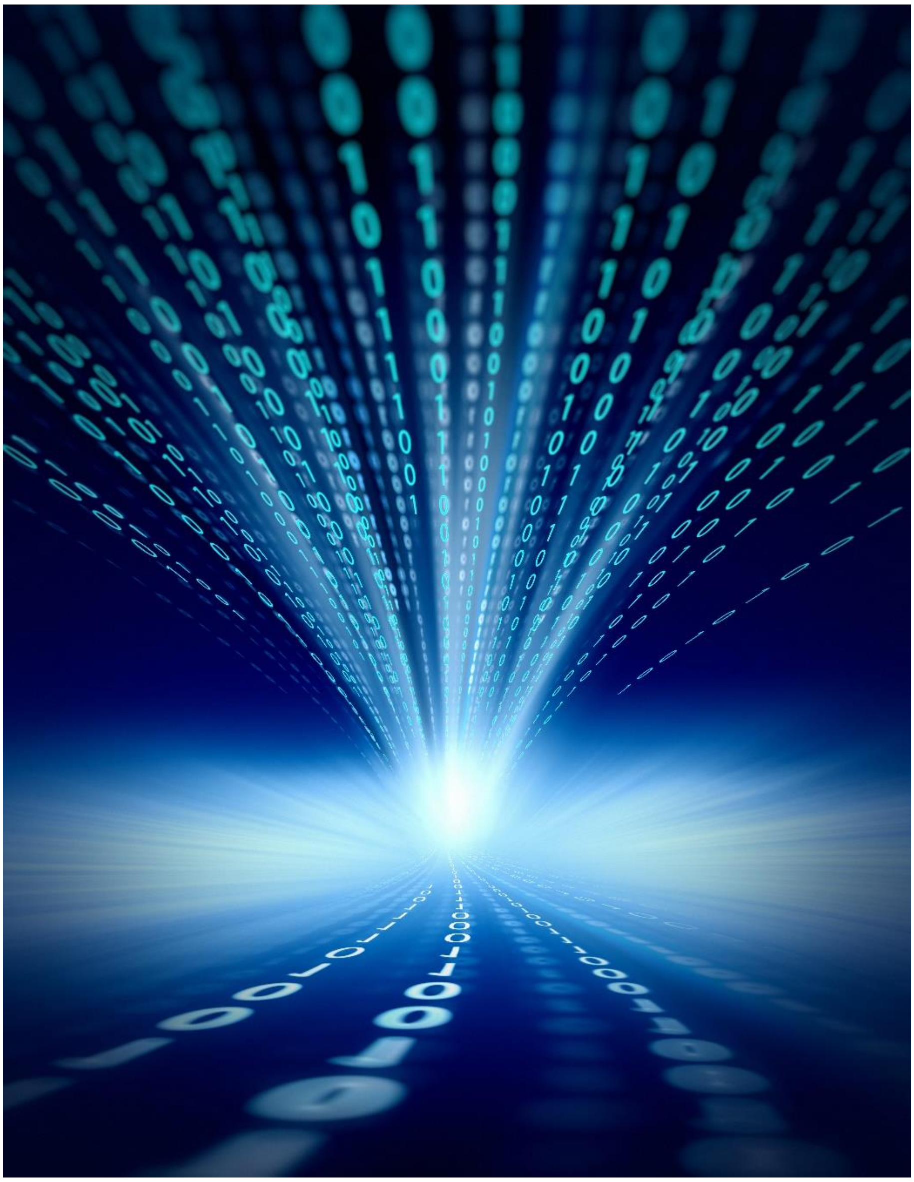
Paving the road towards intelligent transportation systems: a governmentality analysis of smart traffic management in the Netherlands



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I. ABSTRACT

Tuning in on the polarized smart city debate that has taken city halls, the academic community and the tech industry by storm, this thesis inquires into the shifting power dynamics implied by smart urbanism. Focusing on smart traffic management, it examines how smart technologies are transforming the tripartite relations of power between governments, market actors and drivers in the processes of governing road traffic in the Netherlands. Adopting a perspective informed by the writings of Michel Foucault, it scrutinizes these power relations by analyzing (1) the political rationalities of traffic management, (2) how drivers are sensed and made knowable, (3) the new modes of governing drivers and (4) in what ways the roles between public and private actors in traffic management are changing. Making use of three qualitative data collection methods – interviews, observations and document analysis – it examines several key trends in the Dutch traffic management sphere, providing the context for a case study of the Praktijkproef Amsterdam, the Netherlands' largest practical trial for smart traffic management. The results indicate several changes in how power is exercised in traffic management. A core observation is that traffic management is becoming more data-driven. By expanding the surveillance gaze using a growing amount and variety of stationary and mobile 'in-car' sensors, the individual and collective behavior of motorists is becoming more measurable, knowable and governable. In line with this development, governing actors are increasingly employing techniques of centralization, automation, personalization, responsibilization, statistical analysis and prediction. Here, cost-effectiveness is thought to be the primary rationale, since these techniques reduce manual labor, allow for the optimal exploitation of space in the road network and minimize uncertainties through pre-emption. Moreover, road authorities are also experimenting with outsourcing traffic management tasks to private contractors, since the market is claimed to be capable of governing with greater efficiency (i.e. against lower costs). Though these developments indicate significant transformations in the power relations between public authorities, drivers and the market, it remains difficult to predict how these will develop in the future, given that many of these changes are recent developments that are still in the trialing phase.

Key words: *The Netherlands, traffic management, smart cities, mobility, power relations, surveillance, governmentality, policy, discourse, data, neoliberalism, Michel Foucault, case study, Praktijkproef Amsterdam.*

II. ACKNOWLEDGEMENTS

Though I had been aware of the topic of smart cities for quite some time, my academic interest for smart cities was particularly boosted by two courses I took along my master's trajectory. First, Dr. Ingrid Boas' lectures in the context of the 'Governance for Sustainable Cities' course offered me a comprehensive overview of smart urbanism and its accompanying socio-political questions, including in the areas of privacy, privatization, citizen empowerment and inclusion. Second, Dr. ir. Jan Vreeburg's course 'Managing Urban Environmental Infrastructures' helped me to appreciate some of the technical components associated with smart 'next generation' infrastructures, most notably in the areas of demand side management, infrastructure development and infrastructure maintenance. Moreover, I would particularly like to express my gratitude to my supervisors, Sanneke Kloppenburg and Ingrid Boas, for their invaluable feedback, enthusiasm and encouragement, which were of significant help in the writing process. In addition, I would like to thank my friends and family for their seemingly endless support along the road towards the completion of this thesis. And last – but not least – I would like to thank all the interviewees who were kind enough to devote some of their time to participate in this study, as well as the organizers of the DITCM roundtables and the Expo Verkeer, Mobiliteit & Parkeren for allowing me to attend their events. With this thesis, I hope that I can return some of the (intangible) value their input created for me.

III. MANAGEMENT SUMMARY

In recent years, the notion of the smart city has gained significant momentum as a social imaginary in academic and policy discourses, envisioned by its proponents as a societal template that could remedy today's most pressing sustainability challenges. In discordance of such visions, critics have voiced concerns over a number of issues – which include looming privacy violations, a growing digital divide, the corporatization of city governance and new cyber-security risks – dismissing these optimistic conceptualizations of smart urbanism as 'naïve', fearing that attempts to actualize them could set off turmoil. The overarching theme in this discussion is the question of power: who is expected to benefit from a smarter, more data-driven society, and who will not be able to reap its benefits, or even be disadvantaged? While smart urbanism has been heralded as both a panacea and pandemonium, the number of case studies reviewing actual smart city projects is surprisingly low. Latching onto Michel Foucault's relational conceptualization of power, this thesis therefore inquires into the changing ways in which power is exercised in the smart city. Focusing on the field of traffic management, the main question posed is: *''How do smart technologies transform the power relations in the governance of road traffic in the Netherlands?''*. Utilizing several of Foucault's concepts and following his claim that power should be analyzed as something which circulates and functions in the form of a chain, this question is split up in four sub-questions, which respectively consider (1) the political rationalities underpinning traffic management, (2) the means of knowledge production, (3) the ways in which motorists are governed and (4) the changing roles between public and private actors. In pursuit of these questions, this thesis studies the changing tripartite relationships of power between governments, the market and drivers by examining the macro-trends in traffic management, which serve as a contextualization for a case study of the Praktijkproef Amsterdam [PPA], the largest practical trial for smart traffic management in the Netherlands. Here, data has been collected using three methods: interviews, observations and document analysis.

First, based on a review of recent developments in policy and the PPA, this study has identified efficiency to be the key rationality driving the smart traffic management discourse. In particular, stressing the economic burden of congestion and inefficiencies in the use of the road network, policymakers seem to primarily legitimize infrastructural changes based on economic reasons (optimizing network throughflow and cost-effectiveness). To a lesser extent, the Beter Benutten [BB], Beter Geïnformeerd op Weg [BGOW] and PPA policy documents refer to the potential environmental benefits of smart traffic management, and express that no concessions may be made to road safety.

Second, regarding the ways in which knowledge is produced and utilized, there are significant changes as well. Over the years, the traffic surveillance apparatus in the Netherlands has grown in size and intricacy. On the one hand, the road network has been retrofitted with a greater variety of stationary roadside sensors, including Bluetooth sensors, Automatic Number Plate Recognition [ANPR] cameras and radar systems. On the other hand, due to the increasing ubiquity of mobile 'in-car' devices used by motorists (e.g. smartphones and navigation systems), Floating Car Data [FCD] has rapidly gained the interest from traffic managers as both a supplement and alternative to roadside sensors. By mobilizing a theoretically unlimited number of mobile devices as sensors for traffic management, the surveillance gaze is untethered: no longer bound to a limited number of fixed locations, it gradually becomes able to pervade every part of the network. As a result of this development, roadside sensors are partially rendered redundant, leading many to believe that their numbers will dwindle in the future, since this presents public actors with the opportunity to cut spending on the acquisition and maintenance of such instruments. Additionally, responding to fragmentation in the processes of data collection, storage and analysis, the centralized National Data Warehouse for Traffic Information [NDW] was established, making traffic data ever more accessible to actors involved in the governing process. Here, the NDW is not only a databank, but also functions as a central

node for expertise on traffic data analysis, stimulating continuous improvement in the standardization, quality, speed and availability of such data, aiming to provide its stakeholders with the *''best possible information''*. Altogether, a growing constellation of roadside and in-car sensors is progressively cloaking the road network, collecting vast amounts of data stored and analyzed in a centralized databank, in turn rendering motorists ever more knowable, dividualizing them into sets of network performance indicators, and thereby tipping the nature of power from discipline towards control.

Third, the growing data-drivenness of traffic management has consequences for the modes of governing. First, the growing availability of traffic data combined with the introduction of fiber optic cables and wireless systems has facilitated greater degrees of centralization, meaning that drivers can now be managed from-a-distance by control room operators, who increasingly view and manage the road network as one holistic entity. This approach is frequently referred to as network-wide traffic management. Second, the growing volumes of data – the lifeblood of ICT systems - allow for greater degrees of automation, where human operators delegate some of their managerial agency to software. Third, in a similar vein, the coupling of traffic surveillance infrastructure and its connected databases to pattern detection software and automated traffic intervention systems entails a shift from reactive to more predictive management. Together with the previously identified trend of automation, this development is understood as a move towards algorithmic governmentality. Moreover, capitalizing on the possibilities offered by in-car traffic information systems, traffic managers are experimenting with techniques of personalization (as opposed to collective influencing), where drivers receive travel information and advice tailored to their real-time location and preferences. Granting motorists greater agency in governing their own actions, the deployment of in-car devices is understood as a form of responsibilization, indicative of an emerging neoliberal governmentality where technologies of the market are utilized to achieve the objectives of government. This implies a transformation in the functioning of power, where mobile applications are used to create a certain social reality tailored to the individual, and the behavior desired by road authorities arises naturally from within the motorist based on his or her own rational assessment of the information he or she is presented with, as opposed to the imposing of external commands by road authorities.

Fourth, faced with new opportunities and challenges posed by disruptive technologies produced by the market, road authorities are slowly starting to outsource some traffic management tasks to private contractors, as evidenced by – for example – the commercialization of traffic information. In part, this inclusion of market actors in the governing process has arisen out of necessity. Given that governments possess relatively little expertise related to developing, integrating and maintaining traffic management infrastructure, outsourcing such tasks to private contractors appears as an inevitable consequence of technological advancements. Moreover, taking a user-centric view, navigation system developers are primarily concerned with helping drivers to secure their individual optimum (i.e. by advising the shortest or fastest route), as opposed to the collective optimum (i.e. the 'public interest') pursued by road authorities maintaining a network-oriented view. In an attempt to resolve the conflicts of interest that may ensue, many public and private actors advocate closer collaboration between such service providers and road authorities. Privatization, however, is not only encouraged by the private sector, but also finds support within policy circles. In light of austerity measures, and guided by the claim that the market is capable of governing with greater efficiency (i.e. against lower costs), governmental agencies are trialing the delegation of new roles to the private sector – an approach integral to the BB, BGOW and PPA programs alike. These developments can be interpreted as the potential renegotiation of the social contract between the state and citizens, where it is reformed into a corporate contract involving various levels of government, private actors and drivers. As such, one could speak of an emerging neoliberal form of governmentality: not only are some of the operations of government transferred from state to non-state actors (i.e. cost-effectiveness is a primary factor in determining who is in charge of governing), but the logic of the market also extends into state functions (e.g. through the use of market nomenclature: framing drivers as 'customers').

Nevertheless, it remains highly uncertain which roles the market will adopt in the future. Although the aforementioned governmental programs encourage public-private governance and are experimenting with new roles for private consortia, this study found that there is disagreement on (1) the roles market actors should have and (2) what their business models should look like. First, within the public realm, there are different visions on the degree to which traffic management tasks should be outsourced. While most levels of government are in favor of outsourcing traffic management (viewing it as an opportunity to externalize the associated costs), some public road authorities (notably Rijkswaterstaat) are reluctant of this. Second, this study has found that most private contractors have failed to identify viable business cases within the conditions stipulated by public road authorities. Therefore, they are in favor of a business-to-government model, also referred to as 'traffic management as a service'. However, this option has thus far not been on the table for most public actors, who favor business-to-business and business-to-consumer models. Hence, this finding casts doubt on the hypothesis found in the smart city literature that the privatization of urban services is mainly vendor-driven, as the findings presented in this study suggest that public authorities are also driving this development – albeit under strict conditions – since it could allow them to externalize some of the costs of traffic management and make it more cost-effective.

On a final note, this study notes that it remains uncertain if optimization of the network capacity and throughflow will also yield environmental and road safety benefits, given that some theoretical models suggest that this may invoke a 'rebound effect' and lower the resilience of such infrastructural networks. For this reason, it is argued that optimization is not a sovereign remedy to all the sustainability issues of transportation, but should instead be regarded as one piece of the puzzle, one of the palette of options that can together unlock a more sustainable society. It is concluded that the smart city is anything but a given: a highly malleable concept, it can materialize into both a utopia and dystopia, but most likely it will evolve into something on the continuum in between. Here, our collective decisions as a society will determine towards which of these ends we will navigate.

IV. ABBREVIATIONS

ANPR	Automatic Number Plate Recognition
BB	Beter Benutten [*Optimizing Use*]
BGOW	Beter Geïnformeerd op Weg [*Better Informed on the Road*]
CAN	Controller Area Network
CCTV	Closed-Circuit Television
FCD	Floating Car Data
FVD	Floating Vehicle Data (see FCD)
GNV	Gecoördineerd Netwerkbreed Verkeersmanagement [*Coordinated Network-wide Traffic Management*]
GPS	Global Positioning System
GSM	Global System for Mobile Communications
ICT	Information and Communications Technology
MAC	Media Access Control
MIM	Ministerie van Infrastructuur en Milieu [*Ministry of Infrastructure and the Environment*]
NDW	Nationale Databank Wegverkeersgegevens [*National Data Warehouse for Traffic Information*]
PPA	Praktijkproef Amsterdam [*Amsterdam Practical Trial*]
PRIS	Parkeer Route Informatie Systeem [*Parking Route Information System*]
PVD	Probe Vehicle Data (see FCD)
TDI	Toeritdoseerinstallatie [*Ramp Meter Installation*]
VRI	Verkeersregelinstallatie [*Traffic light*]

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1. INTRODUCTION

1.1 PROBLEM DESCRIPTION: AN INTRODUCTION TO SMART CITIES

The year 2007 marked the beginning of a new era for mankind: for the first time in history, more people dwelled in urban areas than in rural areas (United Nations [UN], 2014). Ever since, the share of the global population living in urban areas has only expanded further, showing no signs of stagnation. By 2050, urban areas are projected to house two-thirds of the world's population, which by then is expected to grow to 9.7 billion people (UN, 2014; UN, 2015). Accompanied by an unstable economic climate and pressing environmental issues such as resource scarcity and climate change, these demographic trends put the future of cities - and humanity at large - in jeopardy (Shelton et al., 2015; Hollands, 2015; Halpern & Günel, 2015). Increasingly, cities worldwide are struggling with traffic congestion, energy provision, air pollution, growing income inequalities, crime, lack of basic services, unplanned development and surges in waste disposal levels (Edwards, 2016). Now, the dominant discourse holds that in order to secure global economic, environmental and social sustainability, there has to be a change in the way resources are governed and societal services are organized - particularly in the city (Kitchin, 2015; UN, 2013; European Commission, 2010; International Electrotechnical Commission, 2015). This focus on cities to tackle global sustainability issues is understandable, considering that they are the nexuses of economic activity, innovation and people (Townsend, 2013). Furthermore, cities account for 75 percent of the global energy consumption and 80 percent of greenhouse gas emissions (Hollands, 2015). Therefore, there is a growing emphasis on the need for a city level-approach to tackle global sustainability challenges (Kern & Bulkeley, 2009).

Recently, one particular concept addressing the aforementioned problems has rapidly gained terrain within policy and academic spheres alike: the idea of the 'smart city'. While an agreed upon definition is lacking, Kitchin (2014) identifies two main interpretations of the concept: one technological, one social. The former revolves around the automation of urban services and the development of data-collecting ICT infrastructure in cities, which is used to inform and steer policy and management in order to make the managed processes in the city more efficient (Caragliu, Del Bo & Nijkamp, 2011; European Parliament, 2014; IESE Business School, 2016; Frost & Sullivan, 2013). This data-collecting ICT infrastructure comprises a wide array of sensors and other electronic devices, such as CCTV cameras, microphones, motion detecting sensors and smartphones. Embedded in the urban fabric, these devices together generate dizzyingly large, continuous flows of unstructured data sets - often referred to as 'big data' (Pan et al., 2013). Able to process, analyze and act upon this big data in real-time, smart technologies can presumably improve the efficiency of urban services, thereby lowering resource consumption levels and enabling cities to become more competitive and environmentally sustainable (Kitchin, 2014). The latter conceptualization of smart cities focusses on investments in social capital and education (Hollands, 2008; Caragliu et al., 2011, Ojo et al., 2015; Neirotti et al., 2014). Here, scholars note that a smart city must have smart citizens; people that are creative, innovative and entrepreneurial. According to this interpretation, ICT infrastructure does not necessarily make a city smart, but can enhance economic growth, human capital, education and governance. These two interpretations are thus different, but not necessarily mutually exclusive, and are both grounded in a neoliberal perspective that advocates deregulation, privatization and the alleviation of trade barriers, sketching smart cities as techno-utopia where information technologies form the panacea to some of the most pressing urban sustainability issues (Kitchin, 2014; Hollands, 2015; IEC, 2015; Schneider Electric, 2014; Gibbs et al., 2013).

Despite being hailed by some as the solution that will make cities sustainable, competitive and improve quality of life for all citizens, the idea of the smart city remains controversial. Several scholars and activists are voicing concerns over privacy issues (Edwards, 2016), a growing digital divide (Calzada & Cobo, 2015; Nieminen, 2016), corporate influence on public policy (Hollands, 2015; Klauser et al., 2014; Sadowski & Pasquale, 2015) and security vulnerabilities (Elmaghraby & Losavio, 2014; Cerrudo, 2015) that stem from the digitization of urban services processes and the collection of 'big data' by ICT infrastructure in the city. In the area of privacy, some note that with the growing omnipresence of data-collecting infrastructure, cities are constructing a panopticon: an all-seeing structure that can monitor the activities of every individual in the city (Edwards, 2016; Seele, 2015; Kitchin, 2014). Already, IT corporations and governments alike have engaged in forms of surveillance and 'dataveillance' through algorithmic monitoring of big data and tracking of civilian activities - actions clearly at odds with privacy rights as recognized by the UN and other national and supranational jurisdictions (Seele, 2015; UN Human Rights Council, 2014; Kitchin, 2016). This ability raises the question of how the power embedded in smart city technologies affects the relationship between citizens and governments and citizens and corporations, as Townsend (2013), Wadhwa (2015), Kitchin (2016), Penney (2016) and Elmaghraby and Losavio (2014) argue that this surveillance could have chilling effects by inducing self-censorship in people's behavior, which they perceive as detrimental to democratic society.

The second point of criticism lies in extension of this argument. Scholars such as Calzada and Cobo (2015), Hollands (2008), Townsend (2013) and Brown and Marsden (2013) question whether smart cities will live up to the promises of empowering citizens and enhancing democracy. These authors perceive the growing digitalization of the city as an omen for an emerging digital divide, where people with meager digital literacy and access - such as the elderly and the poor - are in fact disempowered by technology, since they have trouble participating in the fundamental processes of urban governance. Similarly, Söderström et al. (2014) criticize the smart city discourse for overemphasizing the role of data and software, offering little room for different interpretations, values and forms of knowledge in city management. Here, Kitchin (2014) argues that data-driven systems are often presented as being objective and value-free, even though these systems may carry within them the normative judgments and political values of their designers and stakeholders.

Third, much like smart city technologies are expected to alter citizen-government and citizen-corporations power relationships, some are concerned over the growing influence of private actors in city governance, leading to a supposed 'corporatization of city governance' (Kitchin, 2014; Söderström et al., 2014). Edwards (2016), Hollands (2015), Kitchin (2014) and Townsend (2013) observe that some of the biggest proponents of smart cities are large corporations in the field of information technologies, such as IBM, Cisco, Siemens, Vodafone, Philips, Microsoft and Oracle. According to Hollands (2015), these actors promote a technology-driven smart city ideal in an attempt to create a new market for their own products, and similarly Schaffers et al. (2011, p. 437) state that *''smart city solutions are currently more vendor push than city government pull based''*. Indeed, the global market for smart city technologies is now estimated at a value of roughly $40 billion, and is growing fast (Hollands, 2015). Moreover, by developing, financing, providing, maintaining and operating the infrastructure of smart cities, private actors also become managers of public space (Hollands, 2015). This is in line with the global salience of neoliberalism in public policies since the 1980s (Monfaredzadeh & Berardi, 2015; Kitchin, 2014). A possible consequence of this development is that cities could fall into a technological lock-in, where they become dependent on the products and services of technology vendors for long periods of time, who in turn gain increasing power in governance arrangements (Kitchin, 2014; Vanolo, 2014). Furthermore, there has been a gradual shift in data ownership, where private companies - instead of public agencies - are collecting and analyzing data on citizens' activities, data which then becomes their property instead of those who are being monitored, and can thus be sold to or shared with other parties (Krishnamurthy et al., 2016). Regarding this topic, Nieminen (2016) claims that there exists a *''policy and regulatory vacuum''* (p. 22) on both the European level and level of individual states regarding the application of ICT technologies (particularly on what data may be collected), and warns that this legal void is likely to be filled by commercial operators if it is not patched by national and supranational authorities. In this way, he claims that tech corporations could alter the way of understanding and regulation of themes such as privacy and city governance (Nieminen, 2016).

Lastly, several new security issues might arise from the proliferation of smart city technologies. As cities increasingly rely on systems and sensor-equipped devices connected to the Internet and each other, they become progresssively prone to cyber-attacks. These devices are pieces of infrastructure that are not operated by humans, but instead rely on artificial intelligence, and interact not only with humans, but also with other devices. The Internet then becomes less the domain of man, and more of machines, leading several academics and corporations to adopt the term 'Internet of Things' (Zhou, 2013). However, Internet of Things devices are frequently not tested prior to their installment, and generally have poor or non-existent security. Securing these smart city assets is difficult due to their complexity and interdependence, providing a large 'attack surface' for actors with malicious intentions. Furthermore, governments often have little expertise on cyber security, and frequently lack emergency plans if the system fails or the system's safety is compromised. All these issues put cities in danger of cybercrime and cyber-terrorism, where sensitive data can be stolen or urban functions disrupted. In this sense, Cerrudo (2015) argues, the smartest cities might be the most vulnerable. (Cerrudo, 2015; Elmaghraby & Losavio, 2014; Kitchin, 2016)

Summarizing the aforementioned sections, the concept of the smart city has both been framed as a utopia - where the creation of social and technical capital in cities facilitates economic prosperity, environmental sustainability and a more just and inclusive society - as well as a harbinger of an Orwellian dystopia, where the privacy of city-dwellers is violated, social inequalities are exacerbated, city governance increasingly becomes the domain of private actors and growing threats loom in the area of cyber security. Nevertheless, most authors position themselves on the spectrum in between these perspectives (see for example Townsend, 2013; Shelton et al., 2015; Vanolo, 2014; Wiig, 2015; Albino et al., 2015; David et al., 2015). Indeed, according to Hollands (2008), it is difficult to make such generalizing statements about smart cities, since there are vast differences in the way the idea is executed. What can be deduced from this is that a deep understanding of the smart city landscape and their implications can only be achieved through a broad study of the many ways in which the concept manifests itself.

Tying together the aforementioned points of discussion is the question of power: who will be empowered by the smart city discourse, and who will not be able to reap the benefits (or even be relegated in the process) of digitization? How do automation, monitoring and the securitization of (what is deemed to be) the public interest relate to freedom and the autonomy of the individual in smart societies? Surprisingly, as noted by Casbarra et al. (2014) and Meijer and Bolivar (2016), a quick review of the existing smart city literature shows that research covering the theme of smart city governance – particularly in the form of comprehensive analyses of power relations between public actors, private actors and civilians in smart cities - is practically void. Most existing academic publications have thus far focused on either (1) citizen participation in smart city initiatives or (2) singled out a handful of corporate-driven megaprojects, such as Songdo in South Korea and Masdar in the United Arab Emirates, arguing that large tech corporations are increasingly gaining influence in city governance (Edwards, 2016; Hollands, 2015; Halpern & Günel, 2015; Albino et al., 2015; Rossi, 2015). However, little attention has been paid to how specific choices for smart technologies affect the tripartite power relations between government, the market and citizens in existing, previously 'dumb' cities (Shelton et al., 2015). From a theoretical angle, the current smart city literature is lacking in a Foucauldian perspective that scrutinizes the forms of knowledge, means and goals that together form the smart city discourse and set these projects into motion (Rodrigues, 2016). Furthermore, according to Curry et al. (2016) and Luque-Ayala and Marvin (2015), there is a need for more case studies on successful and unsuccessful smart city deployments in order to provide insight into their challenges and offer lessons for the future. Responding to these gaps in the academic literature, this study will examine the changing power relations between public authorities, private actors and civilians in the smart city, and how these are shaped by the choices for specific smart technologies. More specifically, it will focus on smart traffic management in the Netherlands, since the area of mobility is one of the areas where smart city initiatives have proliferated the most, and is also a major field within environmental policy (Benevolo et al., 2016; Siemens, 2015; United Nations Economic Commission for Western Asia [UN ESCWA], 2015; PBLQ, 2016; Centre of Regional Science, 2007; Djahel et al., 2015).

1.2 NARROWING THE FOCUS: SMART TRAFFIC MANAGEMENT IN THE NETHERLANDS

Over the course of the last years, there has been an increase in traffic in European cities, resulting in more traffic congestion, air pollution, noise pollution, traffic accidents, respiratory problems and the delay of emergency services. Together, these traffic-induced problems aggregate into an annual economic burden on the European economy of roughly 100 billion Euros, as well as high greenhouse gas emission levels (Calabrese, 2013; Clingendael Institute, 2016; Djahel et al., 2015). These challenges have been fertile ground for the idea of smart mobility. Though it is still as nebulous as the smart city concept it is subsumed under and is rarely operationalized, it generally encompasses two types of solutions: low-tech and high-tech (Benevolo et al., 2016). First, smart mobility comprises lowering the dependence of cities on fossil fuels by enabling and stimulating low-carbon transportation modes such as public transport, bicycle programs and electric cars (Kitchin, 2016). Second, smart mobility is about optimizing transportation flows, which in return reduces travel costs, minimizes energy consumption and carbon emissions (Papa & Lauwers, 2015). Though projects in the area of mobility are not necessarily ICT-intensive, ICT is becoming more and more the locus of smart mobility given the growing complexity, integration and extension of smart mobility programs (Benevolo et al., 2016; Kitchin, 2016). As noted by Docherty et al. (2016) and Dowling and Kent (2015), all these solutions involve a renegotiation of the relationship between private interests, (urban) residents and the state.

The Dutch government has the ambition to make the Netherlands a global leader in smart mobility, particularly in the area of intelligent transportation systems [ITS]: an umbrella term for the application of a wide range of heterogeneous ICT technologies that aim to increase the efficiency, reliability, safety and sustainability of traffic (Connecting mobility, 2016a; 2016b; 2016c; Benevolo et al., 2016). Branding itself as a global 'transport hub' that ranks among the top countries with respect to digital connectivity levels, quality of transportation infrastructure and competitiveness of the domestic high-tech industry, the Netherlands has launched a great number of ITS trials in hopes of realizing this vision. Strikingly, most of these smart mobility projects revolve around the management of road traffic, since (1) automobiles form the dominant mode of transportation in the Netherlands, (2) there is a lot of expertise related to traffic management in the country and (3) surging amounts of vehicles on the road have given rise to major sustainability challenges, including CO_2 emissions, air pollution and congestion (Connecting Mobility, 2016a; 2016c; Ministry of Infrastructure and the Environment, 2016). For this reason, the subject of traffic management will be the focus of this study. Here, the focus extends beyond the analysis of how drivers are governed in new ways, and also looks at public-private power relations. Where the Dutch state and its subsumed institutions traditionally had a monopoly on data collection in public space and traffic management, these activities have been increasingly opened up to private actors (Ottenhof, 2015; Nieminen, 2016; ''Stedelijke bereikbaarheid'', 2014). Hence, it is interesting to study how private involvement came to surge in the field of traffic management, and how the inclusion of private actors in traffic management affects the way in which mobility issues are governed within the Netherlands.

1.3 RESEARCH OBJECTIVES

In response to the aforementioned claims that (1) there is a growing emphasis on data-driven (or ICT-driven) forms of smart mobility, that (2) the creation of smart cities could result in the corporatization of city governance and that (3) the relations between the governing and governed subjects are changing, this study will examine to what extent these claims can be supported by empirical evidence. Investigating the politics of smart traffic management technologies using a Foucauldian governmentality approach, the goals of this thesis are trifold. First, it aims to analyze the changing ways in which drivers are governed using smart technologies. Second, it attempts to find how the smart traffic management discourse is altering the power relations between public and private actors in the processes of governing traffic flows in the Netherlands. Third, by conducting a case study of traffic management in the Netherlands, the final objective of this thesis is to contribute to the empirical assessment of the aforementioned claims made in the smart city literature. Here, it seeks to move beyond the imagined utopian and dystopian visions on smart cities by providing a concrete illustration of an actually existing smart mobility project, shedding light on a concept that has thus far remained little more than a buzz phrase in the planning and transport literature (Papa & Lauwers, 2015).

1.4 RESEARCH QUESTIONS

The main research question of this thesis is:

''How do smart technologies transform the power relations in the governance of road traffic in the Netherlands?''

This research question can be split up in the following subquestions:

<u>Subquestion 1:</u> *''What are the key rationalities underpinning the move towards smart traffic management?''*

This study starts off with a critical reflection of the rationales that drive 'smart traffic management' in the Netherlands, since the exercise of power is preceded by the interest, vision or objective of a particular individual or group.

<u>Subquestion 2:</u> *''In what new ways are drivers sensed and made knowable*?''

Latching onto the Foucauldian notion that power can only be exercised through the use of knowledge, this question takes the processes of data production, processing, storage and analysis as its vantage point. Conceptualizing data as the fuel for traffic management, its purpose is to map what new types of traffic data are being produced in the Netherlands, how it is organized and who can access this data.

<u>Subquestion 3:</u> *''How are smart technologies altering the ways in which drivers are governed?''*

While subquestion 2 focuses on knowledge, subquestion 3 looks on the other side of the coin, seeking to find how new forms of data and new technologies are leveraged to govern traffic flows in new ways. It analyzes how the extent and nature of the 'conduct of conduct' (the exercise of power over motorists) is changing.

<u>Subquestion 4:</u> *''How and to what extent have the roles of public and private actors in traffic management changed under the influence of smart technologies?''*

Last, this study looks at how the 'smart traffic management' discourse has altered the relations between public road authorities and private contractors.

In this research, an attempt will be made to answer these research questions using Michel Foucault's concepts of power relations, power/knowledge, discourse and governmentality. These concepts are further elaborated on in the next chapter.

1.5 THESIS OUTLINE

This thesis is structured as follows. Outlining several Foucauldian rudiments of power (e.g. power/knowledge, discipline, subjectification and governmentality), chapter 2 discusses the theoretical lens used in this study. Having acquired a framework for data interpretation, chapter 3 elaborates on this study's methodology, shedding light on the research strategy, data collection methods and the scope and limitations. Subsequently, by giving a brief overview of the societal trends, scientific concepts and policy developments related to traffic management, chapter 4 provides the backdrop for results chapters 5 and 6. Reviewing the field of traffic management in the Netherlands, chapter 5 analyses the meta-developments in the ways in which traffic is governed. Consecutively, chapter 6 zooms in on the Praktijkproef Amsterdam, performing an on-the-ground analysis of new developments in traffic management, illustrating the new opportunities for governing traffic and the limitations therein. Forming the apex of this study, chapter 7 provides the conclusion of this thesis by answering the posed research questions and providing recommendations for further research.

2. THEORETICAL FRAMEWORK

2.1 POWER RELATIONS: INTRODUCING MICHEL FOUCAULT

As stated earlier, this study will focus on the changing power relations between governments, private actors and drivers in the Netherlands and how smart traffic management is framed. One of the most cited authors on power relationships, framing and discourse is the French philosopher Michel Foucault (Mol, 2008; Al Amoudi, 1999). While Foucault never attempted to provide an in-depth definition of the term power (Al Amoudi, 1999), he roughly conceptualized it as a *''complex strategical situation''*, consisting of *''multiple and mobile fields of force relations''* that are perpetually unstable, showing his emphasis on the relational aspect of power (Foucault, 1978, as cited in Cheong & Miller, 2000, p. 374-375). He studied power as the structuring of the field of action of others through a broad range of instruments, techniques and procedures through social relations (Hindess, 1996). This study of how power is exercised by actors in society is a recurring theme in his work (Al Amoudi, 1999). In ''Surveiller et punir: Naissance de la prison'' (''*Discipline and Punish: The Birth of the Prison*''), Foucault (1975; Kelly, 2009; Lynch, 2011) identifies five properties of power:

1) Power is non-subjective: power is not accumulated within actors nor does it exist de facto in their environment: it is an anonymous force existing outside of agency and structure.
2) Instead, power is relational, only coming into existence when it is exercised by one actor upon another, as Foucault would later claim that ''*power relations are rooted in the system of social networks*'' (Foucault, 1982, p. 793).
3) Power is decentered; it does not operate hegemonically and is not concentrated in one individual or class. Instead, Foucault poses that it is exercised in myriad ways, stating that *''power is everywhere; not because it embraces everything, but because it comes from everywhere''* (Foucault, 1990, p. 93).
4) Power is multidirectional: it is exercised not only by the more powerful upon the less powerful, it also comes from below. There is thus a continuous resistance against the dominant powers.
5) Power is strategic in nature. It is exercised intentionally, that is, with certain aims and objectives. However, since it is non-subjective, it does not result from the will of an individual subject.

This was a radical departure from previous conceptions of power, viewing it not as an instrument that can be seized, accumulated or shared, but instead as a force resulting from social relations (Foucault et al., 1988). In 'The Subject and Power', Foucault (1982; Blain, 2009) identifies five points that need to be addressed when analyzing power relations:

1. The *system of differentiations that permit one to act upon others*. Here, Foucault refers to the practice of division and classification of actors (for example in dichotomies, taxonomies, typologies, spatial and temporal differences) - a process he refers to as 'subjectification' - that together form knowledge. Hence, he understands the subject not simply as a synonym for 'person'; instead, it captures the way in which an actor is conceptualized and represented, such as 'the madman', 'the hero', 'the criminal' or 'the soldier'.
2. The *types of objectives* that actors pursue with their actions, such as the maintenance of privileges, the accumulation of capital and the exercise of authority.
3. The *means of bringing power relations into being*: the tools used to exercise power, such as speech, the threat of arms and systems of surveillance.

4. *Forms of institutionalization*: The types of institutions and legal structures used in the process of exercising power.
5. The *degrees of rationalization*: the effectiveness and certainty of the instruments of power used in achieving the desired results. It also comprises the costs and benefits (for example economic, political or amount of resistance) of the exercise of the power relation.

While Foucault identified a great many forms of power - such as biopower, pastoral power and sovereign power - he particularly emphasized disciplinary power as one of the cornerstones of power in modern societies (Skålén et al., 2007; Morgan, 2010; Taylor, 2009). Therefore, this chapter will begin with a brief overview of one of his earliest and most famous publications on disciplinary power: Discipline and punish. With themes of disciplinary power, surveillance and knowledge at its core, multiple authors on smart cities have spotted parallels with the previously posed questions on the subjects of surveillance, data ownership and power relationships arising from the smart city discourse (Lynch, 2011). Next, the concepts of power/knowledge, discourse and governmentality will be explained. These concepts provide the foundation for a theoretical framework of power relations.

2.2 DISCIPLINARY POWER AND THE PANOPTICON

In ''Discipline and Punish'', Foucault (1975) draws extensively upon the panopticon - a theoretical architecture of a prison conceived by the British philosopher Jeremy Bentham. The panopticon is characterized by its circular design, where inmates are placed in equally sized cells surrounding a central watchtower with a guard. The design allows the guard to see inside each of the cells, but obstructs the line of vision of the inmates on the guard, making it impossible for them to tell when or whether they are being watched. The result is that the inmates start to act as if they are being watched, for they can never be sure that they have escaped the gaze of the watchman. As such, they internalize the disciplinary power and start to engage in a process of self-regulation, where they conform their behavior to the rules of the prison (Seele, 2015). Surveillance thus establishes a certain power relationship between the observer and the observed subject: it is the exercise of disciplinary power (Mol, 2008). Hence, at the core of disciplinary power - the exercise of control over populations - lie three techniques: 'hierarchical observation', 'normalizing judgment' and 'examination'. Here, hierarchical observation refers to the processes of uninterrupted monitoring, and normalizing judgment comprises the mechanisms aiming to correct aberrant behavior. These two techniques are linked by examination, where the observed behavior is compared with the desired behavior - the norm - in order to detect and subsequently eliminate deviances (Boomsma, 2013).

Foucault sees in the architectural design of the panopticon a microcosm of the way in which power is exercised in a great many modern institutional orders, ranging from prisons to hospitals, schools and factories (Simon, 2005), describing it as *''the diagram of a mechanism of power reduced to its ideal form''* (Foucault, 1975, p. 205). In the modern age, surveillance becomes economically efficient, where the few are able to watch the every move of the many, and the panoptic model becomes a template for many institutions in society. Hence, due to its greater effectiveness, disciplinary power trumped former societal orders based on sovereign power, where control was not exercised over populations by governmental institutions, but instead over territories by a sovereign through public punishments, such as executions and torture (Foucault, 1975). Even today, this thought is echoed by several scholars (see for example Klauser et al., 2014; Kitchin, 2014; Seele, 2015), who also think of smart cities as panopticons: just like a prison aims to correct criminals, ICT technologies integrated in the urban fabric aim to discipline and normalize citizens' behavior through a process of uninterrupted monitoring.

In a sense, the architectural design of the panopticon makes the observer obsolete, as he or she does not have to be present for the model to function: the inmates can never know whether the guard is there, and thus always have to assume that they are being watched, inclining them to behave according to the rules. As such, the exercise of power is automated (Wood, 2007). According to Foucault (1975), this makes clear the anonymous and unappropriatable nature of power. Furthermore, the model showcases the relationship between power and knowledge: if the inmates are unaware of being watched and the rules they have to conform to, they would be unaffected by panoptic power (Simon, 2005).

2.3 POWER/KNOWLEDGE AND DISCOURSE

According to Foucault (1975; 1980), from this follows that there exists a reciprocal, co-producing relationship between power and knowledge: instead of viewing them as the same, he argues that the knowledge-power relation is circular. Power is based upon knowledge and utilizes it, while power also reproduces knowledge by shaping it in such a way that it reinforces the existing power relationship. Power thus produces reality: a certain framework that identifies which issues are of relevance, and favors certain solutions to tackle them (Digeser, 1992). Knowledge is therefore never neutral: it is always part of a certain 'regime of truth'; a discourse that is accepted by a society which in it bears the mechanisms that determine what is true and false (Foucault, 1980).

When a certain discourse becomes dominant, other alternative truths become marginalized. Foucault refers to these alternative truths as subjugated knowledge: *''The ways of thinking and doing that have been eclipsed, devalued, or rendered invisible within dominant apparatuses of power/knowledge''* (Foucault cited in Sawicki, 2005, p. 381-382). The knowledge of a certain dominating discourse is then internalized by societal actors and normalized, meaning that the assumptions on which the discourse rests begin to appear as being self-evident (Foucault, 1980).

In the area of policy, discourse - understood as a collection of ideas, claims, terminologies and categorizations - constructs the physical and social realities that policy acts upon, and restricts the choice of policy interventions that can be used to address problems (Bisaro et al., 2015). This is done through the process of problematization: it defines what practices and discursive objects are problematic, and subsequently renders these issues visible and knowable, simultaneously concealing other problematizations (Arribas-Ayllon & Walkerdine, 2008). Similar claims have been made by several academics studying smart cities. According to Kitchin et al. (2016), in the smart city, data is produced, managed, shared, analyzed and used in ways that are never objective and neutral, since there are always underlying values and goals within the institutions that use it. Similarly, Van Brakel and De Hert (2011) pose that in a smart city, the *surveillance gaze* is selective, prioritizing data collection on specific parts of the population, city areas and subjects that the operators deem to be important (Van Brakel & De Hert, 2011).

In contrast to most other conceptualizations of power, Foucault sees power not only in negative terms, but also as positive. Power is both a productive force and a constraining force: it produces the social world and affects the way in which the world is framed and talked about, while simultaneously ruling out other ways of talking about and framing the world (Sheridan, 1980; Skålén et al., 2007). Similarly, a discourse is not just a medium that transmits, reproduces and reinforces power relations; it simultaneously undermines and exposes itself, offering possibilities to bring about change (Foucault, 1990). The strength of this particular view on discourse is thus that it does not only explain how specific actions and claims about the world are legitimized by a dominant discourse in society, but also how social changes occur, attributing these to shifts in relative influence between different discourses (Sharp & Richardson, 2001).

2.4 GOVERNMENTALITY

A culmination of Foucault's writings on knowledge, power and the subject is his concept of governmentality (McGushin, 2011; Lemke, 2002). The term 'governmentality' or the 'art of government' ''*involves the development and employment of particular technologies, which are built from and act to reinforce particular rationalities, which leverage and create a particular set of knowledge, and thus right behavior in the world''* (Sturup, 2013, p. 133). Here, the terms 'technologies', 'rationalities' and 'knowledge' that Foucault employs need further specification. In Foucault's understanding, the term 'technologies' does not only encompass technical means, but also encapsulates 'human technologies': standardized methods and examinations such as customer satisfaction schemes, mentoring, and debates that promote a certain type of control of human behavior (Skålén et al., 2007). Through the use of certain technologies of government, authorities try to discipline populations and mold, normalize and instrumentalize their thought, conduct, decisions and aspirations in order to attain the objectives they consider desirable: they attempt to create conditions where individuals self-regulate their behavior in accordance with the objectives of the governing actors and their actions (Sturup, 2013; Miller & Rose, 1990). The 'rationalities' that Foucault refers to are the forms of reasoning that define the objective of the action (Lemke, 2002; Klauser, 2013). Lastly, governing actors must have access to some types of data on the populations they are trying to govern in order to render them governable, and in return also create a particular set of knowledge through the act of governing (Rodrigues, 2016). Governmentality is thus discursive: a way of defining problems and proposing solutions (Miller & Rose, 1990).

Latching on to Foucault's (predominantly) state-centric approach to governmentality, Miller and Rose (1990; Rose and Miller, 1992) further developed the governmentality framework for the analysis of power in what they call 'advanced liberal democratic societies'. They argue that Foucault's notion of 'government' stretches beyond the actions of the state, as Foucault himself stated that his understanding of the term was based on the older notion of 'the act of governing', which is to *''structure the possible field of action of others''* (Foucault, 1982, p. 790); it is the conduct of conducts through an *"ensemble of institutions, calculations and tactics"* (Foucault, 1991a, p. 102). In turn, Miller and Rose (1990) argue that this can be done by any actor. This apprehension paved the way for the notion of 'neoliberal governmentality', which entails the transfer of some of the operations of government from state to non-state actors, accompanied by the extension of the logic of the market into state functions, where public institutions - if not privatized - are designed to run as businesses (Ferguson & Gupta, 2002). Similarly, while governmentality is directed towards populations, these do not necessarily comprise bodily persons (Foucault, 1991a).

Rose and Miller (1992) offer an operationalization of governmentality using a tripod framework, which can be seen in Figure 1. In line with Foucault, they perceive government as the processes of problematization and the subsequent internalization of values by the governed subjects.

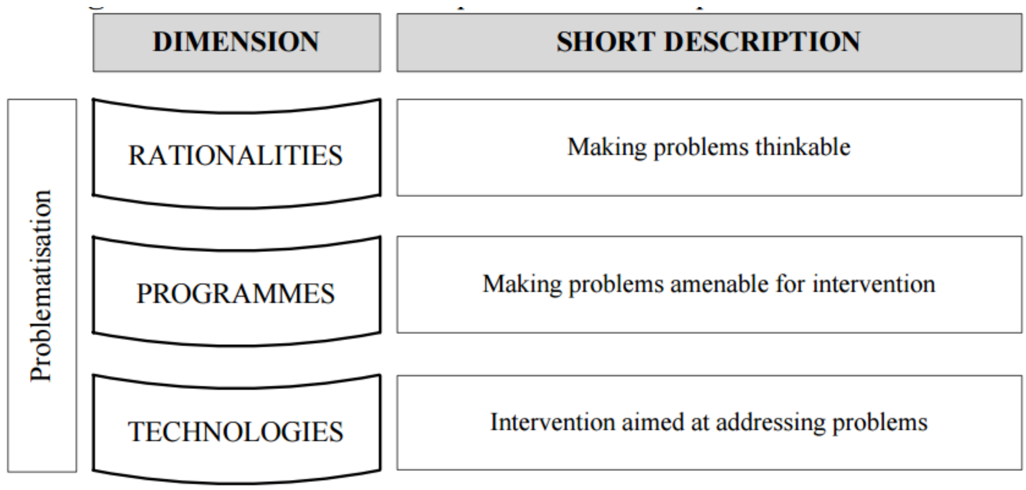

Figure 1: Overview of the problematization process (Boomsma, 2013).

In contrast to the aforementioned definition that splits up governmentality in 'rationalities', 'technologies' and 'knowledge', this framework exchanges 'knowledge' for 'programmes'. Here, rationalities are translated into programmes, which are subsequently translated into technologies, whose effects in turn can reinforce or alter the rationalities of government. Below, the aspects of each of these three dimensions are listed.

Rationalities of government - or political rationalities - define and address problems, in turn rendering them thinkable and visible. These consist of three aspects. First, they appeal to a certain *moral form*, in which the ideas or principles that should drive government - such as efficiency, quality, freedom or justice - are articulated. Second, they have a particular *epistemological character*, specifying the subject to whom government should be directed. Third, they are characterized by a *distinctive idiom*, as they employ a certain type of language to articulate the rationalities (Rose and Miller, 1992; Boomsma, 2013).

Bridging rationalities and technologies, programmes of government comprise the way in which political ideals are translated into practical, feasible and assessable ambitions and goals. First, programmes invoke particular types of *knowledge* in order to legitimize interventions, particularly laying claim to quantitative and objective knowledge. Second, programmes presuppose a *programmable reality* in the sense that the behavior of governed objects stems from certain determinants, rules, norms and processes that can be improved and acted upon by authorities. Lastly, programmes are defined by an *eternal optimism*, holding that government can always be more effective, and that the failure of one policy will result in the development of new policies that will work better (Rose and Miller, 1992; Boomsma, 2013).

From programmes of government flow technologies of government: certain intervention mechanisms that translate rationalities and programmes into action. The list of these mechanisms is unlimited, but examples are procedures of examination, assessment and standardization (Rose and Miller, 1992; Boomsma, 2013).

2.5 ALGORITHMIC GOVERNMENTALITY

Building upon Foucault's notion of disciplinary societies, Deleuze (1992) introduced the concept of 'societies of control'. Where Foucault analyzed the exertion of power in enclosed spaces - the factory, the barrack, the hospital - Deleuze observes that, in late Modernity, these mechanisms of disciplining populations are spreading beyond the confines of modern institutions, and start to function in open and networked systems, effectively creating 'societies of control'. Key to this shift are new technological advancements in the realm of ICT, allowing for greater control over societies through ubiquitous systems of automated and preventive surveillance, assessment and intervention. Increasingly, individuals are not assessed as persons - where they are monitored by humans that register a multitude of qualities related to their appearance and behavior - but are broken down into 'dividuals', as they are monitored by sensors that isolate and represent individual qualities of their behavior (Sadowski & Pasquale, 2015; Galič et al., 2016). Hence, as sensors and computers replace the human perceptual apparatus as the instruments of surveillance, the individual is no longer a self-contained entity that forms the smallest unit of society, but becomes endlessly divisible, reducible and representable as infinitesimal numerical data (Deleuze, 1992; Galič et al., 2016). As such, the classic divide between the individual and the masses is blurred, since the individual can be atomized into specific factors to be selected, scrutinized, surveilled and targeted, while the masses become 'samples' or 'data' in which statistical patterns can be established (Sadowski & Pasquale, 2015; Rodrigues, 2016).

Deleuze's notion of societies of control lies at the core of a specific form of governmentality attributed to smart cities that Rodrigues (2016), Leszczynski (2016) and Rouvroy (2011; 2013) call 'algorithmic governmentality', where the process of governing is facilitated by digital technologies, specifically algorithms. 'Algorithmic governance' - or 'governing through code' (Klauser, 2013) - has two functions. First, it is about the identification of patterns in collected data. Second, it concerns the detection of anomalies in these patterns (Pasquinelli, 2015, as cited in Rodrigues, 2016). Here, control is exercised by identifying normal patterns, and exercising disciplinary measures towards anomalies in these patterns. By establishing patterns in data and attempting to govern future actions based on these patterns from the past, it becomes a speculative governmentality based on prediction, which attempts to 'govern the ungovernable' (Rodrigues, 2016; Leszczynski, 2016; Rouvroy, 2011). By mirroring society in seemingly objective digital models free of contradictions and complexities, it reproduces and naturalizes existing power relations and social inequalities, despite being built on assumptions using certain techniques for the collection and analysis of data (Rodrigues, 2016; Rouvroy, 2011). Hence, S.D. Graham (2005) argues that digital technologies have rationalities embedded within them that produce specific forms of knowledge and thus reproduce existing power relations, stating that *"code-based technologized environments continuously and invisibly classify, standardize, and demarcate rights, privileges, inclusions, exclusions, and mobilities and normative social judgments across vast, distanciated domains"* (p. 563).

In conclusion, Rouvroy et al. (2013) identify three stages of algorithmic governmentality:

1. *The collection of big data and the constitution of data warehouses*: the conduct of 'dataveillance' through the automatic collection and storage of massive amounts of unfiltered data from various sources.
2. *Data processing and knowledge production:* this refers to the process of 'data-mining', where the collected and stored data is automatically analyzed in order to reveal statistical correlations, free of predetermined hypotheses. Instead, from this machine learning arise hypotheses that are produced directly from the data.
3. *Action on behavior:* in its final stage, algorithmic governmentality involves putting the generated hypotheses and statistical probabilities into action, where the behavior of individuals is actively anticipated on and linked to profiles.

2.6 CONCEPT SELECTION AND CONCEPTUAL MODEL

This thesis seeks to analyze two types of power relationships in the field of traffic management in the Netherlands (see Figure 2). First, it analyzes the dynamics of power between the governing actors (traffic managers) and the governed actors (drivers). Since this comprises the 'conduct of conduct' through 'smart' technologies, the central concept used will be that of 'algorithmic governmentality'. Likewise, it explores and examines to what extent market actors are becoming involved in traffic management (a development previously referred to as ‘corporatization’), and how the responsibilities for governing traffic are rearranged between public road authorities and private service providers. Here, the concept of neoliberal governmentality is used.

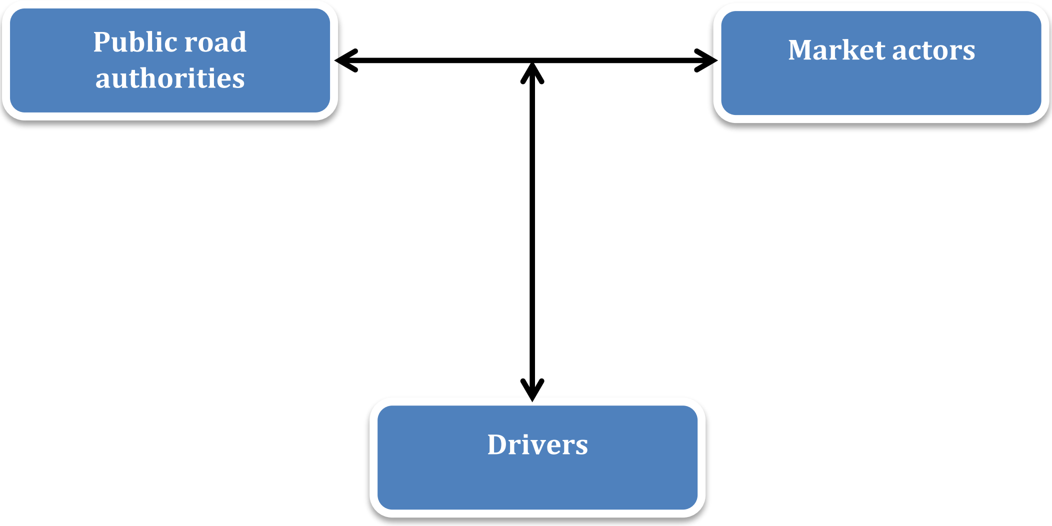

Figure 2: Author’s conceptualization of the power relations examined in this thesis (Own work).

3. RESEARCH METHODOLOGY

''All my books ... are little tool boxes. If people want to open them, to use this sentence or that idea as a screwdriver or spanner to short-circuit, discredit or smash systems of power, including eventually those from which my books have emerged ... so much the better!'' (Foucault, 1975, cited in Patton, 1979, p. 115)

3.1 INTRODUCTION

This chapter is intended to bridge the theoretical framework of the previous chapter with the empirical field, showing the methods that have been used in order to answer the aforementioned research questions. As reflected by the quote presented above, Foucault was reluctant to adhere to or prescribe a fixed methodological approach for studying power relations, since he viewed these modes of scholarship as lending truth status to knowledge - a notion he was very suspicious of (Foucault, 1991b; L.J. Graham, 2005). Instead, he intended his work as a toolbox from which researchers could draw as they wish in order to follow an approach to their object of study they saw fit (Foucault, 1994). Therefore, I have not necessarily followed a prescribed set of methodological steps. Instead, I have used a set of approaches that appeared as being the most sensible and appropriate.

In the following sections, the research strategy employed in this study will be discussed, after which it will describe the utilized methods of data collection. Subsequently, the methods of data analysis are discussed. Last, the scope and limitations of this study are outlined.

3.2 RESEARCH STRATEGY

The function of the research strategy is to ensure that the evidence collected answers the initial research question in the most comprehensive and unambiguous way (De Vaus, 2001). As becomes clear from the research objectives and questions of chapter one, this study is qualitative in nature: rather than interrelating quantifiable variables in order to find generalizable statements, its aim is to gain in-depth knowledge (Creswell, 2007; 2014). More specifically, the selected strategy is the case study, as Yin (2003) recommends a case-study design when:

- How or why questions are being posed
- The investigator has little control over the events
- When the focus is on a contemporary phenomenon within some real-life context

All these points are reflected by the subject and central question of this research, which aims to scrutinize the way in which power is exercised within a specific setting – the field of traffic management in the Netherlands – and how this is changing by adopting a Foucauldian perspective. Thus, this study examines two aspects: (1) how power is – and has been – exercised in the area of traffic management, and (2) how the modes of power are changing as a result of the smart traffic management discourse. The first aspect primarily entails an analysis of trends: it examines how the contemporary traffic management model came to be, and how power functions therein. The second aspect, however, is trickier, since the studied developments are still in motion. Since the question put forward in this thesis seeks to analyze how the social dynamics of smart traffic management technologies are unfolding, an in-depth study of a single case seems most appropriate. However, the last years have witnessed the launch of a plethora of new projects related to smart mobility and traffic management on a variety of scales (e.g. the international ITS corridor, sensor city Assen, De Innovatiecentrale), trialing a diverse array of innovative technologies and organizational structures. This complicates the selection of a singular 'microcosmic' case that embodies all the core trends within traffic management. Nevertheless, this study aims to surmount this point by focusing on a project that approximates an exemplary (also known as 'paradigmatic' or 'typical') case: the Praktijkproef Amsterdam. Seeing that the Ministry of Infrastructure and the Environment presents the project as largely capturing the essence of its smart mobility program (Connekt, 2013), it seems reasonable to assume that the Praktijkproef Amsterdam is at the locus of the dominant traffic management discourse. Hence, it will likely have a significant role in the process of shaping the ways in which traffic is managed in the future. (Flyvbjerg, 2006; Yin, 2003)

Yet, there is another reason for choosing a case study design. As argued in the introduction chapter, most conceptualizations of smart cities have thus far been rather nebulous and abstract, quickly finding themselves reduced to utopian and dystopian caricatures. By studying actual developments on the ground, this thesis seeks to break free from such partisan and idealized social imaginaries, aiming to paint a more nuanced picture of the multifarious notion of the smart city by showing and analyzing how an actual smart mobility project is materializing in the real world.

3.3 DATA COLLECTION METHODS

Studying the changing power dynamics in traffic management requires some forms of data. Since qualitative, single case studies are intrinsically susceptible to bias and other challenges related to validity, the use of multiple data collection of methods (known as data triangulation) is recommended to - at least partially - overcome weaknesses associated with individual data collection methods (Creswell, 2007; Denzin, 2006; Yin, 2003). As such, this study has made use of multiple means of data collection: interviews, field observations and documents. These will be further specified in the sections below.

3.3.1 INTERVIEWS

11 semi-structured interviews with professionals in the field of traffic management were conducted between November 2016 and January 2017 (see appendix A). The purpose of these interviews was twofold. First, they were conducted with the aim to expand the pool of available data (which mostly comprises text documents) on traffic management and the PPA project. In particular, they offered insight into the viewpoints and experiences of particular actors involved in traffic management, adding richness, depth and illustrations to the (more general and descriptive) documents that were consulted. Second - and arguably of equal importance - the interviews served as a vehicle for clarification, allowing me to test and discuss my preliminary hypotheses and observations with the interviewees, and also offered me the opportunity to inquire about details I felt were unclear. A semi-structured approach was chosen because structured interviews leave little room for follow-up questions (and thus do not provide much depth) and unstructured interviews are very time-consuming and difficult to manage. Semi-structured interviews provide a middle ground by offering the researcher several key questions to explore, but also allow the interviewer and interviewee to diverge from these in order to explore certain areas of interest in greater detail (Gill et al., 2008).

The interviewee identification and recruitment process began with desk research, where the organizations and individuals involved in traffic management (and specifically the PPA project) were identified. Subsequently, these actors were contacted by email, some of which were later also contacted by telephone. Second, a few interviewees were identified using snowball sampling, where participants recommended other potential interviewees for the study. Lastly, one interviewee was contacted in person at the Verkeer, Mobiliteit & Parkeren

Expo (see field observations). In the process of sampling participants, an attempt was made to include interviewees from both public and private organizations. Furthermore, since the public road authorities are particularly variegated in their responsibilities and expertise, I attempted to interview individuals from different organizations.

Prior to the interviews, some preparatory desk research was done in order to prepare a list of themes to discuss. Consecutively, the interviews were conducted using a semi-structured approach, and were held in Dutch, since all participants were native Dutch speakers. Since the participants had different types of expertise and were not all involved in the same (sub)projects, the list of themes was tailored to each interviewee. The data generated through the interviews was captured in two ways. First, after the interviewees gave their consent, the audio of all the conducted interviews was recorded in .WAV format. Simultaneously, key notes of the themes discussed were taken during the interviews, which served as an overview of the key themes discussed. One National Data Warehouse for Traffic Information [NDW]-affiliated interviewee was also contacted twice by e-mail after our interview in order answer a few additional questions.

After the interviews were conducted, they were transcribed using a combination of the Transcribe! software and Microsoft Word. Since the items discussed in the interviews varied significantly and the number of interviews was not very large, I did not code the interviews, since this technique is mainly used to categorize and sift through large volumes of data in order to uncover central themes (Lichtman, 2012). Instead, the interviews were summarized by highlighting central passages and recurring subjects or phrasings. This helped to identify certain trends and discourses present in the interviews, as well as ruptures therewith.

3.3.2 PARTICIPATION AND FIELD OBSERVATIONS

Next to interviews, data was gathered by means of participation and field observations, allowing me to see traffic management in action. Observations were made on three locations: a mobility trade fair, a national mobility roundtable and at a traffic control center. Here, I made notes where I wrote down general impressions and conspicuities. First, I attended the Verkeer, Mobiliteit & Parkeren (Traffic, Mobility & Parking) trade fair in Houten on November 23 and 24, 2016. Featuring a wide variety of lectures by experts and a trade show floor with over 150 exhibitor booths, it is one of the largest annual events for the mobility industry in the Netherlands. By attending a number of presentations, walking amidst the array of flashy technologies showcased by exhibitors and speaking with attendees, I was able to get a general impression of the 'hot items' in the field. This, in turn, helped me in the process of identifying trends and points of debate.

Second, additional data related to privacy issues surrounding intelligent transportation systems was gathered by attending one of the Smart Mobility roundtables organized by the Dutch Integrated Testsite Cooperative Mobility [DITCM]. A joined initiative by Connekt (a platform set up by the Ministry of Infrastructure and Environment) and AutomotiveNL (the trade organization of the automotive industry), the purpose of the roundtables is to share and expand the amount of knowledge on smart mobility. Here, I attended one of the 'legal aspects' roundtable meetings, specifically with to aim to learn more about privacy issues surrounding intelligent transportation systems.

Third, following an interview with a traffic management consultant at a Rijkswaterstaat traffic control center in Velsen-Zuid, he was kind enough to give me a brief tour of the facility, including the traffic control room. This allowed me to get an impression of the structure of the building and of the way it functions.

3.3.3 DOCUMENT ANALYSIS

The last method used to collect data was desk research, which entailed an extensive literature study of articles by professionals, policy documents and other reports. In particular, two websites served as the main sources of data. First, the bulk of the data about general developments in the field of traffic management was retrieved from *NM magazine*, the quarterly journal of the Dutch mobility sector. Launched in early 2006, it serves as an independent platform where experts and professionals from both public and private institutions discuss the latest developments in the area of traffic and transportation. Reading through a decade's worth of articles by practitioners on traffic management allowed me to identify core developments within the field, together constituting various expert discourses in the field.

Second, most of the information about the Praktijkproef Amsterdam was obtained by consulting the project website (https://www.praktijkproefamsterdam.nl/). The website features a database where a large number of presentations, reports and other files related to the PPA projects can be found. In particular, the PPA sub-project evaluation reports offered a comprehensive overview of the projects, as they reflected on the implemented technologies, the effectiveness thereof and the experiences of the different actors involved in the project.

3.4 SCOPE AND LIMITATIONS

Due to the limited amount of time for this study, only one case could be selected, in spite of the fact that there are numerous innovative projects to be found in the Netherlands related to smart mobility and traffic management; all having a unique approach to smart traffic management. Since these other cases are not included, the findings of this study are difficult to generalize for the entire country. Moreover, given that the understanding and implementation of smart traffic management in the Netherlands is still very much in development, the findings of this study should be regarded as a snapshot of the ongoing developments.

Furthermore, while I approached the theme of smart traffic management from the angle of smart cities, I came to the conclusion that the overarching 'smart city' label was perhaps inadequate for this particular subject. By definition, mobility is relational and decentralized: it does not lend itself as something localized in one particular place (e.g. a city), but happens in a network between places within and between cities. Therefore, this study does not necessarily confine itself to the analysis of smart infrastructure in a single urban area, but instead borrows from and builds upon the smart city literature in the process of analyzing the ways in which smart innovations are realized within the realm of traffic management.

During the research process, I also encountered a few problematic aspects in the process of delineating the scope of this study. Whilst traffic management - and more specifically the governance of drivers – initially struck me as an adequate and manageable demarcation for my study, I discovered that both 'traffic management' and 'drivers' are quite multifarious concepts. As indicated by paragraph 5.2, there is no universally agreed upon definition of traffic management: while some may limit its scope to 'steering' traffic, others also include more subtle means to influence drivers, such as informing, advising and leading. Here, I have chosen to use the latter, broader understanding, since this was the definition used by most interviewees. Similarly, the governed population - 'drivers' - is also more heterogeneous than the name may suggest: many types of vehicles make use of the same network of roads, including trucks, buses, cars/taxis, motorcycles, scooters and bicycles - means of transportation that are often regulated in rather unique and specific fashions. However, excluding some of these means excluding a significant share of traffic on the road, which is not always logical when studying traffic management. Nevertheless, in order to give this study more direction and depth, I have specifically focused the car, since this is the most popular means of transportation in the Netherlands, and thereby also forms the focal point of traffic managers.

From a Foucauldian point of view, there also is an awkward tension when selecting specific documents and interviewees, since this is a process of prioritization: some stakeholders are given a platform to express their views in this study, while others are excluded. To prevent a state of inertia resulting from this notion, an attempt has been made to include some of the 'key players' in the field of traffic management and the PPA project. However, who the key players are is open to debate. For example, when looking at the list of interviewees, one could argue that I should have included motorists, since they also have stakes in way traffic is managed. However, since most of the interviewees also assumed the role of the motorist, I deemed this to be unnecessary. Furthermore, since I had the hunch that most drivers had little knowledge about the details of traffic management infrastructure and the PPA project, I figured that interviewing motorists would not contribute significantly to the aforementioned goals of the interviews.

Next to challenges in scope delineation and empiricism, the use of Foucault's concepts related to power as standalone theoretical devices has been challenging as well. In my experience, the concepts put forth by Foucault seemed a little hollow at times, since Foucault often refrained from providing clear definitions of the terms he used. Consider the case of power relationships: how can one adequately study and grasp power relationship when the author himself for the most part avoids defining the very concept of power? Hence, it comes as no surprise that academics have interpreted and applied his work in vastly different ways (Gaventa, 2003; L.J. Graham, 2005). This greatly frustrated Foucault, who frequently (and perhaps unfairly) complained to be misunderstood (Al Amoudi, 1999). In spite of this critique, the Foucauldian approach to power seems to be most apt for analyzing how power is exercised through smart infrastructures, since the relational aspect of power emphasized by Foucault is exactly what this thesis seeks to explore.

Last, I, quite paradoxically, experienced Foucault's rejection of a fixed methodology - through which he sought to free researchers from constraints imposed on them by existing modes of power – as rather stifling. If there is no pre-existing set of guidelines to draw from, one's methodology could run the risk of becoming haphazard. To safeguard this study from this risk, I have used a rather traditional research design (a case study plus an analysis of the wider societal context) and relied on widely used data collection methods: interviews, observations and document analysis.

4. SOCIETAL TRENDS AND POLICY DISCOURSE

4.1 INTRODUCTION

The traffic management landscape is evolving rapidly. As illustrated in the coming chapters, it is a field continuously redefined by new technologies, lexicons, scientific discoveries and governance arrangements. As argued in chapter 2, these developments should not be seen as isolated events, but are both produced by and exerting influence upon broader societal discourses. Therefore, in order to comprehend and contextualize the trends discussed in the following chapters, one should have basic knowledge of the social developments, traffic engineering concepts and governmental policies that have spawned and legitimized the ensuing new modes of traffic monitoring and intervention. Hence, the purpose of this chapter is to provide the reader with a concise overview of the most relevant developments therein. First, it will briefly discuss the issue of congestion in the Netherlands, after which it will shed light on several relevant core concepts in traffic flow theory. Subsequently, it outlines two recent governmental programs related to intelligent transportation systems: Beter Benutten (Optimizing Use) and Beter Geïnformeerd op Weg (Better Informed on the Road).

4.2 CONGESTION: THE MOTIVATION FOR MANAGING TRAFFIC

The traffic intensity on the Dutch roads is increasing. According to the Dutch agency for statistics - the Centraal Bureau voor de Statistiek [CBS] (2016a; 2016b) – and Trafficquest (2011a) the average distance travelled by car has been increasing over the past decades, increasing with 22% between 2000 (55,6 billion kilometers) and 2015 (67,8 billion kilometers) (see Figure 3).

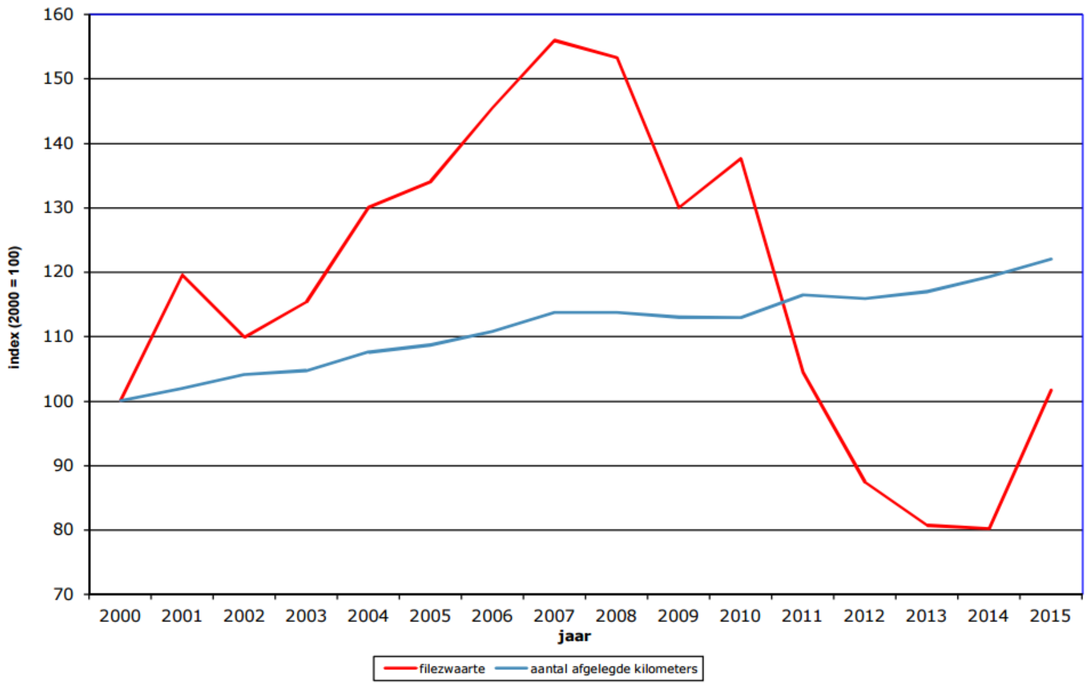

Figure 3: Traffic jam intensity (filezwaarte) and kilometers travelled (aantal afgelegde kilometers) in the Netherlands between 2000 and 2015 (Rijkswaterstaat, 2016a).

Similarly, car ownership levels have surged, rising from 6.3 million in 2000 to 8.1 million in 2015. While such trends may be regarded as signs of economic vitality, they have exacerbated traffic congestion in the Netherlands (Rijkswaterstaat, 2016a; Kennisinstituut voor Mobiliteitsbeleid [KiM], 2016). Indeed, even though the amount of traffic jams took a dip in the wake of the global financial crisis of 2007-2008 (see Figure 3), they have again been on the rise since 2014 as the Dutch economy strengthened (Trafficquest, 2016). Adding fuel to fire, the global oil price plunge of 2015 has functioned as an additional stimulus for car use (Planbureau voor de Leefomgeving [PBL], 2017; KiM, 2016; Rijkswaterstaat, 2016a).

In the *''Future of Traffic Management''* report by Trafficquest (2011a) - the expert organization on traffic management established by Rijkswaterstaat, TNO and TU Delft - the function of traffic management is considered to be ensuring an optimal traffic flow. In other words, traffic managers are primarily concerned with tackling traffic congestion, which is estimated to have an annual economic burden of €2.5 to €3.4 billion on the Dutch economy (Trafficquest, 2011a; KiM, 2016).

4.3 THEORETICAL VIEWS ON CONGESTION

While there is ample evidence that the Dutch road network is facing growing congestion, one might ask what the argument for managing traffic is in the first place, given that traffic flows are quite capable of self-organization and self-regulation. Indeed, under dilute traffic conditions, drivers are generally able to govern their actions in such a way that other users are not negatively affected. However, as roads are used more intensively, this system becomes less stable. As such, traffic jams occur when the capacity of a road is insufficient for the discharge rate: the amount of vehicles that attempt to use it. After a certain quantity of vehicles on the road, a tipping point is reached, where a phenomenon known as the *capacity drop* occurs (see Figure 4). (Trafficquest, 2011a)

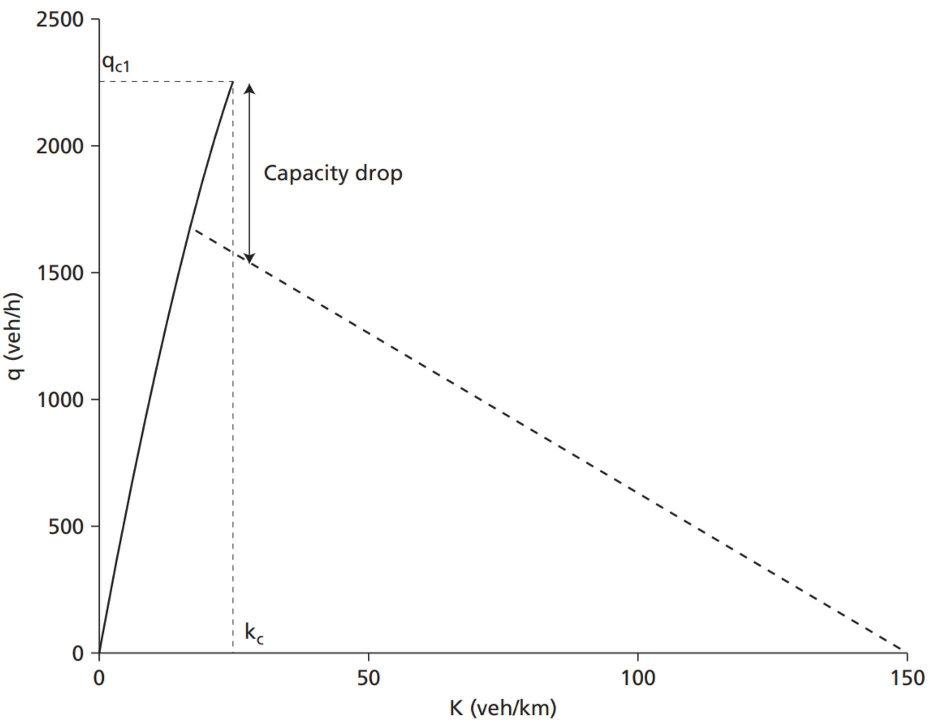

Figure 4: Flow-density diagram showing the relation between the quantity of vehicles flowing out of the network per unit of time (q) and the amount of vehicles in a part of the network (k). At the critical outflow value qc1 and critical density kc, the capacity drop occurs, decreasing both q and k (Hoogendoorn & Knoop, 2013).

The capacity drop refers to the plunge in the amount of vehicles able to make use of a road, and manifests itself when a certain traffic density threshold is reached, where the road capacity can decrease by as much as 30 percent. This phenomenon stems from inefficiencies in drivers' behavior: in a traffic jam, motorists do not maintain headway with the same proximity as before the holdup, leaving larger gaps between cars and lowering the road capacity. In this situation, motorists are not able to drive efficiently and use the available space in line with the network optimum, which leads to stagnation. This observation essentially justifies intervention by the traffic manager, who attempts to administer traffic flows in such a way that the capacity drop is delayed - or even avoided – and the space in the network is used optimally. To achieve this, traffic managers have several options at their disposal, including limiting the network inflow, spreading traffic over the network and expanding the network capacity (by opening peak hour lanes). (Raad voor Verkeer en Waterstaat, 2007; Trafficquest, 2011a; Hoogendoorn & Knoop, 2013)

A related cause of traffic jams is the *shockwave effect*. When a car in crowded but freely flowing traffic suddenly brakes, the tailing cars have to brake as well, perturbing the speed, density and flow of the string of vehicles. This change in the flow-speed-density state is referred to as a shockwave, which ripples backwards through traffic in the form of a cascading sequence of braking and accelerating cars. Similar to the capacity drop, it stems from inefficient driving behavior, such as unnecessary instances of breaking and accelerating by motorists. (Trafficquest, 2011a; Hoogendoorn & Knoop, 2013)

Moreover, a queue of vehicles on one road may 'spill back' to an intersection or conjoining road, where it interferes with traffic approaching the junction from other directions, preventing vehicles from moving forwards through the intersection. The result is a situation known as the *gridlock effect*, where traffic is completely inert on multiple roads, and no vehicular movement is possible in any direction. This, in turn, only exacerbates the situation, and congestion spreads like an oil spill over the network. For this reason, traffic managers usually attempt to prevent queues from becoming too long. (Trafficquest, 2011a; Hoogendoorn, 2010)

Last, an important factor in network congestion is the fact that drivers frequently select routes that can be regarded as suboptimal from a network perspective. Due to the fact that drivers are often not fully informed about the consequences of their own actions for the wider network, they only take their personal interest into account when choosing a route. While this does not significantly affect the network through flow under dilute traffic conditions, a Hardin-esque tragedy of the commons may ensue when the network gets more crowded. As road users start to compete for the scarce network capacity, a road becomes less able to absorb all vehicles that wish to use it, ultimately resulting in congestion when the demand for space exceeds the supply. For this reason, traffic managers are experimenting with a variety of methods to reroute and spread traffic over the network in order to secure the network optimum. (Trafficquest, 2011a)

4.4 BETER BENUTTEN

Responding to the perceived inefficiencies in the use of the Netherlands' transportation networks, the Ministry of Infrastructure and Environment initiated the program 'Beter Benutten' (Optimizing Use) in 2011. Launched amid a political impasse - where neither road expansion nor road pricing managed to gain sufficient support across the political spectrum (''Politiek'', 2010) - Beter Benutten instead focused on increasing the return on investment of the existing infrastructure, presenting itself as a cost-effective third option. Finding wide appeal among the political jigsaw, its primary aim was to achieve smarter, more efficient use of infrastructure by optimizing the existing capacity of transportation networks, creating more and better interlinkages between different modes of transportation, spreading traffic over the day and collaborating with different levels of government and the private sector (Ministerie van

Infrastructuur en Milieu [MIM], 2016; Rijkswaterstaat, 2016a). In her letter to the Parliament, minister Schultz van Haegen gave her motivation for the program, stating that *''[i]n order to strengthen the economy structurally, the Netherlands needs a well-functioning infrastructure of roads, railroads, waterways and public transit that offers optimal accessibility to travelers and businesses''* (Schultz van Haegen, 2011, p. 1).

A nationwide 1.4 billion euro program, Beter Benutten focused on the Netherlands' busiest regions, encompassing close to 400 projects, varying in scale from local to supra-regional, aiming to improve accessibility for all road, water and rail-bound modalities. Setting a 20-percent congestion reduction target for 2014, it attempted to realize this goal using three types of measures (MIM, 2015; 2016):

1) *Demand management* measures, oriented at providing alternatives for commuters with respect to their time of departure, modality and route. Examples are rewarding peak avoidance, stimulating telecommuting and encouraging the use of e-bikes.
2) *Intelligent transportation systems* and *dynamic traffic management*. These measures are aimed at improving the spread of traffic over the network, the provision of traffic and route information, implementing smart traffic lights and improving the quality and coverage of traffic data (referred to as ''basis op orde'': a proper foundation) – the lifeblood of ITS.
3) *Supply management* measures, which focus on modifying or expanding road infrastructure. Examples are the construction of new P+R facilities, investing in public transport, improving the design of traffic junctions and adding peak hour lanes.

After the Beter Benutten program ended in 2014, it was extended to 2017 in the Beter Benutten II project. Different from phase 1, which was mainly oriented on the freeways, Beter Benutten II, also includes lower-level road networks (Bezemer, 2014). Furthermore, the focus has shifted from roadside infrastructure towards innovative in-car solutions (Birnie et al., 2015).

4.5 BETTER INFORMED ON THE ROAD: 'LEARNING BY DOING'

Another important milestone for traffic management in the Netherlands was 7 February 2013, when Minister Melanie Schultz van Haegen issued the action program 'Beter geïnformeerd op weg' (Better informed on the road [BGOW]). In early November of the same year, the Ministry released two products of the action program: the Roadmap and Implementation Agenda (Connekt, 2013). The roadmap was the product of a coalition of public and private actors, who jointly identified the changes that they deemed necessary, along with six transition routes to realize these. These transition routes are 10-year plans for the period 2013-2023 (Connecting mobility, 2016a). The following transition routes were articulated (Connekt, 2013):

1) *From collective influencing towards a smart mix of collective and individual service provision*. The report notes that the rise of private information services, such as smartphones, navigation systems and personal computers, decreases the influence of collective steering, and is therefore rendering this method obsolete. A new development perspective is emerging where there is a 'smart mix' of collective and individual service provision methods, involving a different division of roles and responsibilities between market players and governments. The composition of this mix will likely vary between urban road networks and highways, and will be constantly subjected to change.
2) *A changing role of roadside systems*. In the future, there will likely be fewer stand-alone systems. Instead, roadside systems are expected to become more cooperative in nature, sharing some of their functions with in-vehicle and handheld systems. Furthermore, cooperative roadside systems gain additional functions, such as 'platooning':

coordinating a motorcade of vehicles through WiFi systems. Existing functions, such as data collection and incident detection, will probably change as well.

3) *From local/regional towards nationwide coverage of travel information and traffic management*. According to the report, road users have a holistic view of the Dutch road network, and desire to experience it as a seamless, cohesive whole. Therefore, they should not be able to notice that different road managers are responsible for different parts of the network. Hence, the practices of informing and managing traffic should be shaped on either the regional or national level.
4) *From business-to-government towards business-to-consumer and business-to-business*. Given that (a) governments strive for cost-effective traffic management and (b) businesses are presumably faced with new prospects for private traffic information services, the roadmap poses that there is a lesser need for governments to finance such services. Although the report acknowledges that most of the potential for viable business cases and their boundary conditions is yet to be explored, it argues that the revenue models of these private service providers should primarily have a business-facing and consumer-facing structure.
5) *From data as a property towards maximal openness and availability of data (both public and private)*. In the report, data is regarded to be an important enabler of innovations in traffic information and management. The European Union has required government agencies to share their data with the public. In accordance with this open data policy, most governmental bodies in the Netherlands have made their data related to traffic information and management publicly available, aiming to enable all actors with stakes in these areas to freely access their data. Likewise, the government encourages data owners to make their data available to others as open data; preferably free of charge, but there are options for setting certain conditions and charging fees.
6) *From government control towards public-private cooperation and alliances.* The final observation of the roadmap is that interplay between governments and private service providers is changing, much like the revenue models that underlie these relations. Since these actors are mutually dependent, neither can exert full control over the road network, in turn, necessitating cooperation between the public and private sector. As such, structural discussion platforms need to be established where agreements can be made on subjects such as standardization, data availability and data quality.

The roadmap states that both governments and the private sector have to commit to solving the challenges of traffic management (Connekt, 2013). This statement is echoed by Trafficquest (2015), which also sees a shifting role of the public sector. Where the tasks of planning, developing, executing and managing traffic management systems were long exclusively the domain of public actors, governments and businesses are now jointly exploring the possibilities of externalizing some of these responsibilities to the private sector. Here, public authorities gain a more advisory role. The roadmap is put into practice by the national Connecting Mobility program.

The program strives to create a non-zero-sum 'triple-win' result for motorists, businesses and governments. Ideally, the end result would entail better service provision to road users, new market opportunities for businesses and more cost-effective traffic management for public road authorities (Connekt, 2013). To realize the six transition paths, the alliance of representatives of governments, knowledge institutions and the private sector - known as the '5 November group' - formulated 4+1 themes: domains in which tests can be realized. These can be seen in Figure 5.

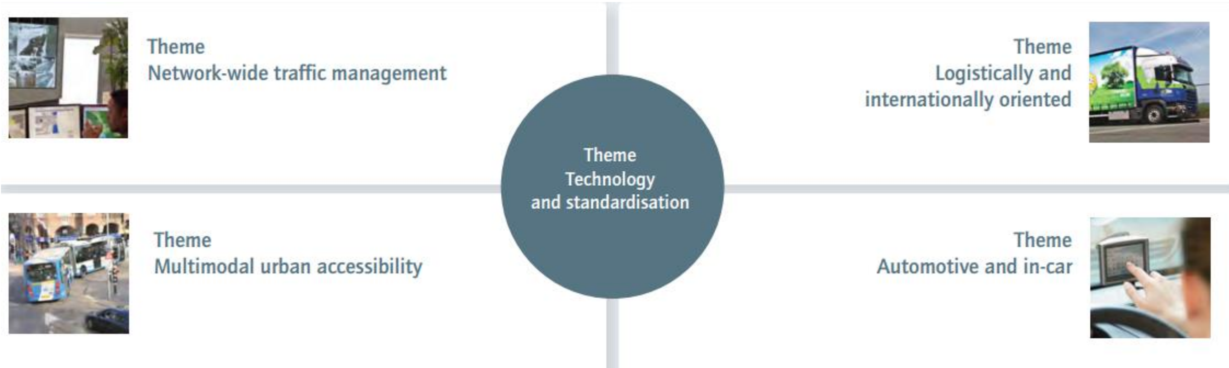

Figure 5: 4+1 themes, the strategic framework for a cohesive approach to trials and experiments (Connekt, 2013).

For each of the four themes, a related project was selected as a 'roadmap project'. The purpose of this was to draw attention to projects that acted in the 'spirit of the roadmap', which could serve as inspiring and educational examples. This, in turn, would benefit the learning process of the Uitvoeringsagenda and would give direction to the practical field. These four projects were:

1. Network-wide traffic management: Praktijkproef Amsterdam [PPA] (roadside track)
2. Logistically and internationally oriented: ITS Corridor
3. Multimodal urban accessibility: Digitale Wegbeheerder
4. Automotive and In-car: Rijden met In-car Systemen; a Compass4D, Spookfiles A58, Coöperatieve ITS corridor, SPITSlive, PPA (in-car track) en Brabant In-Car III

Since the BGOW program particularly emphasizes the PPA as a key project that embodies the vision of the Ministry, this project will be further discussed in chapter 6, serving as an illustration of some of the transitions BGOW wishes to accomplish, and also offering insight in the challenges that may lie therein.

4.6 CONCLUSION

As illustrated in this chapter, the field of traffic management is in a state of transformation. Faced with increasing congestion, new scientific insights, disruptive technologies, austerity and a political impasse, the political discourse has solidified around an 'optimizing use' rhetoric. This entails using the existing road infrastructure in the most cost-effective way using a 'smart mix' of ITS and dynamic traffic management solutions, demand-side measures and supply-side measures. Furthermore, the government aims to externalize some of its expenditures by means of privatizing services related to traffic management, since the market is allegedly able to deliver these services against lower costs.

Moving beyond policy spheres, chapter 5 will review the recent developments in the way drivers are governed in the Netherlands, placing the contemporary ways of governing traffic in a historical context. In turn, this reveals how the current practices in the field of traffic management (that may appear as being self-evident) have emerged, and how the relations of power between the governing actors and governed subjects are being transformed.

5. TRAFFIC MANAGEMENT IN THE NETHERLANDS

5.1 INTRODUCTION

This chapter attempts to identify the developments in the modes of governing within the field of traffic management in the Netherlands. Adopting a Foucauldian perspective, it will analyze the governmentalities that underpin these practices, as well as the ways in which these are enacted. First, it will discuss the definition of traffic management and pinpoint its underlying rationalities in paragraph 5.2. Second, following Foucault's notion that *"*[p]*ower must be analyzed as something which circulates, or rather as something which only functions in the form of a chain"* (1980, p. 98), an analysis is made of the ways in which the motorist is made knowable - and thus governable - through data in paragraph 5.3. This encompasses three trends: the proliferation of roadside sensors, the shift towards in-car sensing and the centralization and institutionalization of data collection, storage and analysis resulting from the establishment of the National Data Warehouse for Traffic Information [NDW]. Third, it will discuss trends in how the motorist is governed and governmentality is enacted: the expansion of the traffic management toolkit, the centralization of traffic management in traffic control centers and the growth of automated and predictive traffic management. Lastly, it closes off by discussing the move towards a more neoliberal governmentality, as tasks such as informing and advising traffic are increasingly delegated to the private sector. An overview of the traffic management components discussed in this chapter can be found in appendix B.

5.2 DEFINING TRAFFIC MANAGEMENT AND PINPOINTING ITS POLITICAL RATIONALITIES

Though traffic management has grown to be an established branch of most governments, there still is some ambiguity about the meaning of the term, as several interviewees had different understandings of what traffic management means. When asked to define traffic management, one interviewee responded:

''Traffic management is the influencing of traffic flows by sheer force. You could compare it to the police and the army: only those institutions are allowed to use violence. Similarly, traffic managers have the ability to forbid you from doing something, which is something only the government can do. Therefore, this excludes travel information services, since these can only attempt to motivate road users to alter their behavior by informing them or giving suggestions, but disobeying this advice is not punishable'' (Technology company spokesman, interview, 19 December 2016).

Following such an understanding, traffic management is a top-down activity only conducted by state actors, and solely comprises the tools that can directly and forcefully steer - or normalize - the behavior of the road user. However, the majority of the interviewees handled a broader definition of traffic management, where most approached it as *''a continuum consisting of four steps: informing, advising, leading and steering''* (Amsterdam municipality spokeswoman, interview, 14 December 2016). This classification can also be found in Taale et al. (2013), Griffioen (2011) and Harms et al. (2013). A schematic representation of this continuum is presented in Figure 6 on the next page.

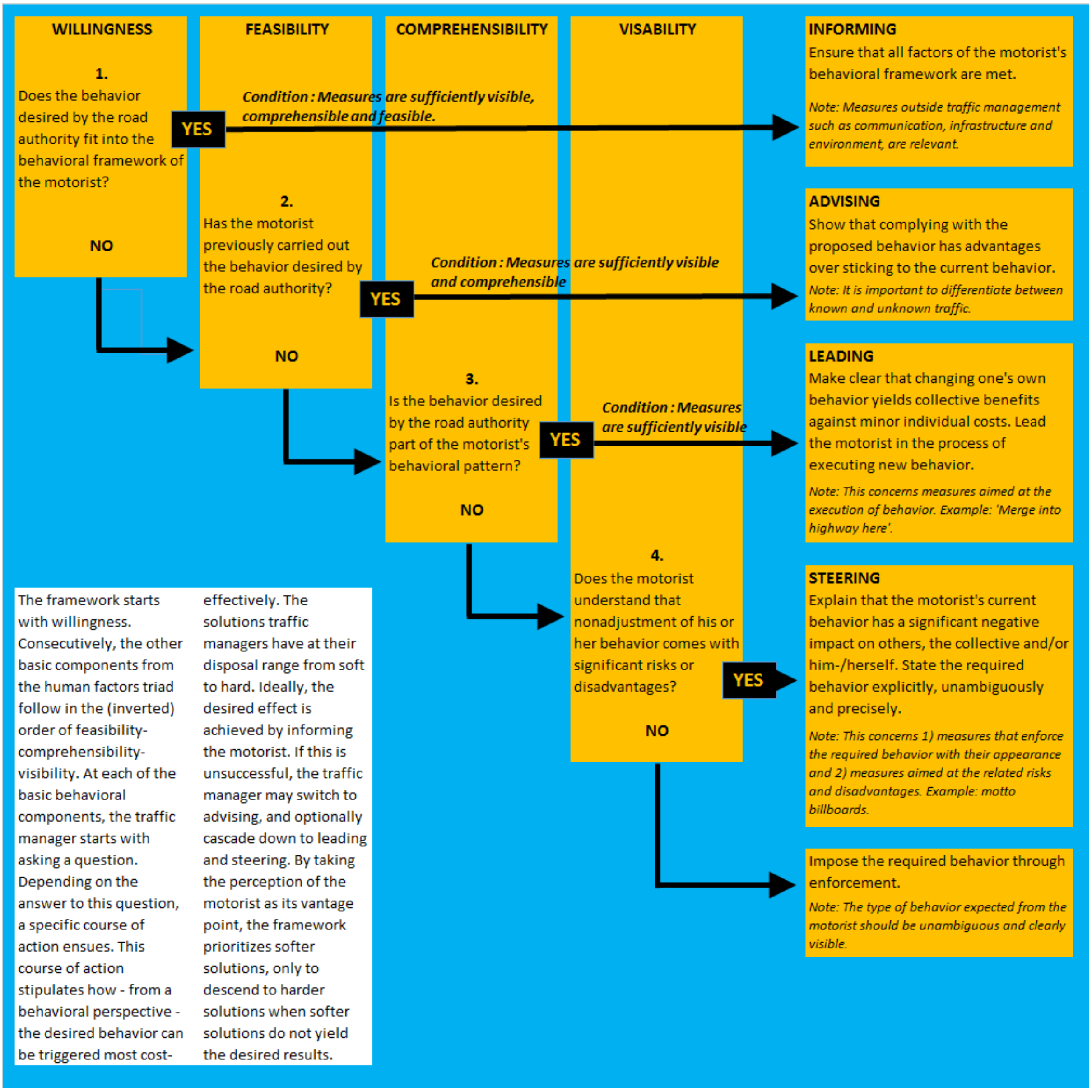

Figure 6: Flowchart of traffic management dimensions (adapted from Harms et al., 2013).

Remarkably, the aforementioned definitions of traffic management circumscribe the management of road-bound traffic. However, some argue that the scope of traffic management is now increasingly evolving beyond the road network, since *"with smart mobility, the focus shifts towards optimizing the overall transportation system, and the different modalities are getting more intertwined. Here, traffic managers will need to extend their focus to other modalities in order to offer travelers the most efficient, the most sustainable, the cheapest and the safest journey"* (Connecting Mobility spokesman, interview, 5 January 2017). In this process, the different types of management - such as traffic, parking and mobility management - seem to be growing closer together, since measures taken in one of these areas almost always affect the others (Troost-Oppelaar et al., 2013). Hence, traffic management is now increasingly conceptualized as managing demand and supply. The storage capacity of the road network is the supply, and the demand comprises the amount of drivers – each driver occupying a certain amount of space in the network - that wish to make use of it at a given point in time (Troost-Oppelaar et al., 2013; Provincie Noord-Holland, 2014; Connecting Mobility spokesman, interview, 5 January 2017). Following this understanding, the Rijkswaterstaat manual for traffic control centers poses that the main task of traffic managers is to find and secure the equilibrium between supply and demand, formulating their goal as *"the optimal throughflow on the road* *network, with safety as a boundary condition''* (Rijkswaterstaat, 2015a, p. 7). Moreover, facilitating a more efficient flow is also seen as an environmental measure, since the amount of emissions per vehicle is lower under non-congested traffic conditions.

5.3. MAKING THE MOTORIST KNOWABLE

At the 2016 Expo on Traffic, Mobility and Parking in Houten on 23-24 November, one of the largest annual conventions on traffic management in the Netherlands, perhaps no subject was discussed more than data. Kicking off the first day of the Expo, Tiffany Vlemmings - project manager at the National Data Warehouse for Traffic Information [NDW] - proclaimed it as the *''raw material for traffic management''* (personal communication, 23 November 2016), signaling the shift from analog, technology-driven traffic management towards more data-driven traffic management (NDW, 2013; Bakker, 2015). This statement aptly encapsulates the rhetoric behind programs such as Beter Benutten and Beter Geïnformeerd Op Weg, which both promulgate the ethos of *''meten = weten''* (Connekt, 2013, p. 36; MIM, 2015, p. 2): measuring = knowing. Moreover, it is indicative of a growing rational, scientific approach to traffic management, where maximizing the quantity, quality and availability of data is widely thought to enable more efficient and effective traffic management (Van Koningsbruggen et al., 2014, Brouwer, 2014; 2016; Van Kooten et al., 2009). Formulated in Foucauldian terms, having more knowledge of the governed object - the motorist – by engaging in a process of hierarchical observation allows traffic managers to produce the subject. In turn, this allows governing actors to identify and problematize anomalies in their behavior through examination, and, in turn, exercise normalizing instruments (e.g. traffic lights) with greater precision, thus augmenting their control over the subject's behavior. Consecutively, the conduct of motorists - their driving behavior - can be molded and aligned with the political objectives of the governing actors through regulation.

This section will discuss three developments in the field of traffic surveillance. First, section 5.3.1 will describe how the roadside traffic surveillance infrastructure expanded over the years, and in what ways these technologies render the motorist visible. Second, section 5.3.2 discusses how – in recent years - traffic surveillance has extended beyond roadside infrastructure by capitalizing on data from in-car devices. Third, section 5.3.3 elaborates on the move towards open data and the institutionalization of data collection, storage and analysis with the establishment of the NDW.

5.3.1 THE PROLIFERATION OF ROADSIDE SENSORS

Until a few decades ago, public authorities were bereft of traffic data (Van Koningsbruggen et al., 2014). In tandem with the notion that greater quantities, quality and availability of data allows for better decision making, the last decades have witnessed a proliferation of various sensors on the Dutch road network (see textbox 1), increasingly making the behavior of motorists known to road managers. Given that governments often do not have the necessary expertise for developing, integrating and maintaining these systems, these tasks have for the most part been outsourced to private contractors (NDW spokesman, personal communication, 15 December 2016). Installed on the main road network and at traffic lights in the lower networks (to trigger traffic lights), vehicle detection loops were the first sensors to be integrated in the fabric of the Dutch roads (Wismans et al., 2009). Using these loops, traffic managers could get real-time data that allowed for the calculation of (1) the average speed of the vehicles in a part of the road network in a specific time interval (known as the 'point speed'), (2) the quantity of vehicles passing a loop location in one hour (known as the 'intensity') and - by measuring the size of the induction profile - the type of vehicle passing the loop (known as the 'vehicle category') (Wijbenga et al., 2010; Uenk-Telgen, 2016). For a long time, these loops were the only means through which Rijkswaterstaat could monitor traffic, and only provided insight in traffic on the freeways (Van Koningsbruggen et al., 2014). Over time, they have remained as an important source of traffic data: Rijkswaterstaat currently exploits loop data from roughly 17.000 locations on the Dutch freeways (Connekt, 2011). Nearly all of these loops are installed on highways and at busy traffic intersections. In the latter constellation, they do not only send data to the NDW, but also to the verkeersregelinstallaties [VRIs] (traffic lights) at the intersection (Van Koningsbruggen et al., 2014).

Next to vehicle detection loops, cameras have long been used by traffic managers. Initially, their sole function was to give operators in the traffic control room a live feed of important sections of the main road network, giving them an additional tool for the early detection of accidents and traffic jams (Consultancy company spokesman, interview, 8 December 2016). Over time, a new type of camera with a more advanced function appeared, known as the Automated Number Plate Recognition [ANPR] or License Plate Recognition [LPR] camera (Consultancy company spokesman, interview, 8 December 2016). Here, a high-resolution camera is equipped with optical character recognition software that allows for automated detection and reading of license plates from images. ANPR data is used for several purposes, including law enforcement and traffic management (Ministerie van Veiligheid en Justitie, 2014). For traffic management, this is most notably to create Origin-Destination [OD] matrices (showing macro-level patterns in the origin and destination of traffic) and to estimate travel times (NDW spokesman, interview, 15 December 2016; Wijbenga et al., 2010). The number of these cameras is growing, and in 2014, Rijkswaterstaat had roughly 1800 operational ANPR cameras on the freeways (Van Koningsbruggen et al., 2014). Furthermore, an inquiry by the Dutch weblog Sargasso (2013a; 2013b) - where it filed a request at the NDW invoking the provisions of the Wet Openbaarheid Bestuur (Act on Public Access to Government Information) - pointed out that the provincial and municipal partners in the NDW jointly exploit around 1000 ANPR cameras that monitor traffic on the provincial and municipal roads.

A third tool to monitor traffic is the Bluetooth sensor. First installed and tested on the road network in 2009, their number has expanded rapidly: as of yet, several hundreds of Bluetooth sensors have been installed along freeways, provincial roads and municipal roads alike (Uenk-Telgen, 2015). Similar to ANPR-cameras, what Bluetooth sensors add to vehicle detection loops is insight into the travel times of individual vehicles and their respective trajectories (aggregated in the form of OD matrices showing the quantities of traffic moving between specific points) (Wijbenga et al., 2010; Uenk-Telgen et al., 2015).

To a lesser extent, other types of roadside sensors are used, which are either still in the test-phase or are only deployed in small quantities. The most prominent example is radar, of which there were around 250 installations in 2011 (Connekt, 2011). The main advantage of radar is that it can detect individual vehicles from greater distances (Adams et al., 2016).

The aforementioned sensing technologies vary significantly in aspects such as costs (for maintenance and purchasing), accuracy and the types of information that can be derived from their data. For example, not every vehicle has devices broadcasting Bluetooth MAC addresses, in turn giving Bluetooth sensors a penetration rate of only 40 to 50 percent (Wijbenga et al., 2010). Similarly, the applicability of ANPR cameras depends on the weather conditions: rain, snow or fog all obstruct the camera's vision, making it difficult for the software to recognize number plates. Likewise, the software cannot detect license plates when vehicles drive too close to each other. Hence, these different types of sensors coexist on the Dutch road network because they are complementary: since there is no all-encompassing tool that provides traffic managers with all the information they need or desire, a variety of sensors is integrated into the fabric of the road network in order to overcome the shortcomings of individual sensing methods. Together, they form the surveillance apparatus that produces real-time information on traffic flows for traffic managers, in turn rendering motorists governable. **Error! Reference source not found.** t the end of paragraph 5.3.2 gives an overview of the benefits and shortcomings of each sensor type.

5.3.2 MOBILE SENSORS: THE RISE OF IN-CAR TECHNOLOGIES AND SOCIAL MEDIA AS NEW SOURCES OF TRAFFIC DATA

Though a growing number of roadside sensors has been deployed alongside roads in the Netherlands over the past decades, it is expected that the amount of fixed sensors will diminish in the future. Instead, there will likely be a shift from roadside sensors to in-car sensing, allowing for a significant cost reduction in terms of maintenance and acquisition of hardware (Beter Benutten, 2014).

With advancements in telecommunication technologies, a new type of traffic data emerged: Floating Car Data [FCD], also known as Probe Vehicle Data [PVD] or Floating Vehicle Data [FVD]. Though FCD refers to all methods of collecting data from onboard technologies in vehicles, it is largely based on the combination of signals transmitted by in-vehicle Global Positioning System [GPS] and Global System for Mobile Communications [GSM] supporting devices, such as navigation systems and mobile phones (Krootjens, 2011; Van Koningsbruggen et al, 2014). As the penetration rate of this method increases due to a growing presence of such devices in cars, FCD is rapidly becoming an important source of information (Trafficquest, 2016). Where fixed sensors only provide a view of specific parts of the network - leaving many blind spots, particularly in the less monitored provincial and municipal networks - in-car navigation systems and mobile phones act as non-stationary sensors able to penetrate any part of the network. What also sets FCD apart from roadside sensors is that this data is already collected by private actors; *regardless* of whether governments have contracted them to do so. Data brokers primarily acquire their data from drivers' smartphone applications, which in the process of running send metadata (e.g. real-time GPS coordinates) to the servers of these service providers. Legally, the collection of FCD is permitted given that (1) the motorist has (implicitly) agreed to the collection of his/her data by accepting the license agreement of the product and (2) that the collected data is not retraceable to the individual motorist further down the data supply chain (privacy-by-design) (DITCM, 2015). Thus, FCD does not require additional infrastructure, allowing government agencies to cut spending on the installation and maintenance of such instruments (Krootjens, 2011; Martens et al., 2015). Moreover, as one interviewed spokesman for the NDW explains, *''FCD allows road managers to fill up the 'blank spots'; parts of the road network without roadside sensors''* (interview, 15 December 2016).

In extension of the growing prevalence of FCD-producing technologies, cars are increasingly becoming computers on wheels. Most vehicles are equipped with a Controller Area Network-bus [CAN-bus], a communication interface that connects and controls electrical components within a vehicle, and can store data from connected sensors. From this data, traffic managers could derive information useful for traffic management, such as vehicle speed, location and even the quality of the road surface and local weather conditions (Hendriks, 2014; Pauwels, 2014; Vlaams Instituut voor Mobiliteit, 2015; Van Koningsbruggen & Van der Perre, 2006). However, as of yet, this data is generally not available, as it can only be acquired when the CAN-bus is read in a garage. Nevertheless, this data could become available in the future, and when the in-car sensor data from the CAN-bus is combined with FCD, this results in Extended Floating Car Data [xFCD] (Van Koningsbruggen et al., 2014).

Lastly, over the course of the last decade, the rise of social networks such as Twitter, Instagram and Facebook has opened up new horizons for traffic managers and data analysts. With every post on social media, motorists produce potentially useful information about events on the road, thereby acting as additional sets of eyes and ears for road authorities, especially in areas where cameras are absent. For example, a geo-tagged photo posted on Twitter related to a disruptive event on the road - such as an accident or a traffic jam - could give traffic managers additional information on the situation on the road, allowing them to act more swiftly and effectively (Van Koningsbruggen et al., 2014; Van Egeraat et al., 2016). For this reason, traffic managers have become interested into ways of capturing and processing this information in order to leverage steering and information mechanisms more effectively. In particular, research has been done in the PPA Zuidoost and in the Innovatiecentrale projects, but thus far it has for the most part remained uncharted territory (Van Egeraat et al., 2016; Innovatiecentrale, 2016; Twynstra Gudde & MuConsult, 2016). Social media analysis tools - such as the Publicsonar software used at the Innovatiecentrale - work through the algorithmic scanning of several social media feeds in real-time, using a predetermined list of keywords. This list includes geotags, the names of roads and highway intersections and event types - such as 'traffic jam', 'accident', 'collision', 'dangerous situation' or 'litter'. Furthermore, it includes a list of words to exclude, in order to filter non-relevant results. When the system matches a location with an event, (for example A10+accident), it is presented as a result to the road traffic manager (Van Egeraat et al., 2016; Innovatiecentrale, 2016).

Textbox 1: the mechanisms behind sensor technologies

Vehicle detection loops
Vehicle detection loops - or inductive-loop traffic detectors - are copper wires installed in the pavement of the road used to sense the presence or passing of a vehicle. These wires generate oscillating electromagnetic fields, and are connected to a detector unit that monitors the base frequency: a pulse indicating that no vehicle is passing. When a vehicle passes a loop, its metal chassis disturbs the loop's electromagnetic field, causing the frequency to increase, which in turn triggers a normally open relay to close: the vehicle is counted. This information may be used to trigger the activation of roadside infrastructure such as traffic lights. After the vehicle leaves the loop, the frequency drops and the relay returns to its normal state. (United States Department of Transportation [USDOT], 2006)

[ANPR] Cameras
When a vehicle passes an ANPR camera, one or multiple images are captured. Next, a filter is applied to the digital image in order to increase color separation and compensate for differences in lighting, allowing for easier procession by the camera's artificial intelligence. Subsequently, the software's algorithms localize the rectangular area of the number plate, and chop up the number plate into single-character segments. The last stage is character recognition, where the contours of the characters are established. Here, the characters are digitised - making them machine-readable, and are matched with an international database of standard license plate templates. (Badr et al., 2011; Mijn-ANPR, n.d.; Politie Amsterdam-Amstelland, 2010; Ondrej, 2007)

Bluetooth sensors
Bluetooth is a short-range wireless communication technique developed in 1994 that works via the exchange of electromagnetic waves between two or more devices, and is supported by a great many technologies ranging from mobile phones, laptops, handsfree in-ear devices and navigation systems. Every device with a Bluetooth function has its own unique identifier, known as a Media Access Control [MAC] address. When Bluetooth is enabled, a device continuously broadcasts its MAC address into its surroundings. As a vehicle approaches and passes a Bluetooth sensor, the identification code of the Bluetooth device is registered by the sensor, and is subsequently (temporally) stored a database. (Wijbenga et al., 2010)

Radar
RAdio Detection And Ranging systems, better known under the acronym radar, work through the beaming of high-frequency radio waves, either continuously or in pulses. When a radio wave hits an object, it is reflected as an echo signal. By monitoring changes in the received signals, radar installations can detect moving vehicles (USDOT, 2006).

GSM
With GSM, phones can be geolocalized by means of their periodical 'pinging' of GSM signals to

cell towers. Cell towers are placed in such a way that they each cover an area shaped as hexagonal cells. GSM devices thus move through a grid of cell towers, and can be localized through either triangulation (connecting with 2 towers) or multilateration (connecting with more than 2 towers). Using this method, the location of a phone can be determined with an accuracy ranging from several kilometers up to 50 meters. This method has a high penetration rate, since there are millions of people in the Netherlands that carry a mobile phone. For a phone to transmit GSM signals, it only needs to be switched on. Using GSM signals, traffic managers can roughly determine the amount of people in a certain area, and gain insight into the origin and destination of their trip. (Van Koningsbruggen et al., 2014; Logghe & Maerivoet, 2006)

GPS

Developed throughout the 1960s and 1970s by the United States Department of Defense as a military tool for real-time positioning and navigation around the globe, GPS has grown to be an extensively used tool in mobile devices. It functions using a constellation of 24 satellites that orbit the earth, which continuously beam signals to any device on Earth equipped with a GPS receiver. The satellites are positioned in such a way that at least 4 satellites are in direct line of sight at any point on the globe, each transmitting a different sequence at different time intervals to a receiver. Through multilateration of these signals, where the 'time-stamp' of each signal (the time at which the signal was sent by the satellite) is compared with the time at which the signal is received, it becomes possible to calculate the relative position of the device to the satellites and to project this on a map. In this way, GPS allows for geographical positioning accurate up to several meters, as well as the calculation of one's speed and trajectory (Logsdon, 2012).

In conclusion, the strengths and weaknesses of the different data collection methods are listed in Table 1 below:

Method	**Intensity**	**Speed**	**Travel time**	**Vehicle category**	**OD-matrix**	**Quality**	**Details**
Detection loops	x	x	(x)	x		+	(x) = with dense road network (freeways)
VRIs	x					-	Depends on location
Cameras (normal)	x	x		x		+	Requires multiple cameras
ANPR-cameras			x	(x)	x	++	Requires multiple cameras
Bluetooth / WiFi		x	x		x	depends on sample size	Requires multiple registration points

Radar / laser	x	x		x		0/++	Significant differences in implementati on, possibilities and quality
FCD		x	x		x	depends on sample size	Possibilities depend on provider

Table 1: Data collection methods (adapted from: Van der Bijl & Benkens, 2016).

5.3.3 THE MOVE TOWARDS STANDARDIZED, HIGH-QUALITY AND OPEN DATA: INTRODUCING THE NDW

Part of Rijkswaterstaat, the Nationale Databank Wegverkeersgegevens (National Data Warehouse for Traffic Information, [NDW]) was established in 2007, and became operational in 2009. It is a joint initiative of 19 public authorities: Rijkswaterstaat, the twelve provinces of the Netherlands, the Stadsregio Amsterdam, the Metropoolregio Rotterdam Den Haag and the four largest municipalities: Amsterdam, Rotterdam, Utrecht and Den Haag (NDW, 2016). According to the brochure, its goal is *''to apply the right data to obtain optimal traffic management and to provide road users with the best possible information resulting in less congestion, lower emissions of CO2 and other pollutants, and improved safety''* (NDW, 2016, p. 3).

Prior to the establishment of the NDW, the processes of data collection, processing and analysis were fragmented: every road authority was responsible for the collection, storage, verification and monitoring of its own data. This resulted in lower quality data, a lack of uniformity, lower availability (resulting in a lack of oversight of the network), higher spending on the procurement of data from private data brokers and less options for data analysis, since most local authorities lack the necessary know-how to perform these. The establishment of the NDW meant that the processes of data collection, processing, storage and analysis could largely be centralized into a single institution (Olman & Solinger, 2007; NDW, 2016), motivated by the thought: *''since traffic managers are becoming ever more professional, their tasks become more demanding, so to be ready for that you have to talk about data uniformity, quality, reliability and speed. Hence, if you really want to be professional at traffic management, you have to be professional with your data''* (Consultancy company spokesman, interview, 8 December 2016).

In the following years, the NDW would grow to be both an institution for traffic data analysis and a data bank offering three types of data: real-time traffic information, road status data and historic traffic data (see Figure 7). First, it provides four types of information in real-time: traffic intensity, point speed, the realized - or estimated - travel time and the vehicle category. This data is derived from combined data from several roadside sensors (installed nationwide at 27,000 locations in 2016) and FCD supplied by private parties. Public authorities in the Netherlands often have to pay a monthly fee to such data brokers - which include Be-Mobile, Vialis HERE and TomTom - in order to gain access to their data, and at the end of 2016, public spending on data procurement amounted to roughly 10 million Euros (Felici, 2016; NDW spokesman, personal communication, 19 December 2016). Subsequently, the real-time information is made available to clients 42 seconds after the measuring time. (NDW, 2016)

Second, the status data comprises 5 types of information: (1) road works and event-related traffic measures on practically all roads, (2) reports of congestion, accidents and incidents on national roads, (3) safety-related announcements (such as a wrong-way driver) that are issued by the traffic control centers, (4) the status (open/closed) of bridges and (5) the status (open/closed) of peak and regular lanes. This data is mostly supplied by the traffic control centers of Rijkswaterstaat, the provinces and the municipalities. (NDW, 2016)

Third, the collected real-time data is accumulated and stored by the NDW as historic traffic data, which is primarily used for traffic analysis. The NDW employs a team of specialized data analysts who work together with - among others - road authorities, policy makers, traffic model designers and knowledge institutions. Together, they can - for example - make assessments on the effectiveness of implemented traffic management measures (often in terms of lost vehicle hours, the amount of time an individual vehicle is delayed on a part of the road network), improve the quality of the collected data or calibrate traffic simulations. (NDW, 2016; Felici & Van Lint, 2016)

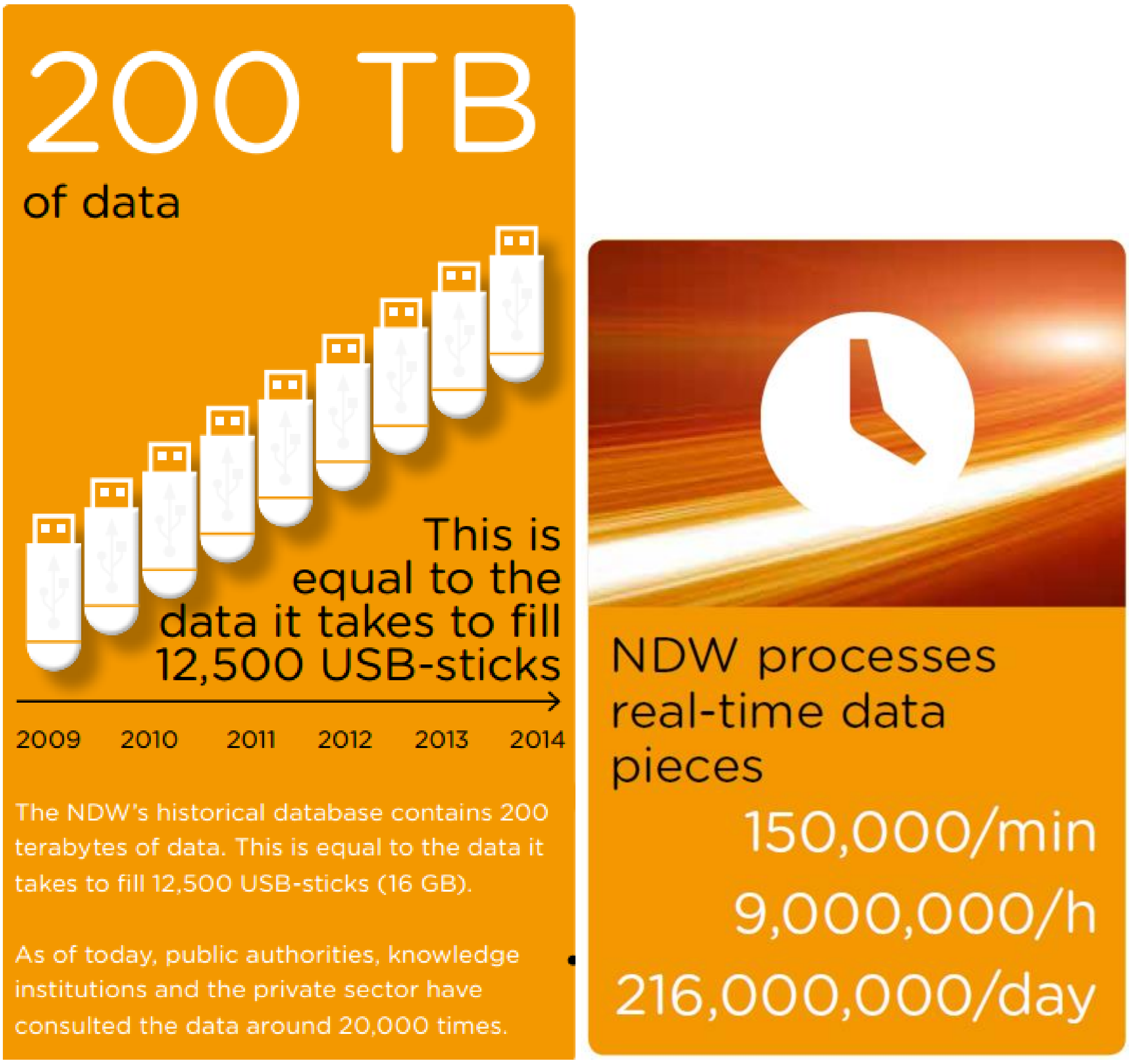

Figure 7: The growing historic database of the NDW (left) and the real-time data stream (right) (NDW, 2016).

As illustrated by the above section, the dizzying amounts of real-time data produced by the assemblage of roadside and in-car sensors are condensed into only a few technical parameters - indicators and statistics that traffic managers and policy makers in turn seek to manage. Interestingly, the parameters provided by the NDW - indicating what actors governing traffic flows deem to be important information - seem to be primarily centered on the network throughflow, and do not include, for example, environmental indicators, such as particulate matter concentrations, noise levels or CO2 emissions. This is explained by the fact that there are few sensors that measure such variables (although they can be calculated using other data), and are rarely used in practice by traffic managers (Eijk et al., 2012; NDW spokesman, interview, 15 December 2016; Consultancy company spokesman, interview, 8 December 2016).

The creation of the NDW - which initially charged a fee for its data but would soon handle an open data policy - also meant that service providers got access to more data (Blankena, 2013). Before the NDW, commercial service providers, such as the ANWB and VID, were not allowed to structurally collect data from road authorities (Brouwer, 2016). Now, the nature of traffic surveillance has to a great extent shifted from panoptic to omnoptic: where traffic monitoring used to be primarily restricted to the road authorities, the collected data is increasingly made publicly available to private actors. In a similar vein, as illustrated by paragraph 5.3.2, private actors now also engage in data collection through traffic surveillance. Hence, the model of hierarchical observation has thus given way to heterarchical observation, where the many can watch the many. However, Frits Brouwer (2016), director of the NDW, predicts that there will be less open traffic data in the future: since the amount of publicly-owned roadside sensors is expected to decrease under austerity measures, governments will likely become more dependent on commercially-sourced FCD. In turn, the licensing conditions attached to this FCD may form a contingency preventing road authorities from sharing this data publicly.

5.4 THE GROWTH OF TRAFFIC MANAGEMENT INFRASTRUCTURE AND THE EMERGENCE OF THE TRAFFIC CONTROL CENTER: THE UBIQUITY, CENTRALIZATION AND AUTOMATION OF TRAFFIC MANAGEMENT

Over the years, traffic management has become an increasingly ubiquitous, centralized and automated activity, and these trends are expected to continue (Immers & Schuurman, 2014). Paragraph 5.4.1 will show how the amount of traffic management infrastructure has grown over the years, arguing that the growing amounts of traffic combined with the inefficiencies in driver behavior created the need to manage traffic. It will identify the VRI, the MTM-system, the TDI and the DRIP as the most prominent technologies used to direct the behavior of motorists in line with the objectives of government. In other words, they are what Foucault calls the 'means of bringing power relations into being' or 'technologies of government'. Paragraph 5.4.2 serves to illustrate the growing centralization of traffic management. Where in the past traffic management was carried out by a great many actors (including police officers, tunnel operators and bridge operators), it has been concentrated in traffic control centers, whose systems are now increasingly linked as well. Paragraph 5.4.3 illustrates how a traffic control center is organized. This data is collected through on-site observations. Paragraph 5.4.4 will discuss the move towards automated and predictive traffic management.

5.4.1 GENEALOGY OF TRAFFIC MANAGEMENT INFRASTRUCTURE: THE TECHNOLOGIES OF GOVERNMENT

5.4.1.1 THE VRI

Following the introduction of the car in the Netherlands at the dawn of the 20th century, cities increasingly required a way to manage the growing, heterogeneous flows of - increasingly motorized - traffic, particularly in the inner city centers. Thus, drawing a great number of spectators, the first traffic conductor - a police officer - was introduced in central Amsterdam center in 1912. In the following years, police officers started to conduct traffic throughout the nation, becoming responsible for directing traffic, enforcing traffic laws and apprehending violators. However, they were immediately confronted with significant challenges related to the visibility and comprehensiveness of their bodily gestures. Hence, they started experimenting with various methods to capture the attention of drivers and enforce traffic regulations more effectively. Some of the trialed methods included the use of sonic and optic signals that allowed or forbade traffic to pass, which ultimately resulted in the development of the traffic light. First installed in Rotterdam in 1926, it gradually came to replace the police officer as the dominant means of managing traffic flows, since this form of automated management with pre-programmed settings enabled governments to cut back labor costs while maintaining roughly the same control over traffic flows. (Van der Gulden, 2016)

Much like the 'stop' and 'go' signals expressed by the police officer, traffic lights are clear examples of systems of differentiation: they are mechanisms of power that control the behavior of drivers through a binary system of red and green, implying stop and go, or forbidden and allowed. Power is exercised by both the settings of green and red: ignoring a red light is both punishable by law and socially unaccepted, while stopping at a green light is socially sanctioned as well. In this way, the forces of power are external - enforced by the police through punishment and other road users through social pressure - as well as internal, in the form of expectations as in how one should behave and how others will behave. The rationale behind this is that road users - consciously or not - exchange some of their individual agency in favor of the interests of the wider network, enabling a safer and faster flow of traffic in areas where the interests of multiple road users are prone to conflict. Over the years, the technology behind the traffic light became more refined. The relatively simple system of lights and a controller - with only a few basic scenarios - evolved into a complex constellation of connected sensors (such as road detection loops and radars), lights and computers, able to interact at the network level and calculate the optimal setting for the traffic lights. An example of this is the creation of 'green waves', which entails coordinating a sequence of successive traffic lights to facilitate the uninterrupted flow of traffic over several intersections in one direction (Schreuders & Fransen, 2009). Thus, the traffic light became what traffic managers call a 'verkeersregelinstallatie' (traffic regulation installation) [VRI] (Van Koningsbruggen, 2016). Though the growth in the number of VRIs has slowed down, their number is still increasing, and in 2015, there were around 5600 operational VRIs in the Netherlands. 80 percent of these are owned by municipal road managers, 16 percent by provincial road managers and 4 percent by Rijkswaterstaat (Willekens, 2016).

5.4.1.2 RAMP METERS [TDIS]

Toeritdoseerinstallaties [TDIs] (ramp meters) are used to 'dose' traffic to freeways. They have three functions: spreading traffic, buffering traffic and combatting rat-run traffic. First, by spreading traffic merging onto the highway over time, abrupt merging actions by drivers entering the highway are prevented in order to limit interruptions of the traffic flow. Second, vehicles can be buffered on the on-ramps to ensure that the amount of traffic on the main road does not reach the critical threshold at which the 'capacity drop' occurs. Third, TDIs are placed in order to discourage motorists from taking shortcuts. (CROW, 2012; Trafficquest, 2014b)

The Netherlands' first ramp metering system was deployed in 1989 in the Amsterdam region, on the ramp from the S101 to the A10 freeway. Prior to the installment, this route was used by motorists attempting to bypass the frequently congested Coentunnel (Middelham & Taale, 2006). Subsequently, this first ramp metering system was seen as a great success, leading to a gradual growth in the amount of ramp meters in the Netherlands. In 2005, Rijkswaterstaat had 54 operational TDIs, and this number would rise to 99 in 2011 (Middelham & Taale, 2006; Connekt, 2011).

Similar to VRIs, TDIs are technologies of power that steer traffic, as they forbid and allow the passage of cars. In this way, they attempt to shape the behavior of drivers in such a way that they cause the least disturbance to the flow of traffic in the entire road network.

5.4.1.3 ROUNDABOUT METERS [RDIS]

Over the last years, a handful of rotondedoseerinstallaties [RDIs] (roundabout meters) has been installed in the Netherlands. A variation on the TDI, the RDI can dose and prioritize traffic on roundabouts using data from detection loops, which provide an indication of the amount of traffic on the adjacent roads. Similar to the TDI, the RDI can time the inflow of traffic in such a way that the stream of traffic on the roundabout keeps running as smooth as possible. Moreover, it can prioritize traffic from certain arteries connected to the roundabout with heavy traffic by giving it a longer green time, with the aim of creating a 'fairer' distribution of waiting times. In these ways, the behavior of the motorist is aligned with the overarching goal of the road managers to create an optimal traffic flow. (Stolz & Bezemer, 2012; Deckers & Van der Veen, 2013)

5.4.1.4 MATRIX SIGNS: THE MOTORWAY TRAFFIC MANAGEMENT SYSTEM

Next to traffic lights, traffic flows on the freeways are managed with matrix signs. In the 1970s, the first matrix signs were placed over the freeways, which, together with the system that controls it, are referred to as the Motorway Traffic Management [MTM]-system (Troost-Oppelaar et al., 2013; Kennisplatform Tunnelveiligheid [KPT], 2016; Klunder et al., 2013). The objectives of this system were trifold. First, it functioned as a queue tail warning system with the goal to lower the amount of accidents. Second, it could help to secure sites where an accident had happened by 'crossing off' a road. Third, it decreased the amount of signs that had to be placed along roads during road works, in turn saving costs (CROW, 2012).

Hence, until the 1990s, the MTM-system was mostly used for incident management. However, from the 1990s onwards, it has been increasingly used as a tool to manage traffic. For example, using the matrix signs, traffic managers can communicate advisory speed limits to drivers or close off lanes in order 'buffer' traffic, both with the aim to realize a better throughflow (CROW, 2012).

5.4.1.5 DYNAMIC ROUTE INFORMATION PANELS [DRIPS]

Another instrument to regulate traffic is the dynamic route information panel [DRIP]: a digital screen placed along or over the road that can display text. In 1990, the first DRIPs were installed on the Dutch roads, the first location being the A8 highway north of Amsterdam (Remeijn, 2007). As of 2011, there are 118 DRIPs above the road and 135 roadside DRIPs (Connekt, 2011). Most of these are operated by Rijkswaterstaat and larger municipal road managers (CROW, 2012).

Generally, the purpose of DRIPs is to make the road network more reliable by providing on-trip information to motorists. Primarily, this information consists of either information on estimated travel times, traffic jams, incidents (such as accidents, events, road works and unforeseen circumstances) or weather conditions. To provide this information, DRIPs make use of data provided by the NDW, MoNiCa (Rijkswaterstaat's loop data collection system) or local sensors such as loops, ANPR cameras and Bluetooth sensors. This is connected to a central DRIP management system, which can automatically generate the information to be displayed on the DRIPs. (CROW, 2012)

DRIPs are placed at strategic locations - for example before highway exits - with the aim to transmit information to drivers in order to allow them to make better decisions. From a Foucauldian perspective, this can be interpreted as a process of self-regulation. Contrary to a traffic light, regulation is not imposed from external forces (social pressure to drive at green), but comes from within: the DRIPs inform the decision of the driver, and make him or her self-regulate their behavior based on this information.

A special type of DRIP is the GRIP (Graphical Route Information Panel), of which there are only a handful, which are installed on the A10 freeway around Amsterdam (Connekt, 2011). These signs visually display real-time information, such as maps of the road network (De Goede et al., 2012).

5.4.2 GENEALOGY OF THE TRAFFIC CONTROL ROOM AND THE CENTRALIZATION OF TRAFFIC MANAGEMENT

As the Dutch economy recovered and standards of living rose in the wake of the Second World War, car ownership increased rapidly, resulting in the construction of a great many freeways and tunnels, such as the Velsertunnel: the oldest highway tunnel in the Netherlands (Rijkswaterstaat, 2015b). These tunnels were equipped with underground operating posts that operated and secured the tunnel, which one interviewee described as *''the prototypes of the contemporary traffic control room''* (Consultancy company spokesman, interview, 8 December 2016). Over time, some of these tunnel operation posts were consolidated into small-scale traffic control centers, and gained the task of incident management, which was the first official task of traffic control center (Consultancy company spokesman, interview, 8 december 2016; Van Kooten et al., 2009; Trafficquest, 2011b).

To facilitate incident management from-a-distance, the MTM-system was introduced in the 1970s, followed by the deployment of DRIPs in the early 1990s. These tools allowed traffic managers to close off lanes and communicate information about accidents to motorists (Troost-Oppelaar et al., 2013; KPT, 2016; CROW, 2012; Consultancy company spokesman, interview, 8 December 2016). Somewhere in the 1990s, traffic control centers gained a secondary task: traffic management (Technology company spokesman, interview, 14 December 2016; Consultancy company spokesman, interview, 8 December 2016). Discussing the acquisition of this responsibility, one interviewee who worked as a traffic management consultant stated: *''everyone came to realize that we could do more with the roadside equipment than incident management: it could also be used to manage traffic, for example to dose or reroute flows''*. In line with this observation, another interviewee who was involved in the design of the Netherlands' first large traffic control center 'De Wijde Blik' in Velsen-Zuid expressed:

''The idea was that with (the introduction of) fiber optic cables, it became possible to control from a distance, and we could put the people operating bridges and tunnels together in one room. This allowed us to improve the quality and simultaneously cut costs, because conducting these activities from a central point is easier and cheaper''. (Technology company spokesman, interview, 14 December 2016)

Thus, centralization is thought to facilitate a greater degree of rationalization by improving cost-effectiveness: it allows for greater certainty of achieving the desired result - formulated as 'the quality' – at lower costs. This development can also be observed in the municipal traffic control centers, which started as centers that monitored VRIs (as so-called VRI-centers) and increasingly became able to operate and manage VRIs, DRIPs and Parking Route Information Systems [PRISs] from a distance, lending them the status of traffic control centers (Trafficquest, 2011b).

Up until this point, traffic management was mostly a localized activity, and was lacking in a holistic approach. The responsibility for governing road traffic was split up between Rijkswaterstaat, the provinces and municipalities, whose traffic control centers were mainly focused on managing traffic within their administrative boundaries (Taale & Westerman, 2005). However, in 1996 - the same year 'De Wijde Blik' was constructed - road managers involved in the 'DACCORD' project started to brainstorm about the possibilities for what they called 'gecoördineerd netwerkbreed verkeersmanagement' (coordinated network-wide traffic management) [GNV]. In extension of the increasing concentration of traffic control in specialized centers - where authorities could operate traffic management infrastructure from a distance - this approach involved a departure from local towards more holistic traffic management, where traffic is managed with the aim to optimize traffic flows in the entire network (Van Kooten & Hoogendoorn, 2014; Trafficquest, 2016). Next to increasing efficiency (Raad voor Verkeer en Waterstaat, 2007), the rationale behind this move towards even more centralization through regional cooperation was that *''the motorist is our customer, who does not* *know or care about administrative boundaries, and we as road authorities decided it was best to approach him or her in the same way; by engaging in regional traffic management in service of our joint client."* (Consultancy company spokesman, interview, 8 December 2016). Yet, network-wide traffic management proved to be challenging to execute in practice, since it requires significant organizational and technical changes for road authorities, and the network-wide consequences of an intervention have proven to be difficult to assess (Van Kooten et al., 2009; Van Kooten & Hoogendoorn, 2014; Troost-Oppelaar & Van Hout, 2013). Nevertheless, the centralization of the operation of traffic management instruments has continued to this day (Trafficquest, 2011b; Van Kooten et al., 2009). This is evidenced by developments such as (1) the establishment of Rijkswaterstaat's national traffic control center alongside its 5 regional traffic control centers in 2004, (2) the increasing interlinkage of the operation systems of the traffic control centers of different road authorities (which started in 2008 with the Trafficlink SCM system linking the traffic control centers of Rijkswaterstaat, the Province of North Holland and the municipality of Amsterdam), (3) the establishment of 'region-desks' in traffic control centers that communicate with other nearby road authorities and (4) the formation of Regional Tactical Teams [RTTs] from 2010 onwards, in which different road authorities collaborate on the operational, tactical and strategic level (Trafficquest, 2011b; Trafficlink, n.d.; Troost-Oppelaar & Van Hout, 2013; Van Koningsbruggen, 2013; Van Haasteren, 2015; Rietkerk et al., 2012). In the near future, centralization is expected to continue given that the exploitation costs of a traffic control center are high, which will likely result in the 'merging' of some of these control centers (Van Haasteren, 2015).

5.4.3 THE CURRENT ORGANISATION OF TRAFFIC CONTROL CENTERS: OBSERVATIONS AT DE WIJDE BLIK

Located just outside Velsen-Zuid, a town on the northwestern outskirts of Amsterdam, Rijkswaterstaat's traffic control center 'De Wijde Blik' is one of three traffic control centers operating in the Amsterdam region, the other two being owned by the Province of North Holland and the municipality of Amsterdam. These traffic control centers are in charge of managing the freeways, provincial and municipal roads respectively (Rietkerk et al., 2012). Not far away are the Velsertunnel and the Wijkertunnel, reminiscing the building's former status as a tunnel operation post. A fence sets a perimeter around the center, accompanied by several surveillance cameras. Upon arrival, visitors have to ring a video doorbell camera, identify themselves and state their purpose of visit. Subsequently, the gate is opened remotely, allowing the visitor to proceed towards the building. At the front door of the building, another camera and microphone is installed, and the ritual of identification is repeated. Next, the front door unlocks and the visitor has to enter a 'sluice room', wait until the front door closes, and subsequently the second door of the sluice room opens, allowing the visitor entrance to the building.

Inside the building, several rooms - such as the entrance to the room overlooking the traffic control room - can only be opened with specific key-cards, enabling access to authorized personnel only. This high-security status of the building showcases the degree of power that operators inside the building can exercise using the apparatus of surveillance and control, as they are in charge of critical infrastructure: it is the locus of regional traffic management (Van Kooten et al., 2009; Birnie et al., 2015).

Figure 8: Traffic control room of Rijkswaterstaat-owned De Wijde Blik (De techniek achter Nederland, 2014).

Roughly stated, the traffic control center can be divided into two departments: the traffic operators and the traffic engineers. Operators are concerned with monitoring the freeways in real-time to detect and address anomalies (such as accidents or emerging traffic jams) in order to ensure the continuity of the network. They are situated in the traffic control room (Figure 8), where live feeds of the main road network are projected on a series of five meter high video walls using the 1013 CCTV cameras installed on Noord-Holland's and Flevoland's freeways (Haarlems Dagblad, 2016). In addition, each operator has a desktop with several monitors running the BOSS Online system, where there is a confluence of a great many streams of raw and processed data from the NDW, each type deconstructing reality and reducing to a single unit of measurement, such as vehicle speed, size, location and time. Instead of persons, traffic operators monitor vehicles - blocks of various sizes flowing through the network. As such, the motorist is an anonymous entity the road network, whose characteristics are dissected, depersonalized and thus 'dividualized'. Likewise, the different parts of the road network, places each with their own particular set of complex spatial characteristics, are abstracted to lines. Together, these streams of data attempt to mirror reality in a comprehensive, simplified and mathematized fashion and play a pivotal role in determining the type of intervention to be made. Using this data, operators assess the situation on the road, and decide whether to intervene in traffic flows using an array of roadside assets - such as DRIPs, matrix signs, TDIs, or VRIs – that allow them to control the flows in the road network from a distance. This decision is made based on a code of conduct, which consists of 'rule scenarios' that proscribe the appropriate course of action for a number of situations, many of which can now be activated and run automatically by the BOSS Online system, a development further described in the next section. Ergo, at the core of the traffic control room lies a 'detection-diagnosis-response' mechanism that functions in real-time.

The work of the operator is facilitated by the traffic engineers, who enable the people in the traffic control room to conduct their work 'as optimally as possible'. Their main tasks include planning ahead, developing new scenarios and evaluating past performances of the control center. Different from the traffic operator, the field of the engineer is not so much defined by uncertainty (such as accidents or sudden traffic jams) as by certainty: they develop scenarios for planned road works, provide expertise in infrastructural projects and evaluate the effectiveness of existing scenarios with the aim to calibrate them in order to realize a better traffic flow.

5.4.4 THE RISE OF AUTOMATED AND ANTICIPATORY TRAFFIC MANAGEMENT

Another visible trend is the growing automation and anticipatory nature of traffic management. The first automatic mechanism that could respond in real-time to traffic on the road was the earlier described MTM-system deployed in the 1970s, which had an Automatic Incident Detection [AID] mechanism. Using the data from local detection loop pairs, the system could determine whether an accident had occurred, and could consecutively generate and display instructions to drivers on the road using matrix signs (Connekt, 2011).

Increasingly, incident management and traffic management tasks at the traffic control center are delegated from human operators to computers, which can process vast amounts of data in real-time. In Dutch traffic management circles, this is referred to as 'dynamisch verkeersmanagement' (dynamic traffic management) [DVM] (Ottenhof et al., 2015; Rijkswaterstaat, 2015a). DVM also entails a shift from reactive to more predictive traffic management: DVM systems can for example predict if a traffic jam might occur based on a combination of real-time and historic traffic data, and can take measures even before a traffic jam occurs in order to delay or even prevent it from happening. This can be interpreted as a move towards a) an even more centralized form of traffic management and b) algorithmic governmentality. First, as illustrated by the introduction of Trafficlink SCM system, DVM requires much data, and needs data from many different parts of the system in order to calculate the best solution.

However, the extent to which 'action', the decision-making processes in the traffic control center, should be automated remains contested, which has resulted in different degrees of automation between different traffic control centers in the Netherlands (Technology company spokesman, interview, 19 December 2016; Consultancy company spokesman, interview, 8 December 2016). Several pros and cons have been identified. There are two advantages. First, *''the amount of data traffic control centers receive is now so incredibly big, and comes from so many different sources, that an operator - in spite of his amount of experience or skill - is not capable of processing all this information, and thus cannot identify the most optimal intervention''* (Consultancy company spokesman, interview, 8 December 2016). Thus, automation responds to the cognitive limitations of the human operator, since software is more capable of processing large amounts of data, and can calculate the most optimal decision using specific weights, such as the relative importance of different parts of the road network in terms of securing throughflow. Currently, human operators and software work in tandem. Since 2011, Rijkswaterstaat uses the BOSS online module, a decision support system that can propose solutions to operators. Second, while these systems arguably can operate with at least the same effectiveness as human operators, further automation would allow for the reduction of human labor hours, realizing a cost reduction and thus greater cost-effectiveness (Technology company spokesman, interview, 19 December 2016; Consultancy company spokesman, interview, 8 December 2016).

There are also some perceived drawbacks to automation. First,

''proponents argue - given that operators almost always agree with the system's proposal in practice - we could skip the 'click-to-agree' part, and let the system handle everything automatically. The result of this could be that operators lose the overview of what is happening and what measures have been taken, because this is all done by a 'black box'. Likewise, operators lose the ability to think creatively and use their own insight as traffic engineers. That is a complaint we often hear from operators: there are always scenarios that are not in the system, and where the operator has to come up with a solution. For such situations, it is important that they

are able to use their own insight and creativity" (Consultancy company spokesman, interview, 8 December 2016).

Second, another aspect that is perceived as problematic is that with the introduction of DVM systems, public road authorities - especially Rijkswaterstaat - desire a uniform system for handling traffic management tasks. In turn, road authorities use a single system to perform traffic management, which gives certain private actors monopoly positions in the provision of tools such as software for traffic management or incident management (Ottenhof et al., 2015; Technology company spokesman, interview, 14 December 2016).

In line with the increasing automation, traffic management is increasingly becoming less reactive and more predictive, anticipatory or 'pro-active' (Trafficquest, 2011a; Bulsink, 2006; Raad voor Verkeer en Waterstaat, 2007). Thus far, management instruments – such as informing drivers about traffic jams and proposing alternative routes – have been mostly reactive in nature, in the sense that they are implemented when a traffic jam has already occurred. In this approach lies a problematic of government: traffic managers are troubled by belatedness inherent to their spatio-temporal distance, in turn limiting their effectiveness. What a pro-active approach entails is that action is taken prior to such events using advanced algorithms that leverage vast amounts of data in order to predict what could happen (Schreiter et al., 2012). In this way, traffic managers shift some of their focus from remedying local bottlenecks to monitoring, anticipating and preventing congestion in the network as a whole (Raad voor Verkeer en Waterstaat, 2007; Trafficquest, 2011a), and become not only managers of the present, but also of the future.

5.5 PRIVATIZATION AND THE MOVE FROM ROADSIDE TO IN-CAR: COMMERCIAL SERVICE PROVIDERS IN TRAFFIC MANAGEMENT

Until the mid-1990s, public actors were responsible for the dissemination of traffic information to motorists. The practices of informing and advising drivers in real-time started out with radio announcements, made by the Korps Landelijke Politiediensten [KLPD] (National Police Services Agency), and later with roadside equipment such as DRIPs and matrix signs, controlled by Rijkswaterstaat's traffic control centers (VID, n.d.; Rood et al., 2013; Linssen & Benschop, 2012). In 1996, a change occurred in the organization of these practices when the Ministry of Transport, Public Works and Water Management opted for the commercialization of traffic information, delegating the responsibility for informing drivers to the private sector (such as the ANWB and VID). From this moment on, the market would be in charge of all forms of non-roadside communication, including radio, telephone services, teletext, television, navigation systems and the Internet. Public road managers, in turn, would limit themselves to the collection of traffic information – first with the establishment of the Traffic Information Center [TIC] in 1998, and later with the Verkeerscentrum Nederland (established in 2004) and the NDW (established in 2007) (Linssen & Benschop, 2012; Eurlings, 2008; Rijkswaterstaat, n.d.a; n.d.b).

As of yet, many commentators expect that the roles of the public and private sector will change in the coming years resulting from changes in the technological landscape, but indicate that it is uncertain how these will develop (Immers & Schuurman, 2014; Den Hollander et al., 2015; Kruijssen et al., 2016; Trafficquest, 2011a). Nevertheless, in the earlier described developments one can identify a withdrawal of government, where some tasks in the field of traffic management are delegated to the market. As such, one could speak of a shift towards neoliberal governmentality in traffic management, where the social contract between the state and citizens is renegotiated and reformed into a corporate contract involving various levels of government, private actors and drivers. Here, some urban services – such as the provision of traffic information – have become privatized.

Market actors, however, have done more than merely taking over previously public tasks: through technological innovations (i.e. portable, in-car computing devices), they have reimagined how traffic can be directed, taking a user-centric view as opposed to a network view. Ever since the first portable car GPS navigation systems were introduced in the 1990s and their costs plunged around the turn of the new millennium, commercial in-car information systems have taken a flight (Brodsky, 2015). Fanning out in a broad range of smartphone apps and navigation systems, these tools allowed private parties to supply road users with additional information to regular roadside information, and could also suggest routes, thus affecting the decisions of drivers and ending the state monopoly on informing and advising road users (Troost-Oppelaar et al., 2013). Therefore, Vroom (2016) labels navigation systems as 'the biggest traffic managers in the Netherlands'.

And so, in extension of informing drivers about events on the road, private service providers have also appropriated some tasks related to 'advising' and 'leading' motorists, which were previously exclusive to public road authorities, in turn challenging, disrupting and destabilizing the top-down traffic management model. Instead of aiming for the collective optimum, it is in the interest of market actors to supply their customers with information to secure their individual optimum, given that they often desire to know the fastest route to their destination (Den Hollander et al., 2015; Ottenhof, 2013; Van Strien, 2016; Vroom, 2016; Potgraven & Doelman, 2014). One interviewee notes: *''if we let service providers such as TomTom have their way, they will eventually send drivers over shortcuts – through villages, or over provincial roads. For the service provider, this is the optimal solution, but for the system, for society as a whole, this is not desirable at all''* (Stadsregio Amsterdam spokesman, interview, 6 December 2016). Here, multiple governmentalities are enacted simultaneously and compete with each other in the process of steering the behavior of the driver: one attempting to instill behavior ensuring optimal network throughflow, the other facilitating self-regulation. This has led to some resistance from public road authorities, as one interviewee notes that *''most governments are still desperately trying to discourage the use of these applications, as evidenced by the 'turn navigation off' signs alongside some roads, albeit to no avail''* (Technology company spokesman, interview, 14 December 2016). Nevertheless, the general opinion of the interviewed public and private representatives was that the new in-car technologies have necessitated closer collaboration between road authorities and market actors in order to resolve conflicts of interest and to pursue a network optimum – a view that is also widespread in the literature (see for example Connekt, 2013; Ottenhof, 2013; Joostema, 2014; Vroom, 2016). Here, more than preventing negative externalities, public road authorities also expect to benefit from this cooperation: since drivers are more inclined to follow up on tailored and personalized in-car route advice, road authorities can use these devices to communicate desired behavior more effectively (Connekt, 2013; Rathenau Instituut, 2013; Trafficquest, 2011a; Troost-Oppelaar et al., 2013; Van Haasteren, 2015; Amsterdam Smart City, n.d.). Though this collaboration is still in its infancy (Vroom, 2016), traffic management is now gravitating more towards 'self-steering', where road authorities engage less in 'collective influencing' practices and more in facilitating the self-management of drivers, only intervening when societal boundary conditions such as safety, accessibility and livability are in danger of being compromised (Op de Beek, 2016; Van de Weijer, 2014; Adams & Schröder, 2013; Connekt, 2013). Instead of imposing *external* commands onto the motorist, mobile applications are increasingly used to create a certain social reality tailored to the individual, where the behavior desired by road authorities arises *naturally* from *within* the motorist based on his or her own rational assessment of the information he or she is presented with. This can be interpreted as a transformation in the functioning of power, where the model of state intervention partially shifts towards a model of 'responsibilization' of the driver. Here, technologies of the market are utilized to achieve the objectives of government, and thus enact a form of neoliberal governmentality.

Now, there is a discussion on whether some roadside sensors and traffic management assets can be partially replaced by in-car services. In 2013, Rijkswaterstaat announced that it would remove some of its DRIPs, and the roadmap BGOW also indicates that roadside systems become less necessary (''Minder DRIPs'', 2013; Connekt, 2013). Likewise, authors such as Van de Weijer (2014), Dicke-Ogenia et al. (2015) Kruijssen et al. (2016) and Trafficquest (2014a) identify a similar trend, arguing that public expenditures could be reduced through these measures. Nevertheless, there is uncertainty and skepticism about the extent to which roadside systems can be replaced by their in-car counterparts (see for example Trafficquest, 2011a; Swaans et al., 2007; Bezemer, 2014; Dicke-Ogenia et al., 2015; Vialis, 2014). The penetration rate of in-car information systems is still relatively low, which would mean that most drivers would not be able to receive it. Likewise, even those who own in-car devices can switch them off, yielding the same communicative problems. Furthermore, between users of such devices, there are numerous other significant technical challenges: does everybody receive a notification at the same time? Is the information presented in the same way? Is the communicated information comprehensible to all road users (Dicke-Ogenia et al., 2015; Vialis, 2014)? In the interviews, a similar concern was voiced:

''Roadside equipment allows the government to have control over traffic on the road. If it would make the full switch towards in-car, it would not be able to prove whether motorists abide by the instructions of road authorities, as opposed to – for example - a DRIP-sign along the road indicating a speed limit of 50 kilometers per hour, where a local police unit with speed cameras can enforce this limit. Suppose that an in-car traffic light turns red, a motorist ignores this sign and collides with another vehicle: the driver might then claim that his or her device did not indicate this red light, and there is no way to prove the contrary. Hence, though the government might theoretically want to cut all spending on roadside systems, removing all of this equipment is totally unrealistic''. (Technology company spokesman, interview, 19 December 2016)

Ergo, the bulk of the interviewees and the practitioner's literature indicate that the amount of roadside infrastructure will likely decrease over time, but roadside systems are expected to remain necessary in the near future.

5.6 CONCLUSION

The developments in traffic surveillance described in this chapter aptly fit in Deleuze's notion of societies of control. Where a few decades ago drivers were monitored by human actors such as police officers and traffic managers using CCTV cameras, drivers are now for the most part monitored by sensors that register and represent isolated qualities, such as their vehicle category, point speed or trajectory (in the form of OD matrices), breaking down individuals into dividuals.

Moreover, assemblages of roadside sensors, acting as spatial surveillance enclaves, are gradually being supplemented – and will likely be replaced by – mobile, in-car sensors. This development can be interpreted as being parallel to Deleuze's hypothesis that the enactment of power shifts from enclosed and fixed spaces – characterizing disciplinary societies - towards open, fluid and networked spaces, which lies at the core of societies of control. Since the motorist can now be sensed and made knowable through a virtually unlimited number of swarming non-stationary sensors, the surveillance gaze is not bound to a limited number of geographical locations, but can theoretically penetrate every part of the road network. In a similar vein, in-car information systems are now increasingly used alongside roadside traffic management instruments in order to govern the behavior of drivers more effectively. They do so not only by disentangling the instruments that govern motorists' behavior from fixed locations through supplying mobile, in-car information, but also have the potential to mold such governance mechanisms to individual characteristics and preferences by supplying specific 'personalized' information, in turn augmenting the degree of control over the motorist.

Second, juxtaposing Rouvroy's (2013) three stages of algorithmic governmentality to the earlier described proliferation of roadside and in-car sensors, the establishment of the NDW, the growing efforts to scientifically analyze traffic data and now the increasing capability of systems to automatically intervene in traffic flows in real-time, these developments seem to satisfy all three stages of algorithmic governmentality.

Third, technological advancements have been accompanied by a growing presence of private actors in managing public space, nudging towards what can be considered a form of neoliberal governmentality. The development of increasingly complex market-mediated technologies seems to automatically imply a role for the private sector: since governments possess little expertise related to these technologies, public-private collaboration becomes necessary.

6. CASE STUDY: THE PRAKTIJKPROEF AMSTERDAM [PPA]

6.1 INTRODUCTION

Thus far, this study has outlined how traffic is governed in the Netherlands, and what developments have taken place in the field over the last years. Building on the previous chapter, this chapter will review how these developments are reflected and configured in the Praktijkproef Amsterdam (Amsterdam Practical Trial) [PPA], one of the four 'routemap projects' defined by the Ministry of Infrastructure and Environment in the Beter Geïnformeerd op Weg [BGOW] program and the world's largest trial of 'smart' traffic management technologies in a live environment (Connekt, 2013; Praktijkproef Amsterdam, 2016a; Twynstra Gudde, 2015). Particularly, this project is of interest since it is expected to primarily contribute to the following transition paths of the BGOW roadmap (Van Kooten & Hoogendoorn, 2014):

1) From collective influencing towards a smart mix of collective and individual service provision.
2) A changing role of roadside systems.
6) From government control towards public-private cooperation and alliances.

Hence, the case serves as an apt illustration of the recently emerging forms of governing traffic described in the previous chapter, exploring the possibilities of in-car information technologies, software-mediated (algorithmic and centralized) ways of steering traffic (primarily for roadside systems) and new roles for public and private actors. Reviewing these trials thus reveals how new forms of governmentality are enacted in traffic management, as well as the challenges and limitations that may lie therein.

This chapter will review how new modes of governmentality are enacted in the PPA using roadside systems, in-car applications and public-private partnerships. First, it will briefly introduce the PPA project. Second, it discusses innovations in the way roadside systems are operated. Third, it will shed light on the new ways of governing traffic through smartphone apps. Last, it discusses the changing roles between the public and private sector in traffic management, which is followed by a conclusion.

6.2 INTRODUCING THE PPA: A BIRD'S EYE VIEW

The PPA is a pilot project in the Amsterdam region where the latest innovations concerning in-car and roadside technologies are tested in everyday traffic (Trafficquest, 2015; Connekt, 2013; Rijkswaterstaat, 2016b). Set against the backdrop of surging traffic volumes in the Netherlands, the project is part of the Ministry's response to the issues of congestion, CO_2 emissions, road safety and noise pollution, which are all exacerbated by this trend (Praktijkproef Amsterdam, 2016a). Until recently, the modus operandi of the government has been to expand the road network, particularly in effort to alleviate the economic burden of congestion (Van de Weijer, 2013; Kuiken, 2016). However, in line with Van de Weijer (2013), several interviewees described this option as becoming *''increasingly politically unfavorable''*, since *''the costs of building new roads are high''*, and *''space is becoming increasingly scarce in the Netherlands''* (Consultancy company spokesman, interview, 8 December 2016; Technology company spokesman, interview, 14 December 2016). Moreover, an epiphenomenon hereof is tardiness, given that *''it often takes years to negotiate, plan and construct a new road, which means that you never catch up with the quickly fluctuating demand''* (Technology company spokesman, interview, 14 December 2016). Deviating from this trajectory in recent years, the Ministry has –

under the flag of austerity measures and the Beter Benutten and BGOW programs outlined in chapter 4 – started to inquire whether the existing infrastructure can be used more efficiently, as it has found that the current road capacity is not being exploited to the fullest. Employing a 'learning-by-doing' logic, it seeks to explore the potential of new 'smart' technologies for realizing more cost-effective traffic management systems in a series of practical trials (Ministry of Infrastructure and the Environment, 2016; Van Strien, 2016; Rijksoverheid, 2015). In the PPA, the following three innovative concepts are being tested in and around Amsterdam:

1) Upgrading roadside systems with GNV software to test its potential for automated, holistic/coordinated, actuated and predictive traffic management;
2) Using mobile 'in-car' applications to facilitate self-steering of drivers in accordance with the policy objectives of public road authorities, and integrating these applications with roadside systems;
3) New 'smart' forms of collaboration between the market and road authorities.

The PPA started out as a series of trials of the GNV concept, which constitutes one of the central discursive tools underpinning the project. Prior to the PPA, GNV was essentially a theoretical model, grounded more in mathematical simulations than practical evidence. Although the concept dates back to 1996, it had long been shelved due to technological limitations, only resurfacing and gaining momentum as a viable solution in the last years. Commenting on this process, one of the PPA project managers noted that *''[t]he Ministry picked up the idea from traffic engineers at the Delft University of Technology, who had developed traffic flow theories such as GNV and simulations aiming to identify and use unexploited network capacity. They successfully lobbied at the Ministry saying: it would be a waste of money to build new roads, because you're not using this remaining 10 percent of the road capacity''* (Rijkswaterstaat spokesman, interview, 2 December 2016). Consecutively, the Ministry issued a large-scale trial to test the theory in practice. GNV poses that road networks susceptible to congestion – such as that of the Netherlands – require proactive traffic management on a network level in order to optimize the aggregate throughflow. Given that local interventions by road authorities can have consequences for the throughflow of entire network, the model asserts that closer collaboration between the different road authorities (and thus centralization of management) is required in order to attain the network equilibrium. Furthermore, in order to respond to volatile traffic flows, anticipate on flow-disrupting events and assess the effects of interventions, vast quantities of reliable real-time data and automation become necessary in order to calculate the possible outcomes of such interventions and to implement them at the optimal time. Hence, GNV has the following characteristics: (1) a centralized, network-wide view, (2) a high degree of automation and data-drivenness and (3) vehicle actuation and anticipation: adapting the programs of roadside systems to meet both real-time and future demand. (Landman et al., 2012; Hoogendoorn et al., 2016; Mak, 2013)

In parallel to the roadside trials, the Ministry has opted for an in-car track, where it investigates the extent to which mobile route information applications can be used to achieve public policy objectives. Particularly, this involves achieving a better throughflow by spreading traffic more evenly over the network by providing route information that is both tailored to the individual and aligned with the 'collective interest'. Moreover, it creates an opportunity to map the opportunities and challenges therein, providing public road authorities with much-needed experience in anticipation of intelligent 'connected' vehicles, which will likely include a multifarious array of such in-car information applications (Linssen & Jak, 2014; Van Koningsbruggen et al., 2015). Ultimately, the PPA project initiators aim to consolidate the in-car apps with the roadside systems, creating one integrated traffic management system. As illustrated by Figure 9 on the next page, the two tracks are projected to confluence over the course of several sub-trials, which are conducted between 2013 and 2018 and are spread out over 3 phases.

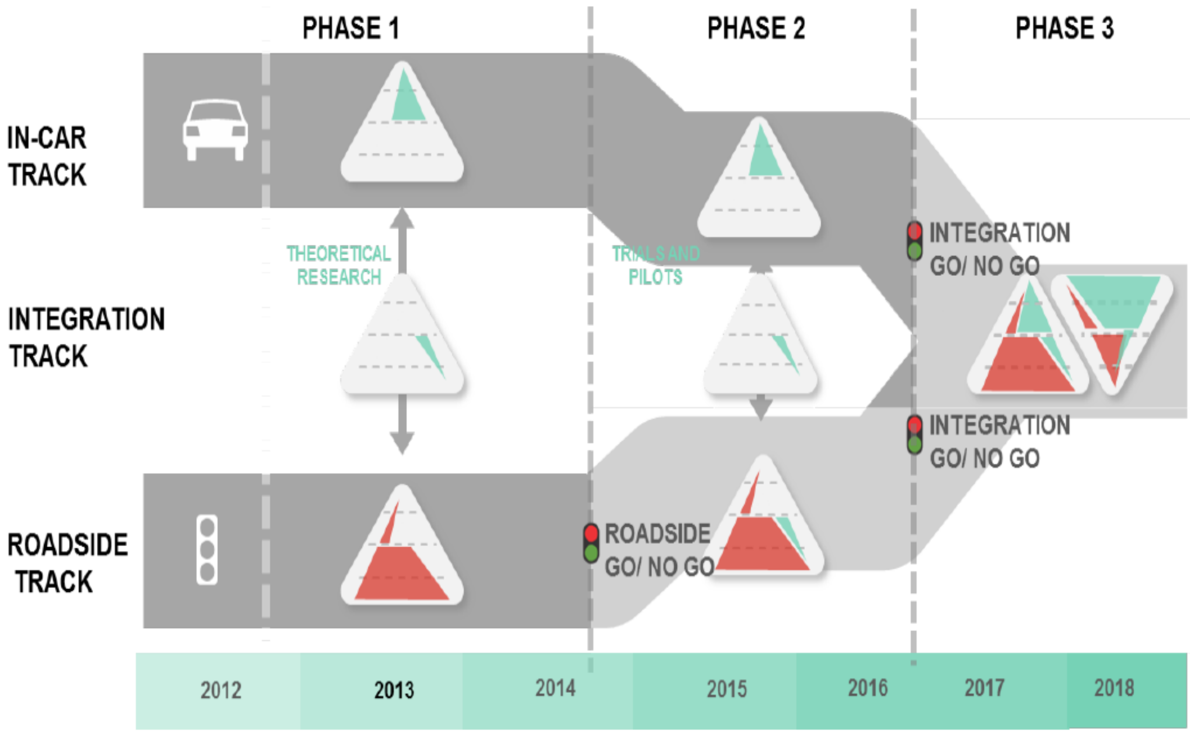

Figure 9: The PPA roadmap (Stevens, 2016).

Last, the project is also unique in the Netherlands due to its university-business-government triple helix structure, which is referred to as the 'golden triangle'. Here, public and private actors jointly explore the possibilities of innovative in-car and roadside systems to improve the traffic flow. Five public institutions are involved in every trial: the Ministry of Infrastructure and Environment, Rijkswaterstaat, the municipality of Amsterdam, the Province of North Holland and the Amsterdam Metropolitan Region. Likewise, a plurality of businesses and knowledge institutions are involved, but the participating actors vary between the subprojects. This is illustrated in Table 2. (Trafficquest, 2015; Praktijkproef Amsterdam, 2016a; Stevens, 2016)

Phase	Project	Project partners*	Project description/goals
1	Roadside	• Delft University of Technology • Ziut • Technolution • IT&T • Fileradar • MARCEL • Arane • Vialis	The project is focused on testing the potential of GNV to contribute to the policy objectives of the national government and Amsterdam region. Specifically, the project aims to delay traffic jam formation on the A10 West freeway and to decrease the duration of traffic jams by proactively buffering traffic on the on-ramps, and by coordinating and automating the TDIs and VRIs in the network (Twynstra Gudde, 2015).
	In-car	<u>Consortium 1:</u> ARS Traffic & Transport Technology [ARS TT&T], TNO <u>Consortium 2:</u> Arcadis, VID	The short term goal of the project is to gain experience with new in-car technologies in the Amsterdam region on a large scale, focusing on individualized and tailored informing and influencing of drivers' behavior, with the aim to optimize the traffic flow in the Amsterdam region, thereby significantly reducing the amount of lost vehicle hours. The potential long-term goal is to reduce the need for the government to inform drivers about

			optimal routes, and explore the extent to which some of these responsibilities can be transferred to the market. (Twynstra Gudde, 2015)
2	Zuidoost (Southeast)	• Eindhoven University of Technology • VU Amsterdam • Consortium 1: Technolution, KPN, Brand MKRS Creative Agency, Goudappel Coffeng, Dat.Mobility, Flitsmeister, BeMobile • Consortium 2 (De Digitale Wegbeheerder): the National Research Institute for Mathematics and Computer Science (Centrum Wiskunde & Informatica), Intemo, Ko Hartog verkeerstechniek, Schmit parkeersystemen, TrafficLink, Trinité, V-tron	The primary objective of PPA Zuidoost was to improve the processes of informing and steering drivers during events by integrating in-car systems – similar to those developed in phase 1 - with roadside systems, where public and private partners work together on an equal footing in order to optimize the use of space in the network and in parking facilities, ultimately contributing to the transition paths of Connecting Mobility. (Twynstra Gudde & MuConsult, 2016; Trafficquest, 2016)
	West	• Transpute (using INRIX data) • BeMobile • DAT.Mobility • Arane Adviseurs • Fileradar • TomTom	The goals of the project are twofold. First, it aims to trial several improvements to the GNV concept as developed in phase 1 of the PPA. Second, it looks at the role that FCD can play in the process of managing and steering traffic, in lieu of the detection loops used in the first phase. (Praktijkproef Amsterdam, 2017a)
	Noord (North)	• Municipality of Zaanstad • Delft University of Technology • VU Amsterdam • KxA Software Innovations • ARS TT&T • Technolution	The goal is to gain insight into the possibilities and cost-effectiveness of the application of the optimized rule concept [GNV], developed and tested in the first phase of the PPA, in other situations. With this, it aims to attain a production-ready GNV module that can be implemented in the rest of the Netherlands and beyond. (Praktijkproef Amsterdam, 2015; 2017b; Krikke et al., 2016)
* The Ministry of Infrastructure and Environment, Rijkswaterstaat, the province of North Holland, the municipality of Amsterdam and the Stadsregio Amsterdam are not listed, since these participate in every project.			

Table 2: Overview of the PPA projects of phase 1 and 2 (Own work).

While the project focuses on several parts of the Amsterdam road network, most striking is the dominant focus on the A10, the Ring Road around Amsterdam. The reason for this focus was stated by one of the PPA project managers, who gave an analogy with the human body:

''Above all, keeping the Ring running is our highest priority: if traffic is not moving on the Ring, and cars are unable to enter or exit the road, the entire road network will clog up. You can compare it to the human heart: blood has to flow there, or else you will die. Other parts of the body are less important, since you can still survive when blood is not flowing to your limbs, for example. This is why lower level networks such as municipal and provincial roads have a lower priority.''
(Rijkswaterstaat spokesman, interview, 28 November 2016)

Here, 'keeping the ring flowing' was mentioned by several interviewees and is included in various policy documents, and has thus solidified as a discursive object, a key rationality of the project. Moreover, what makes the area unique is the fact that there is a confluence of many different types of roads, such as highways, provincial roads and local roads, each governed by a separate road authority. Here, many different types of traffic flow through the area, such as commuters, cargo trucks, event visitors and local inhabitants. Last, there is a tunnel, which forms a bottleneck that increases the probability of traffic congestion. All these factors result in a complex environment that forms a challenging site for a trial to govern the behavior of drivers in new ways (Van der Weijer, 2013).

6.3 ROADSIDE SYSTEMS: ALGORITHMIC GOVERNMENTALITY, CENTRALIZATION AND GNV

6.3.1 POWER IN THE PPA ROADSIDE TRIALS

''The PPA showcases the new 'Dutch way' of steering traffic. Most of the world uses 'fixed-time signals' for traffic lights, meaning that the cycle times between green and red, as well as the order of service for each arm of the intersection, are pre-programmed. This system is inefficient, since traffic is stopped even in cases where there are no vehicles approaching the intersection from other directions. There are two ways of dealing with this issue. Conventionally, traffic managers approach this problem by re-programming the traffic lights, further refining the programs using knowledge about the behavior of traffic flows. We may know, for example, that most traffic flows in one direction in the morning, and that this 'dominant flow' turns around in the afternoon, on the basis of which we can allocate longer green times. However, traffic does not always behave in this way, so this method still cannot respond to variations in these patterns. What we have developed is a different approach, where the system is flexible and can monitor the amount of traffic in the area, anticipate on it, and adjust the green times accordingly. This 'vehicle actuation' allows us to improve the network throughflow and make more use of the space in the network, enabling us to get the most out of it.'' (Stadsregio Amsterdam spokesman, interview, 6 December 2016)

The quote above highlights how GNV differs from previous methods of steering traffic: the relatively simple reactive, fixed and fragmented model has been replaced by a more complex predictive and real-time system that uses cloud computing in order to enable a new form of centralized and automated steering. In this section, the PPA trials that attempt to translate GNV into practice will be closer reviewed: PPA roadside, PPA West and PPA Noord. Here, I will argue that these projects manifest a new form of algorithmic governmentality.

The first GNV module was deployed in the roadside track of PPA phase 1, where several pieces of roadside infrastructure – a constellation of VRIs, TDIs and detection loops – were made 'smarter' by retrofitting them with new software using an enterprise service bus [ESB]: the 'PPA bus'. This interface functioned as an open platform, enabling the project partners to connect their software and hardware components to each other, effectively creating a fully automated traffic management system. This system was tested on inner ring of the A10 West freeway and the adjacent 'city routes', which are a series of urban arterials denoted by the letter S followed by a three-digit number (Beenker et al., 2015; Arcadis, 2015; Hoogendoorn et al., 2016). This can be seen in Figure 10 below.

In the second phase of the PPA, the GNV module for the roadside systems was further developed in West and Noord trials. Different from the roadside trial, these experimented with new types of data to operate roadside infrastructure. In PPA West, the project initiators explored the possibilities of Floating Car Data [FCD] as a new source of data for the GNV module, and tested this system on the outer ring of the A10 West. This experiment was conducted to investigate whether a) the quality of the data could be improved; b) detection loops could be removed to reduce costs and c) if new types of information could be used to improve the functioning of the system (e.g. OD matrices) (Hoogendoorn et al., 2016). Similarly, PPA Noord experimented with the use of radar sensors for the purpose of estimating queue lengths. Moreover, PPA Noord differed from the first GNV trials by exploring the potential of GNV in a different context, as it focused exclusively on the urban network, where several VRIs (at intersections), a bridge and a TDI along the N516 provincial road were controlled by the system (Praktijkproef Amsterdam, 2017b).

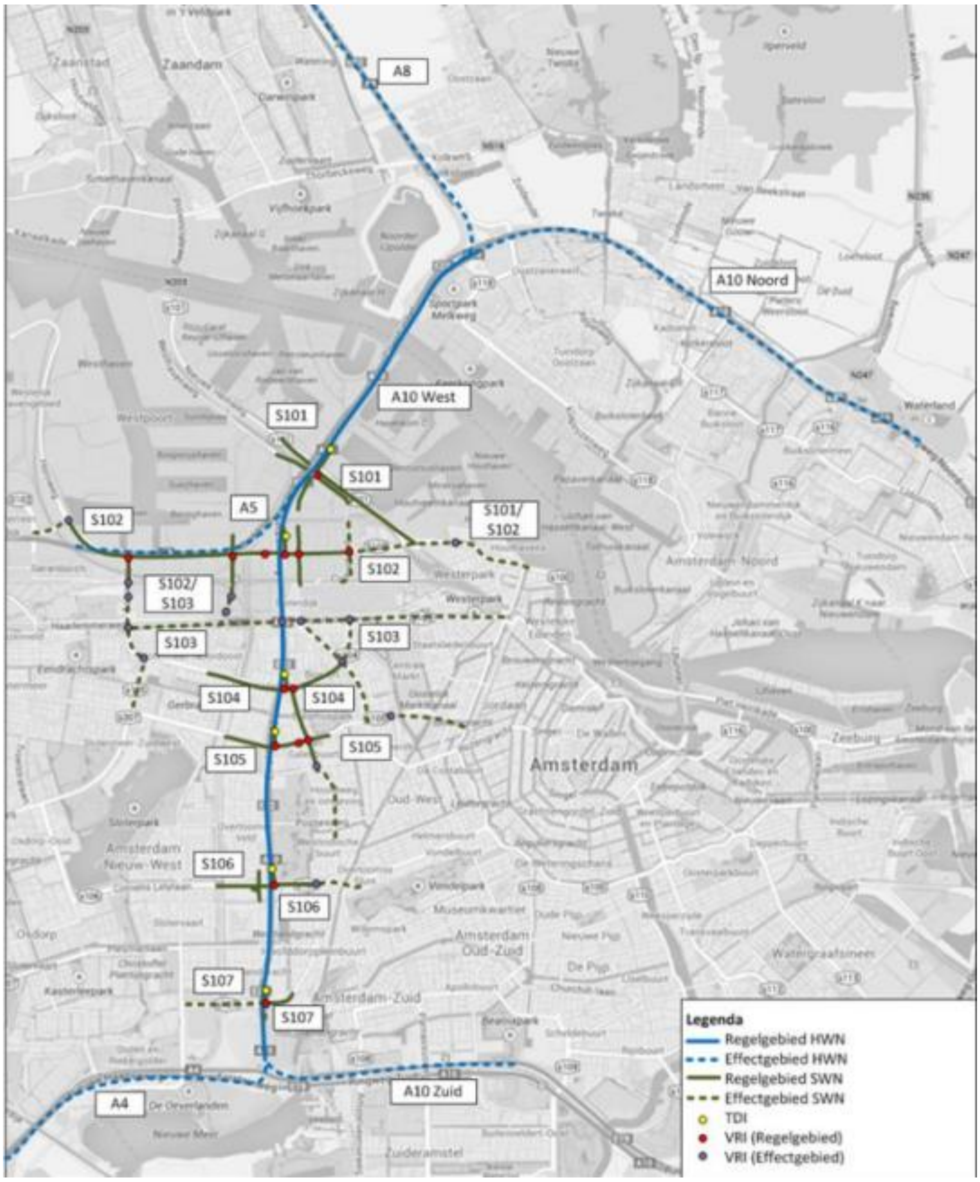

Figure 10: The PPA Roadside test site, consisting of the A10 freeway (blue), urban arterials (green), TDIs (yellow) and VRIs (red) (Beenker et al., 2015).

Past research had accrued to a set of four rules for the A10-West freeway (Hoogendoorn et al., 2016; Van Kooten & Hoogendoorn, 2014):

1) Don't react to traffic jams, but anticipate on them. By acting before a traffic jam occurs, capacity drops and congestion can be prevented.

2) Bottlenecks need to be resolved on the level at which they occur. This requires a layered management approach, where a bottleneck is first dealt with on the local level (e.g. using the nearest freeway on-ramps as buffers). Upscaling (seeking space elsewhere in the network) should only be done when local storage space for traffic is running out.
3) Unnecessary obstructions to traffic - such as spillback, blockages and gridlocks – that may result from buffering at intersections and on-ramps should be avoided by keeping queue lengths within acceptable limits.
4) The spare capacity of the network should be exploited optimally in relation to prevailing traffic conditions. This entails that the maximum allowable usage of bufferspace is fluid: it inflates when traffic conditions deteriorate, and shrinks when the density of traffic decreases.

These rules were implemented by translating them into two types of algorithms (sets of mathematical rules used by a computer to solve a particular problem): Logical Monitoring Units [LMUs] and Logical Control Units [LCUs] (see appendix C for a detailed overview). The LMUs essentially comprised a digital apparatus of surveillance, attempting to diagnose the current state of the network and predicting how it will change over time. On the A10-West, the freeway ramps and at the intersections in the urban network, the loop detectors functioned as a sensory system, allowing the LMUs to map the average speed, density and flow of traffic in specific parts of the network, as well as the amount of free 'buffer space' on the on-ramps. Coupled with historical databases (NDW data or 'V-log' data retrieved from TDIs and VRIs), the system was also able to compute future scenarios. On both the freeway and the urban network, it could predict a bottleneck and its location up to three minutes in advance by combining real-time loop data with data about *'hot-zones'*: locations where traffic regularly breaks down (which thus have a high probability of becoming bottlenecks). Similarly, it was able to estimate and predict queue formation and growth on off- and on-ramps. The LMUs were connected to the LCUs through problematization mechanisms, which compared both the real-time and predicted network performance values (e.g. on-ramp queue lengths, traffic densities on the freeway and the remaining network capacity) against certain critical 'threshold values'. Together, these values delineated that which is considered acceptable or within the norm, since transgression of these system boundaries makes the network prone to congestion, resulting in sub-optimal network performance. (Van Kooten & Hoogendoorn, 2014; Hoogendoorn et al., 2016; Van Hinsbergen, 2014)

The LCUs, in turn, comprised the software units which - based on the data from the LMUs – continuously assessed the necessity for intervention, calculated the optimal course of action and deployed the mechanisms of intervention (TDIs, VRIs and supervisor algorithms). When the traffic density on a part of the freeway exceeded the established threshold value (indicating a looming bottleneck), this would trigger the nearest upstream TDI. Subsequently, the TDI limited the inflow of traffic from the corresponding on-ramp in order to prevent congestion on the freeway. In this process, it made use of a feedback mechanism that incessantly gauged the effectiveness of the deployed measures, and adjusted the intensity of the interventions accordingly. The local controllers also communicated bidirectionally with a set of supervisors: algorithms that monitored and coordinated the actions of VRIs and TDIs in different parts of the network (the freeway, intersections of urban arterials and the ramps). When a bottleneck could not be solved by the local controller, these supervisors were able to mobilize TDIs and VRIs located further upstream, which subsequently aligned their actions with the target value defined by the downstream controller. As such, the actions of the TDIs and VRIs in the network could be harmonized, creating a synergetic ensemble of intervention instruments that could detect, ameliorate and prevent congestion on the most effective geographical scale. (Van Kooten & Hoogendoorn, 2014; Hoogendoorn et al., 2016)

Juxtaposing the implemented system to the previous configuration, one can assert a transition in the technologies of power, where the fixed, fragmented, reactive and semi-automated traffic management system has been replaced by one that is dynamic, coordinated, predictive and fully automated. The PPA Roadside project is thus illustrative of a form of algorithmic governmentality, where some of the authority to govern traffic is transmitted to software, and the watchman of the panoptic surveillance model is thus no longer human, but a machine. This is done by embedding certain rules in the software – or how the software 'wants' the road network to function –allowing the system to classify certain volumes of traffic in parts of the network as either tolerable or intolerable and make apposite interventions. Here, the rationale of network throughflow optimization is put into practice through processes of prioritization (Landman et al., 2012), where the software gives traffic on the A10 freeway right-of-way, often at the expense of traffic in the urban road network. In this way, individual drivers on the freeway are privileged, while others are disadvantaged. This prioritization reveals certain normative components embedded in the system, as one interviewee notes:

''Traffic management is not just about optimizing the throughflow, safety or sustainability – it is shaped by policy documents, which reflect what political parties view as important and how they want to shape traffic management. Here, they view some parts of the network as being more important than other parts of the network. Similarly, we may halt traffic on some roads – in the form of buffering – while stopping traffic on others is completely unacceptable'' (Consultancy company spokesman, interview, 8 December 2016)

Moreover, the software does not only attempt to mitigate breakdowns in traffic flows that have already occurred, but also acts on events that are projected to happen in the near future, or: 'how things could be'. Leveraging data from a growing database, a digital data shadow containing both historic and real-time information about traffic congestion and its circumstances (e.g. time, weather conditions, large-scale events and bottleneck locations), it is able to string together patterns in the data, revealing how similar events have developed in the past. In turn, this 'mathemization' of the past creates an augmented, deciphered reality which legitimizes preventive actions attempting to condition the future. Drawing from an ever-growing database of past scenarios, the software becomes a self-learning entity able to forecast traffic scenarios with growing accuracy through processes of continuous refinement. Put differently, the software produces knowledge in the form of statistical data and hypotheses, enabling the system to direct power with greater precision to the subjects (the motorists), yielding outcomes that are ever more predictable. This shows the reciprocity between power and knowledge. This predictability is what authors such as Leszczynski (2016) and Klauser et al. (2014) name 'securitization': the future, an open set of possibilities which may hold all kinds of undesirable scenarios, is preempted, in turn minimizing uncertainties.

What is interesting is the obfuscation - or even 'desubjectification' - of the individual by the system: it does not 'perceive' individual drivers, but instead groups them into flows, only making rough estimations about the quantity of vehicles and their relative sizes, and thus only sensing them as dividuals: blocks occupying a certain amount of space in the network. The system does not necessarily act upon individuals (whose actions are perhaps irrelevant) but instead seeks to manage the macro-level effects of their behavior. Thus, one might argue that the existing models of disciplinary power – where certain types of behavior are instilled in the individual – are now supplemented by control: the system does not only function as a 'conduct of conduct', the molding and punishing of bodies, but instead relies on a system of classification, where the values of several network performance indicators are administered as either 'acceptable' or 'unacceptable'. Such a development is aptly captured by Deleuze's notion of societies of control. This finding is corroborated by the conceptualization several interviewees had about the road network, which they compared to other types of smart utility networks, such as electricity grids, water networks, gas and waste, since *''in the process of transforming to smart, next generation infrastructures, all these networks are essentially facing the same problem: how can we better spread peak loads, and use the available network capacity in the most optimal way?''* (Technology company spokesman, interview, 14 December 2016).

6.3.2 RESULTS AND EVALUATION OF THE PPA ROADSIDE TRIALS

The first results of the PPA roadside trial were ambiguous. On the freeway, the deployed GNV module managed to bear fruits, as it was able to postpone the capacity drop by 7 minutes in both the morning and evening rush hours, and reduced the duration of the traffic jams by roughly 20 minutes. However, the implemented system had significant consequences for the urban road network, where it caused both an increase in travel times and vehicle loss hours, effectively nullifying the net benefits for the network throughflow – which even deteriorated as a result of the trial (Beenker et al., 2015; Arcadis, 2015). *''The simulations created by the TU Delft, which looked great on the computer screen, did not translate well into practice. We found that the prediction module - which buffered traffic on the on-ramps in order to mitigate not yet existing problems on the freeway - negatively impacted the overall throughflow, so it was unnecessarily nagging motorists''* (Rijkswaterstaat spokesman, interview, 2 December 2016). Nevertheless, the project evaluation report by Arcadis (2015) and the interviewees did not necessarily view these findings as problematic, as one interviewee explained that *''it really is a scientific experiment, allowing us to form new hypotheses, and to tweak, fine-tune and improve our existing models without altering the fundamental mechanisms of the system''* (Technology company spokesman, interview, 19 December 2016). Put differently, the unintended consequences of the PPA roadside trial for the urban network are understood as being intrinsic to the learning-by-doing approach, and provide an opportunity to further refine and expand upon the current body of knowledge. Indeed, this fine-tuning paid off in the PPA West and North trials, where a positive cumulative effect on the network throughflow was realized - though the effect of PPA West on the urban network was still negative. Hence, the project partners concluded that the GNV concept is cost-effective and scalable, offering prospects for regional or nation-wide rollout (AT Osbourne, 2017).

6.4 IN-CAR APPLICATIONS: PERSONALIZATION AND THEIR INTEGRATION WITH TRAFFIC MANAGEMENT SYSTEMS IN PPA IN-CAR & ZUIDOOST

While PPA Roadside, West and Noord exclusively employed collective steering techniques using roadside systems, PPA in-car and PPA Zuidoost were more oriented at in-car governing tools, using a series of smartphone applications to direct the behavior of individual drivers. Here, the apps leveraged data about individual motorists, such as their personal preferences or their current location, in order to optimize the interplay between the desires/requirements of the individual and the interest of the collective in the process of generating advised routes. Here, the interest of the collective is understood as the maximization of the network throughflow within the acceptable limits of safety, livability and sustainability. This was made possible by linking the apps developed by the market to the systems of the traffic control centers of Rijkswaterstaat, the Province of North Holland and the Amsterdam municipality. In this way, data exchange between the private and public actors became possible, allowing the project partners to gain a more accurate overview of the network, and integrate both the interests of the individual and those of the road managers in the routes advised by the apps. This can be seen in Figure 11 below. (Praktijkproef Amsterdam, 2016b; AT Osbourne, 2017)

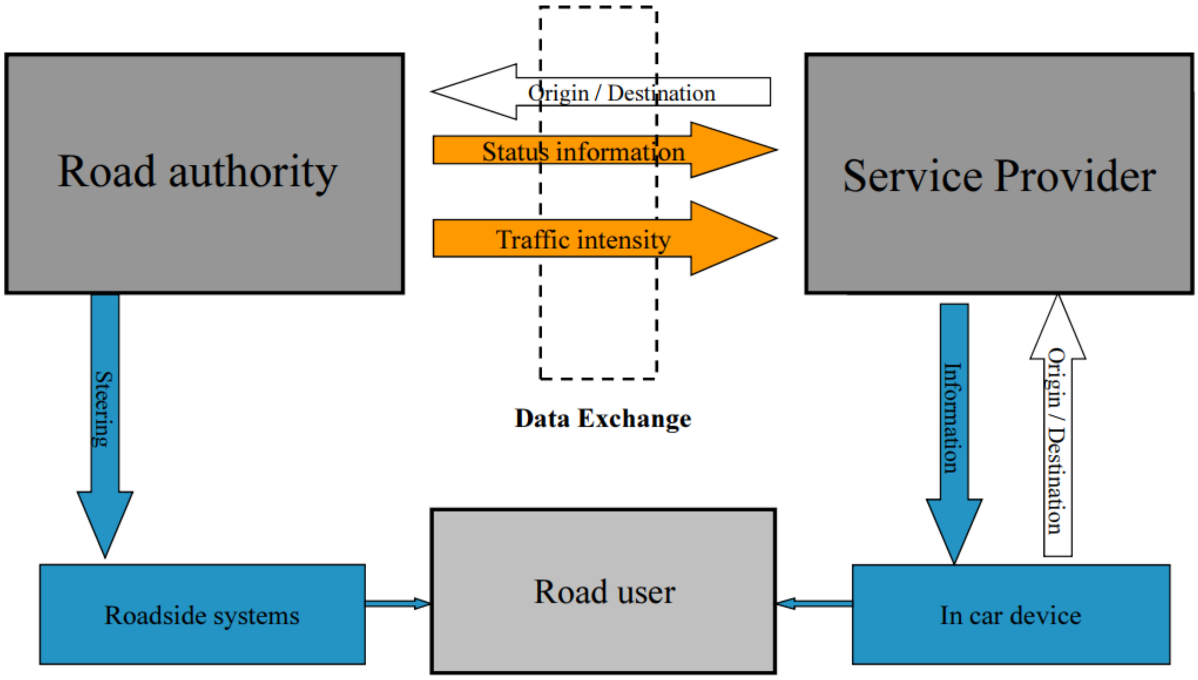

Figure 11: Information flow in the in-car field tests (Adams, n.d.).

Different from the roadside systems, smartphones are simultaneously instruments for data collection and provision, entangled in a continuous and circular flow of data. They blur the previous distinction between surveillance and control mechanisms, since they generate data about individual drivers (making his or her actions knowable), which – after being aggregated and fused with traffic data about the rest of the network – also enables traffic information applications to govern their actions by suggesting particular routes. In contrast to the 'hard' steering mode in the roadside trials, where 'good' behavior is inculcated in motorists by means of prohibition, these apps visualize reality – the situation on the road – in such a way that it nudges their behavior in directions desired by the governing actors. Furthermore, the apprehension of in-car technologies for the purposes of informing and advising traffic can also be regarded as a move towards societies of control, where traffic managers are no longer only bound to roadside infrastructure, but can reach drivers at virtually any place and time through smartphone apps.

In this section, the novel forms of governing traffic through smartphone applications developed in the PPA projects – which, in various degrees, use techniques of personalization, individual-collective interest balancing, prediction and bidirectional operator-driver communication - will be analyzed in greater detail.

6.4.1 PPA IN-CAR

In the in-car track of PPA phase 1, 2 consortia together developed 4 applications, with each consortium producing one app for commuter traffic, and one app for event traffic. Here, the Amsterdam Onderweg [AO] consortium developed the Superroute and Super P-route apps, and Amsterdam Mobiel [AM] developed ADAM and EVA. Since the Super P-route app was integrated in the Superroute app, and the EVA app shared many functions with ADAM, this section will predominantly focus on AO's Superroute app, and AM's ADAM app.

6.4.1.1 AMSTERDAM ONDERWEG: SUPERROUTE

In the Superroute app, one of the pillars for personalization was the segmentation of drivers through profiling. Upon registration, participants were asked to answer a few questions in order to generate a profile (*persona*) corresponding to their personality and preferences. Personas were determined using 2 axes: *stress-tolerance* (tolerantie voor stress) and *goal-orientation* (doelgerichtheid). In this case, 'stress-tolerance' determined the extent to which the participant would be exposed to uncertainty (e.g. suggested routes unfamiliar to the user or at risk of traffic jams) and the amount of en route information he or she would receive. The 'goal-orientation' parameter, in turn, differentiated between process-oriented (procesgericht) users, who valuing the quality of the journey itself, and goal-oriented (doelgericht) users, who find the result – reaching their destination – to be most important. The 2 axes facilitated the subdivision of participants into 4 quadrants, each representing a user group in the form of a fictional character with its own personality traits. As shown in *Figure 12* below, the characters were Aniek (adventure), Damir (goal-oriented), Conny (comfort) and Bram (reliable). (Jonkers & Wilmink, 2016; TNO & ARS, 2016)

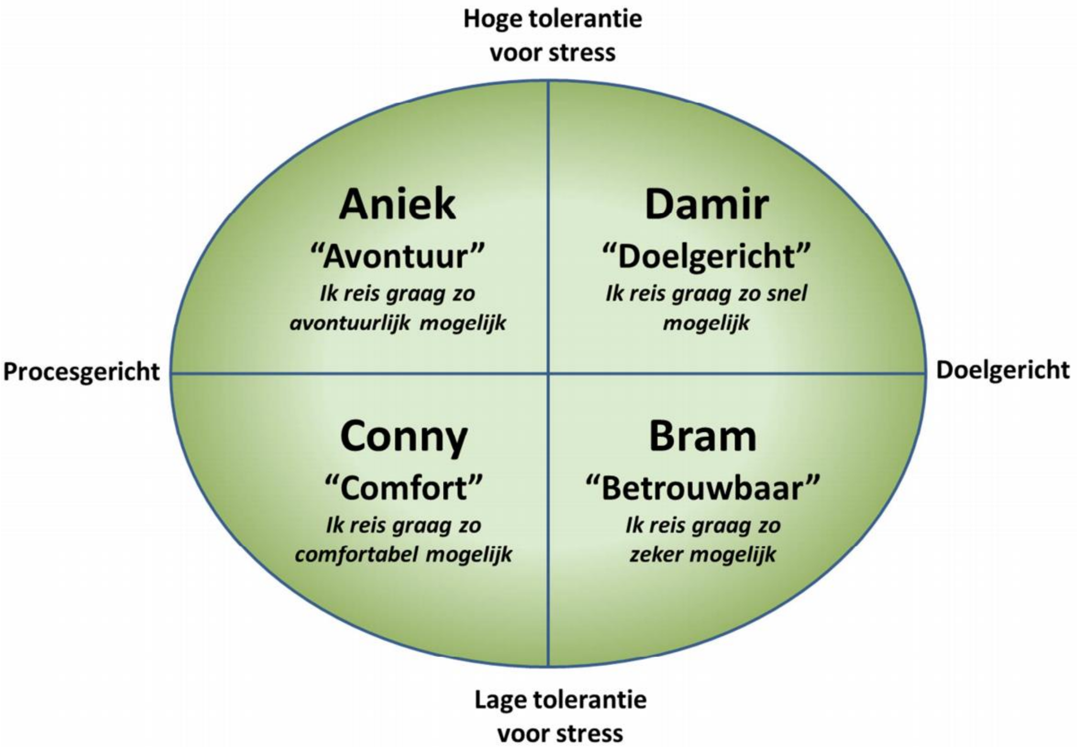

Figure 12: The four personality quadrants of the Superroute app (TNO & ARS, 2016).

In this way, app users could be classified into 4 user groups. This allowed for more personalized design and targeted marketing of specific services, which presumably increases the probability that participants stick to the advised route (TNO & ARS, 2016). Hence, the subject that was created (the persona) was not so much an individual, but more an archetype of segments of the population that shared particular characteristics and required tailored forms of governing. This segmentation can thus be interpreted as a risk-management tool, an apparatus of security aiming to streamline the inherently uncertain behavior of drivers by maximizing the probability that they abide to the routes proposed by the app, in turn rendering their actions more predictable. This corresponds to Pasquinelli's (2015, as cited in Rodrigues, 2016) writings on algorithmic governmentality, who states that one of the universal functions of data mining algorithms is pattern recognition, which includes the detection and segmentation of shared forms of behavior in a population.

Following the registration process, participants could use the app for two functions: pre-trip and on-trip information. First, the app assisted users with planning their trip in advance. Users had to enter their point of departure, destination and their desired departure or arrival time (and their flexibility therein). Subsequently, the app would indicate the 'best' routes (e.g. the fastest route) and provide the corresponding estimated travel times, the optimal times of departure, the estimated times of arrival and - if applicable - the amount of delay. These routes were calculated using a wide variety of sources of historic and real-time data, which allowed the app to estimate the probability of congestion on particular roads and predict travel times in advance. In turn, the app filtered out undesirable routes and selected the routes that were the most aligned with the parameters ingrained in the driver's persona and the interest of the network. This is illustrated in Figure 13 (Jonkers & Wilmink, 2016; TNO & ARS, 2016; Calvert et al., 2015)

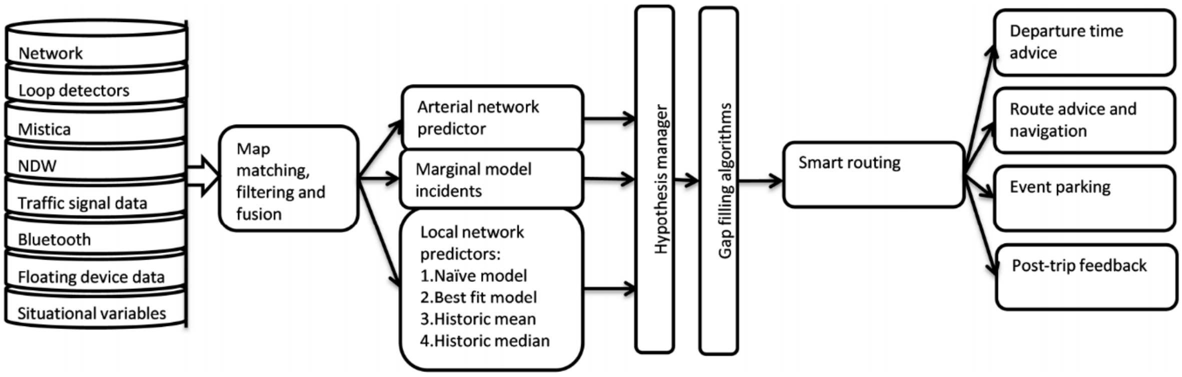

Figure 13: Architecture of the Superroute app (Calvert et al., 2015).

At the start of a trip, users could select one of the route options offered by the app. Subsequently, while on the road, a 'smart routing' algorithm constantly monitored real-time traffic updates (such as traffic jam alerts), and consecutively updated the estimated time of arrival. When no significant flow-disrupting events occurred on the selected route – such as an incident or a surge in traffic – the system did not deviate from the predetermined trajectory. However, in case of an event that could cause a delay, the app would offer suggestions for alternative routes. In order to spread traffic over the network, the app uses 'load balancing'. This means that not all drivers would get the same route suggestions from the application. In turn, this individualization of travel advice was projected to optimize the collective throughflow of the network. (TNO & ARS, 2016)

The Superroute app worked in conjunction with the VerkeersCentrale (Traffic control center) VC-tool (see Figure 14); a tool which AO developed specifically for the trial that allowed public traffic managers to keep track of the use of the app in the planned area. It primarily functioned as a visual surveillance tool, projecting real-time data on traffic intensities, travel times, parking facility occupation rates and the locations, driving speeds and recent trajectories of participants onto a map. Furthermore, the tool featured a historical overview that included statistics about the number of app users and trips made with the app. Last, the tool could be used to intervene in traffic flows using a scenario manager, but this functionality was not capitalized during the trial. Hence, traffic managers had little agency in the trial, as the bulk of commuters were routed by the smart routing algorithm of the Superroute application. (TNO & ARS, 2016)

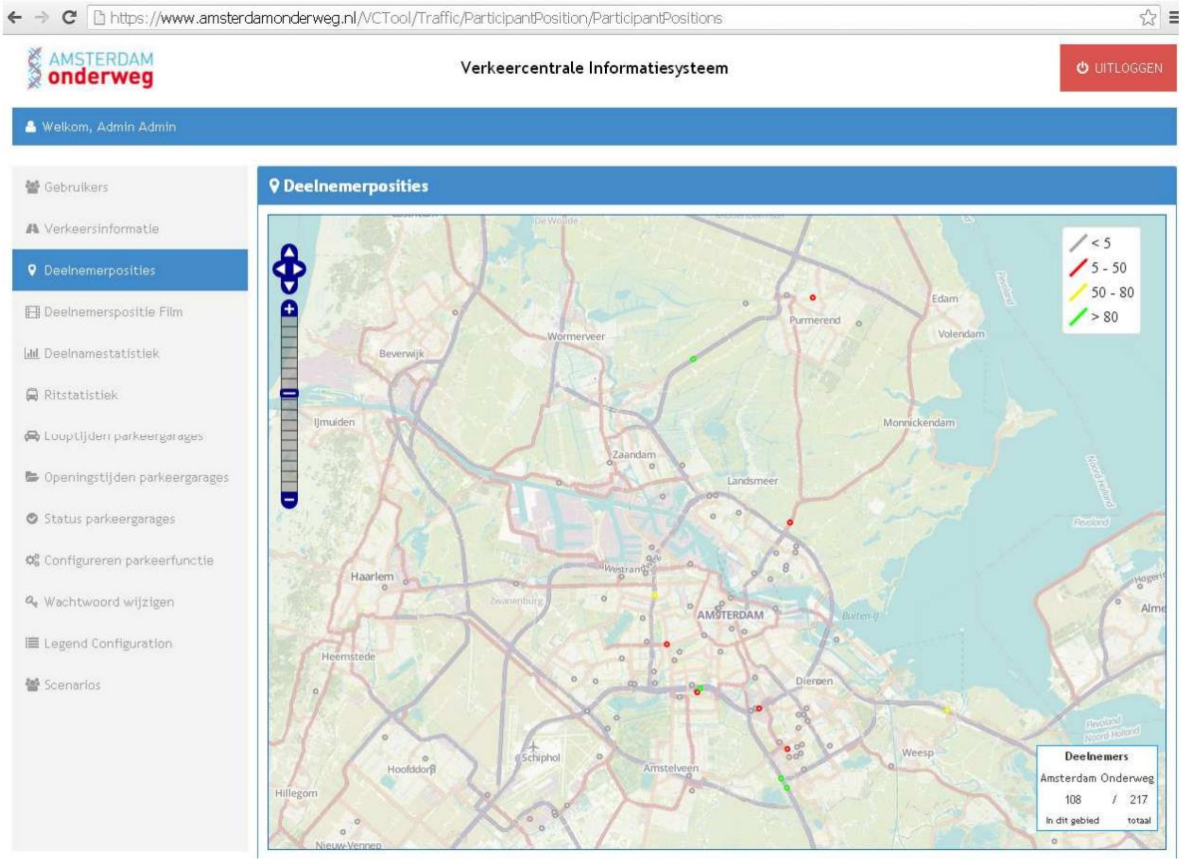

Figure 14: Screenshot of the Amsterdam Onderweg VC Tool (TNO & ARS, 2016).

6.4.1.2 AMSTERDAM MOBIEL: ADAM/EVA

The design and functionalities of ADAM (and EVA) were in many ways similar to the Superroute app, since the application sought to balance the individual and network interests in the provided pre- and on-trip route advices, was linked to the traffic control centers in the Amsterdam area through a monitoring tool (the 'VC-portal') and could suggest alternative routes based on a real-time traffic updates. However, ADAM was distinctly different on a few points.

First, the app facilitated a greater degree of agency for drivers. Different from the Superroute app, where a number-crunching mechanism negotiated between the preferences of the individual and the collective interest of the network in order to generate the optimal routes and departure times for the motorists, ADAM also allowed its users to define their own trajectories prior to their trip. In turn, the app calculated the travel times for both the self-defined routes and alternative routes suggested by the app, after which the user could select a route. Similarly, the app did not suggest departure times, but instead allowed them to tune in to livestreams of traffic control cameras located along their route, giving them an impression of the current situation on the road. Moreover, during the trip, the app made use of 'choice points'; points where multiple possible routes branch off. For each route, the app showed the expected travel time, allowing the user to select the fastest route. (Amsterdam Mobiel, 2015a)

Second, the operators at the traffic control room were also given a greater degree of agency. The VC-portal developed by AM was not only used as a traffic surveillance tool (showing the position, speed, origin and destination of app users), but also as an instrument to actively manage traffic. In the VC-portal, operators could color specific parts of roads with the colors green, yellow and red (though some of this is done automatically) (see Figure 15). Under normal conditions, a road was colored green, indicating that the ADAM app may suggest its use to the motorist. When congestion loomed on a particular road due to heavy use or an incident, operators could attempt to lower traffic on this route by assigning red marks to them.

Subsequently, the ADAM app would not show route alternatives that have been marked red by the operator. Lastly, a yellow color causes the app to only suggest a route if the time-loss is limited (Potgraven & Doelman, 2014; Birnie et al., 2015; Amsterdam Mobiel, 2015a).

Figure 15: 'Coloring' roads with Amsterdam Mobiel's VC Portal (Amsterdam Mobiel, 2015a).

Last, ADAM and EVA were different from Superroute app in the sense that they allowed for bidirectional communication between individual drivers and operators in the traffic control room. Through the app, operators could provide targeted information to drivers located in a specific area or on specific freeway lanes through geo-fenced push-messages, for example about dangerous weather conditions or obstacles on the road. Moreover, operators could ask questions to the project participants. In turn, ADAM users could respond with an audio message using the app's 'voicetweet' function, providing potentially useful information about the situation on the road to the operators. Here, the eyes and ears of drivers are mobilized as 'organic sensors', which can help operators to get a more complete picture of the situation on the ground. (Amsterdam Mobiel, 2015a; 2015b)

6.4.1.3 RESULTS AND EVALUATION OF PPA IN-CAR TRIAL

Together, the apps developed in the PPA in-car project were downloaded over 75,000 times, and used for more than 1,000,000 trips (Praktijkproef Amsterdam, 2016b). However, the first trial was not considered to be a success by the interviewees involved in the project, since the apps were not able to achieve the desired behavioral changes. They stated several reasons for this. First, several public and private parties were critical of the type of solution that was chosen. One of the PPA project managers stated:

''The parties that won the public procurement contract – ARS, VID, Arcadis and TNO - were somewhat outmoded in their knowledge and experience. While they had plenty of experience with roadside traffic information services, none of them had built a mobile app before. Nevertheless, they got the contract anyway, since their proposal seemed to have the best price-quality ratio, even though they had to outsource the app-development. TomTom, on the other hand, offered very nice and innovative solutions, but these were far more expensive''. (Rijkswaterstaat spokesman, interview, 2 December 2016)

Hence, the choice for the aforementioned smartphone applications was to some degree motivated by their price tag. Notwithstanding this point, the decision was remarkable, since this is at odds with the government's efforts to prohibit the use of mobile phones while driving. At the Verkeer, Mobiliteit & Parkeren Expo, several attendees voiced concerns over road safety in relation to smartphone applications; a concern which resurfaced during the interviews, where one interviewee stated: *''I think that the choice to work with smartphones is fundamentally wrong. When one wants to design an app that limits the driver-phone interaction, you run into the intractable nature of smartphones, which generally do not allow apps to suppress the activities of other apps or parts of the phone's autonomous system, such as WhatsApp, e-mail, calls and SMS''* (Technology company spokesman, interview, 19 December 2016).

Second, the penetration rate of the apps was deemed too low to have a visible effect on the traffic flow, as one interviewee comments: *''If 300 people use the app in a traffic flow of 50,000 people, you're getting nowhere''* (Technology company spokesman, interview, 14 December 2016). This lack of participation was attributed to several reasons. First, the amount of participants recruited was too low. Second, only a small part of the users who downloaded the app used it. (Praktijkproef Amsterdam, 2016b).

Third, there was little harmonization between the roadside and in-car applications, as *''the in-car application could make one suggestion, while the DRIP on the side of the road could say something completely different''* (Technology company spokesman, interview, 19 December 2016). As a result, some confusion ensued among app users about what advice to follow (Praktijkproef Amsterdam, 2016b)

Last, the apps had some technical issues as well. *''The Superroute app took 45 seconds just to start up. Similarly, some of the apps were available in the App store, but not in the Google Play store. This led to a lot of frustration among users, who quickly lost their motivation to use the apps in the process''* (Rijkswaterstaat spokesman, interview, 2 December 2016)

6.4.2 PPA ZUIDOOST

6.4.2.1 OVERVIEW AND ANALYSIS

After gaining experience with smartphone applications in PPA in-car, the project partners incorporated the points learned in their design of PPA Zuidoost (see Figure 16), where event traffic was managed in the ArenApoort area during the Pentecost weekend of May 13-15 in 2016. The PPA Zuidoost differentiated from the in-car track of phase 1 by using existing smartphone applications, Flitsmeister and Livecrowd (which will be explained later), instead of developing new apps specifically for the trial. By piggybacking on existing apps that already had a wide user base, the project partners were able to partially overcome previous problems related to a lack of participation (Twynstra Gudde & MuConsult, 2016). Moreover, this was also a way of future-proofing the solution, as one interviewee explained that *''it doesn't matter which application is 'in' or 'out', since all applications can distribute the information in roughly the same way with only a few tweaks''* (Technology company spokesman, interview, 19 December 2016). In other words, by pivoting to this model, the governing parties were able to increase the effectiveness of the exercised power by lowering the resistance thereto, as they could steer clear of the costs and financial risks associated with developing apps, maintaining them and attracting users.

Another difference with phase 1 was that the trial incorporated a greater degree of integration between the in-car applications and the roadside systems. Here, a private consortium established a 'virtual traffic control center' in the Operationeel Mobiliteits Centrum [OMC] Zuidoost (Operational Mobility Center Zuidoost), the traffic management center of the ArenApoort area. Different from phase 1, where a lack of coordination between the governing parties resulted in inconsistencies between the information communicated by the in-car applications and roadside systems, the consortium-led OMC was in charge of both the information presented on the roadside DRIPs and the in-car applications. This increased the communicative effectiveness, since little confusion could arise from incongruent messages by roadside and in-car tools (Van Beek, 2016; AT Osbourne, 2017). In other words: the power to steer traffic became more centralized, since the – previously fragmented – resources to govern traffic of various public and private actors were bundled in the OMC in service of a shared goal. Akin to the previous argument, this is also a form of lowering resistance to power, since the amount of disseminated information that conflicts with the intentions of the road managers is minimized.

Through the open Mobimaestro platform, public road authorities could supply the consortium with a real-time data feed from roadside sensors, as well as status information. This data was supplemented with FCD from the consortium, which the platform subsequently fused in order to create a uniform data flow accessible to all parties involved, which the project partners referred to as the 'common operational picture'. Based on this data, the consortium could request intervention measures from the connected traffic control centers based on the information provided by the MobiMaestro platform. In turn, operators at the traffic control centers would use this advice to operate roadside DRIPs and traffic lights. Likewise, the traffic managers at the OMC were also in charge of providing pre-trip and on-trip information using the Livecrowd and Flitsmeister applications. These will be further described in the following sections. (Van Beek & Van der Vlist, 2016; Twynstra Gudde & MuConsult, 2016; DAT.Mobility, 2016)

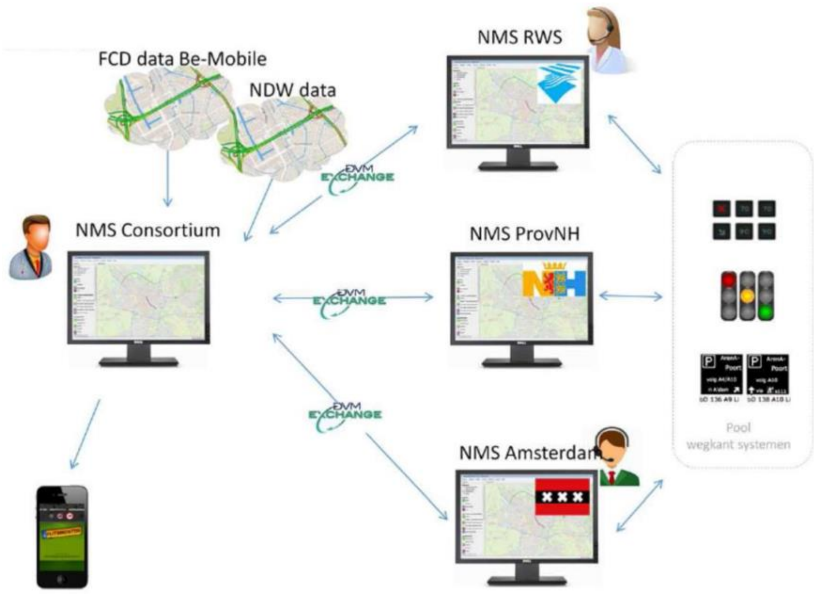

Figure 16: Functional architecture of the PPA Zuidoost trial (Twynstra Gudde & MuConsult, 2016).

6.4.2.2 FLITSMEISTER

With over one million unique users in the Netherlands, Flitsmeister ranks among the country's most popular traffic information applications. Primarily, it is a community platform that crowd-sources information from its users about – among other things - the location of speed cameras, incidents, traffic jams and road conditions. Sequentially, this information is redistributed to other users. For the PPA trial, the app gained a 'virtual DRIP sign' function akin to AM's EVA app, through which users could receive route and parking information. Here, route information was tailored to the driver's location using 'geo-fencing'; a technique applied in telematics where a virtual perimeter is set around a geographical area using GPS data, enabling traffic managers to target drivers in specific areas of the network (XTNT, 2017; Twynstra Gudde, 2017). In service of this function, 10 'choice points' (see Figure 17 below) were established in the area.

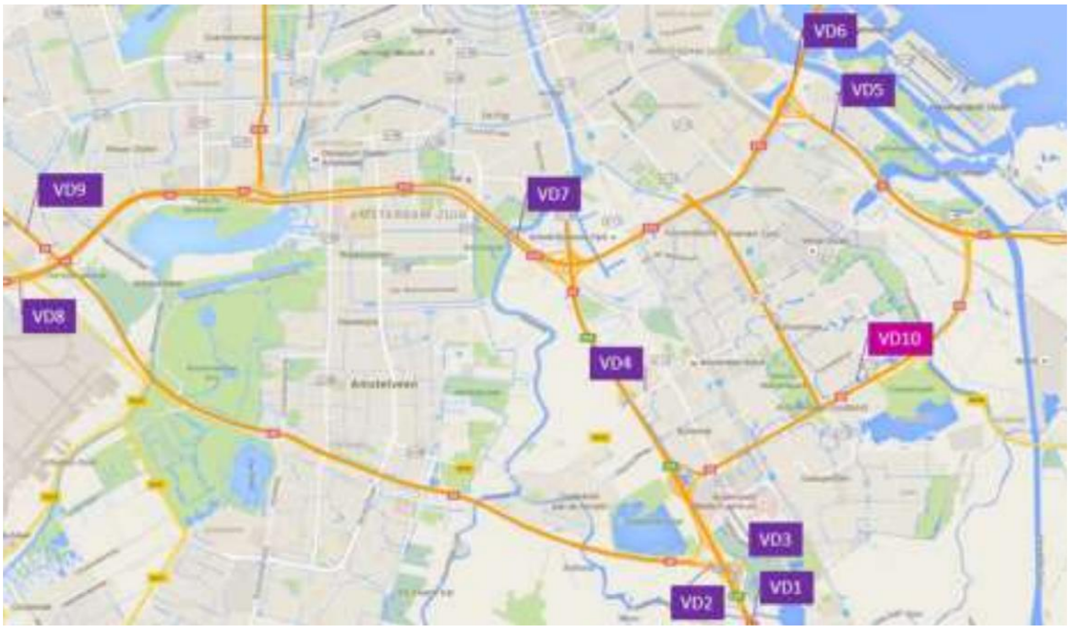

Figure 17: Locations of the 10 choice points in the PPA Zuidoost (Twynstra Gudde & MuConsult, 2016).

When a driver approached one of these points, the virtual DRIP of the Flitsmeister app would suggest an access route to the event site based on his or her current location. Thus, drivers in different parts of the road network would be directed over different routes, leading to a better spread of traffic over the road network and the parking facilities. This can be understood as a technique of segmentation, where drivers are classified based on their location in the network, and receive an advice corresponding to the geographical zone they are in at that particular moment. Moreover, as illustrated by Table 3, this advice could be changed based on so-called ´trigger´ events, which according to one of the interviewees can include ''*a full parking facility, a traffic jam or an incident*'' (Technology company spokesman, interview, 19 December 2016). (Twynstra Gudde & MuConsult, 2016; Van Beek & Van der Vlist, 2016)

Choice point	**Advice - basic**	**Advice - alternative**	**Trigger**
VD1	'Parking Toppers (& Rod Stewart): follow hospital AMC'	'Parking Toppers (& Rod Stewart): follow A9 towards Amersfoort, take exit S112'	Traffic jam formation on S111
VD2	'Parking Toppers (& Rod Stewart): follow hospital AMC'	-	-
VD3	'Parking Toppers (& Rod Stewart): go left'	-	-
VD4	'Parking Toppers (& Rod Stewart): keep to the right, follow P2 to P7. Note: P1 only for reserved tickets'	'Parking Toppers (& Rod Stewart): keep to the right, follow P3 to P7. Note: P1 only for reserved tickets'	Remaining capacity parking locations and queue formation on access routes
VD5	'Parking Toppers (& Rod Stewart): follow A10 towards The Hague, take exit S111'	'Parking Toppers (& Rod Stewart): follow A10 towards The Hague, take exit S112'	Traffic jam formation on S111
VD6	'Parking Toppers (& Rod Stewart): follow A10 towards The Hague, take exit S111'	'Parking Toppers (& Rod Stewart): follow A10 towards The Hague, take exit S112'	Traffic jam formation on S111

VD7	'Parking Toppers (& Rod Stewart): follow A10, take exit S111'	'Parking Toppers (& Rod Stewart): follow A10, take exit S111'	Traffic jam formation on S111
VD8	'Toppers (& Rod Stewart): follow A4'	'Toppers (& Rod Stewart): follow A9'	Traffic jam formation on A4/A10 South
VD9	'Toppers (& Rod Stewart): follow A4'	'Toppers (& Rod Stewart): follow A9'	Traffic jam formation on A4/A10 South
VD10	'Toppers (& Rod Stewart): keep to the right, take exit S111'	'Toppers (& Rod Stewart): keep to the left, take exit S111'	Traffic jam formation on S111

Table 3: Advice provided by the virtual DRIPs (adapted from Twynstra Gudde & MuConsult, 2016)

6.4.2.3 LIVECROWD

Livecrowd (developed by Brand MKRS) is a social media-based application and service profiling itself as ''customer service 3.0'', which can connect with event visitors using Facebook Messenger, WhatsApp and Twitter (which have penetration rates of 76%, 68% and 28% respectively). Different from Flitsmeister, the app formed a bidirectional communication channel between drivers and operators, and personalized route information by allowing users to ask questions related to the event, which included – but was not limited to - the accessibility of the area, parking facilities and routes. In turn, the project partners could provide advice to individual event visitors on subjects such as their departure times, possible routes and available parking facilities through the aforementioned social media channels. Two examples of the information provided by Livecrowd are shown in Figure 18 below. (Van Beek, 2016; Twynstra Gudde & MuConsult, 2016)

Figure 18: Examples of travel advice provided through Livecrowd (Twynstra Gudde & MuConsult, 2016).

Different from the other apps that have been discussed, the Livecrowd app makes little use of techniques of segmentation or automation in the process of providing route information. Instead, it functions more as a direct communication channel between drivers and operators at the OMC, who can provide drivers with information tailored to their specific needs and circumstances.

6.4.2.4 RESULTS AND EVALUATION OF PPA ZUIDOOST

During the trial, the apps functioned alongside the roadside systems, and managed to spread event-related traffic both in time (by suggesting departure times) and space (by advising routes). In this way, drivers were presented with consistent and compatible information from both in-car and roadside devices. Through Flitsmeister, 27,728 messages had been sent to drivers, where between 30 and 40 percent stuck to the advised route, amounting to roughly 10,000 cars (Rijkswaterstaat, 2017). With Livecrowd, 64,171 smartphones were reached. Consecutively, the trial was considered to be a success, given that event visitors managed to arrive in time, the system functioned satisfactorily and users that followed the advised routes were more satisfied about the accessibility of the ArenApoort area than visitors that did not receive an advice or ignored it (Provincie Noord-Holland, 2016). However, while the trial was considered a success, the evaluation report concluded that it was not possible to determine the effect of the trial on the traffic flows, since it was not possible to make a baseline measurement, given that the trial was conducted under exceptional circumstances: the Pentecost weekend, rush hours and several coinciding events (Twynstra Gudde & MuConsult, 2016).

Based on the experiences of PPA Zuidoost, the project managers are looking to introduce 'proactive advising' and automation of the scenario triggers based on FCD and social media (Twynstra Gudde & MuConsult, 2016; AT Osbourne, 2017), which would comprise a move towards more algorithmic steering of drivers.

6.5 NEW FORMS OF PUBLIC-PRIVATE COOPERATION: NEOLIBERAL GOVERNMENTALITY

Next to testing the GNV concept and integrating it with in-car applications, the goal of the PPA is to pave the way for greater public-private collaboration in the field of traffic management, where - as illustrated in Figure 19 - the project partners jointly explore if some functions of operational traffic management can be delegated to the market (Praktijkproef Amsterdam, 2016a).

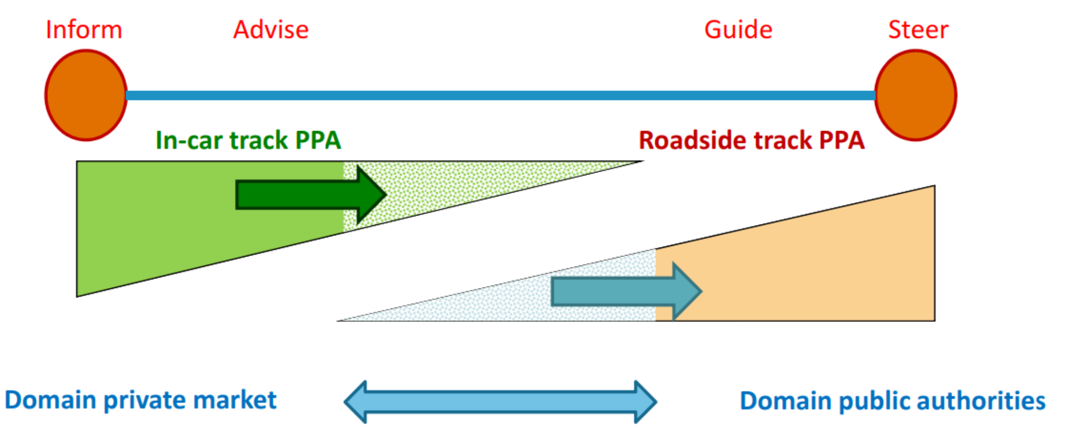

Figure 19: Vision for the PPA, with changing roles for the government and the market (Adams, n.d.).

This was particularly the case in PPA Zuidoost, where the project partners strived to work on an equal footing, abandoning the commissioner-contractor relation employed in the other PPA trials in favor of a more collaborative structure between the market consortia and the public road authorities (AT Osbourne, 2017). Under the mantra of 'Traffic Management as a Service' – a variation on the better known concept of 'Mobility as a Service' - the consortium was allowed to partially take over the wheel from the traffic control centers in the area, testing the waters and potentially paving the way for the delegation of some operational traffic management tasks to the market (Van Beek, 2016; Van Beek & Van der Vlist, 2016). Following the experiment, the 'clients' – being the public road managers – could decide on the extent to which they wanted to outsource operational traffic management tasks to private service providers (Twynstra Gudde & MuConsult, 2016).

After the PPA Zuidoost trial was completed, it was deemed to be a success, as the evaluation report of phase 2 by AT Osbourne (2017, p. 7) states: *''PPA Zuidoost is proof that delivering private traffic management services is possible. Therefore, the knowledge and experience gained in Southeast can and will be applied and further developed in similar situations and areas, such as the iCentrale''.* This can be interpreted as a move towards neoliberal governmentality, where the domain of the market is extended into some aspects of the public realm. Here, formerly public tasks related to traffic management are subjected to the logic of the market, where the actions of public road managers are scrutinized in terms of cost-effectiveness, and compared to the services provided by private actors. The underlying rationality here is one of efficiency, since the research question of the project can be reformulated as: can private actors direct the behavior of drivers in such a way that the capacity of the road network is optimized, and achieve this result against lower costs than public road managers?

Even though the project evaluations describe the PPA projects as laying the foundations for public-private co-creation (AT Osbourne, 2017; Twynstra Gudde & MuConsult, 2016), there are a few peculiar observations that can be made. Similar to phase 1, most of the market parties involved in the trial indicated that they could not find opportunities for viable business cases. Prior to the trial, 8 out of the 12 market teams that showed interest in participating in the trial did not submit a proposal due to this reason (Twynstra Gudde & MuConsult, 2016). Strikingly, even an interviewee belonging to the consortium that conducted the trial described current prospects for business models as being *''hopeless''* (Technology company spokesman, interview, 19 December 2016). The consortium indicated that they were only prepared to participate in a follow-up project if they received a financial compensation; an option that has thus far been off the table for the public project partners (AT Osbourne, 2017; Twynstra Gudde & MuConsult, 2016)

This observation calls into question the previously formulated claims of authors such as Hollands (2015) and Schaffers et al. (2011) that the marketization of traffic management is mainly vendor driven (Hollands, 2015; Schaffers et al., 2011), a result of external pressure from the market on governments. Of course, this claim is valid to some extent, as one of the interviewees from the PPA consortium notes:

''The reason why we participate is to show our solution works, and fuel a discussion – the real discussion, of: who is going to pay for the service? Moreover, it is part of our sales efforts, where we can show that we can change traffic management for the better using products that are already available on the market.'' (Technology company spokesman, interview, 19 December 2016)

However, the perceived lack of perspective for viable business cases in combination with the support for public-private cooperation in the BGOW program of the Ministry of I&M (Connekt, 2013) suggests that the public sector is also promulgating the neoliberal vision of transferring some traffic management tasks to private contractors; albeit on strict terms. These strict terms are illustrated by the case of the Digitale Wegbeheerder consortium, which dropped out of the project during the trial preparation phase due to (1) a perceived lack of commitment from the

PPA steering group, (2) a difference in ambition and (3) the absence of a positive vibe (Twynstra Gudde & MuConsult, 2016). One of the consortia members explains:

''They were not flexible at all, and very dogmatic in their approach, having a mindset of: ''this is how we do things''. For example, since we observed that a lot of traffic flows to the ArenApoort area over the A2 highway, we wanted to start informing drivers at the Oudenrijn, but that place falls under the jurisdiction of the traffic control center in Utrecht, which we could not include since it was not a project partner. Similarly, based on our observations at Disneyworld - where they cleverly conjure up a few Mickey Mouses to hold up visitors – we believed that we could achieve a better spread of visitors walking from the ArenA to the parking facilities using food trucks, but we could not get a permit for this. Since we had significant differences in vision and our solution did not meet all the criteria on their checklist, we failed to reach a consensus following one and a half years of negotiations, and we decided to pull the plug on the project.'' (Technology company spokesman, 14 December 2016)

This quote indicates the complexity of the situation: on the one hand, governments are looking to outsource some aspects of traffic management to the market, but on the other hand they set terms that may be strict to such a degree that the formation of viable business cases is impeded. The dominant role of the public road authorities in the process of determining the contents of the trials was also acknowledged by one of the public project partners, as one interviewee stated that *''most of the project goals and success criteria have been defined by the government, which was very much the case in phase 1, and in phase 2 as well – with the exception of PPA Zuidoost, where we consciously tried to involve the market parties''* (Stadsregio Amsterdam spokesman, interview, 6 December 2016). Furthermore, it casts doubt over the notion that public and private partners were on equal footing in the project, where there was perhaps little flexibility in the contents of the trials. This is corroborated by the evaluation report of Twynstra Gudde and MuConsult (2016), in which the private project partners described the collaboration process as a *''one-way street''* (p. 9) where the public partners introduced more demands, conditions and terms over the course of the project, but offered no prospects for the future. In a similar vein, another consortium member claimed that *''in order to realize a viable business case, the government should provide financial support, but they are currently not willing to pay for our services''* (Technology company spokesman, interview, 19 December 2016). This would mean that there is a cul-de-sac where the public sector pursues greater privatization, but is simultaneously not inclined to satisfy the prerequisite provision of financial support.

These findings suggest that different parts of the government are conflicted in relation to the envisioned role for the private sector, as one interviewee notes:

''Within the government, there are multiple camps that have different visions on the possible roles of the public and private sector. Rijkswaterstaat may say something along the lines of: ''it [traffic management] is our task, our raison d'être''. Meanwhile, different governmental bodies, such as provinces and municipalities may say: ''we would like to outsource traffic management completely, and let the market take care of it free of charge''''. (Technology company spokesman, interview, 19 December 2016)

Similarly, other interviewees also noted that some road authorities are reluctant to privatize operational traffic management tasks, while other parts of the government see significant opportunities for cost reduction therein. Thus, the set of institutions that together form the government is both propelling and resisting the shift towards market-based traffic management. This observation seems plausible given that dis-alignment of visions and priorities was also found regarding other aspects of the trial, as one Rijkswaterstaat-affiliated interviewee noted that *''currently, there is a big ongoing discussion between us and the Ministry [of Infrastructure and Environment]: while we are stressing the importance of testing GNV in practice, the Ministry is already preoccupied with automated driving. Here, the Ministry wants us* *to conduct practical trials with self-driving cars, while we first need to assess safety risks, which they find very frustrating''* (Rijkswaterstaat spokesman, interview, 2 December 2016).

In the same way that the government does not speak with one voice, the private sector is also not a singular entity, but consists of a plethora of actors with competing interests. In the PPA projects, this caused some difficulty to achieve collaboration between the business-side project partners, given that some of them were competitors. This was particularly an obstacle in PPA West, where FCD providers were reluctant to share information about the origin and processing methods of their data with the other project partners, as one publicly-affiliated interviewee explains *''given that they are in near-monopolistic positions, they have vested interests in keeping this information to themselves, making them wary of situations where competitor might be listening''* (Stadsregio Amsterdam spokesman, interview, 6 December 2016). For this reason, the interviewees from public road authorities argued that greater transparency is necessary, but recognized that this is difficult to achieve. (AT Osbourne, 2017)

The project evaluation report of PPA Zuidoost outlines two possible scenarios for the future of public-private traffic management. In the first scenario, the public road managers maintain their tasks on the tactical level, and private parties develop business cases for traffic information services. In the second scenario, private parties engage in both operational and tactical traffic management, where they are allowed to steer traffic by operating roadside VRIs, TDIs and matrix signs. (Twynstra Gudde & MuConsult, 2016)

On a final note, although the outcomes of the first two phases suggest that the innovations developed in the PPA can indeed enable more cost-effective traffic management, one may ask how they relate to other societal issues surrounding intelligent transportation systems, such as environmental sustainability, traffic safety and privacy. Townsend (2013) argues that it is uncertain to what extent smart technologies will live up to the promises of securing more efficient, sustainable and livable societies. He poses that efficiency gains often invoke a 'rebound effect', a supply-induced demand where plunging costs spur greater consumption levels. Extending this argument to traffic management, increasing the carrying capacity of the road network and enabling a smoother traffic flow could result in a substitution of people's transport modes in favor of the car. Drawing from economic theory, Rabari and Storper (2014) argue that this happens because there is a pre-existing equilibrium between road capacity - the supply - and their use - the demand - which traffic relapses to. Hence, increasing the road capacity and throughflow by either building more roads or managing their use more efficiently could - quite paradoxically - ultimately result in more vehicles on the road, only exacerbating the problems of congestion and CO_2 emissions. This concern was shared by several interviewees, one stating:

''In traffic and transport theory, we speak of the BREVER-law [a Dutch acronym for the law of conservation of travel times and transportation], which poses that the average time that people reserve for commuting – between 70 and 90 minutes – is not susceptible to change, given that it has remained constant over the last centuries. Hence, when we improve accessibility by lowering the 'resistance' of the network, people can travel faster, which has the perverse effect that they will start to live further away and travel over greater distances''. (Stadsregio Amsterdam spokesman, interview, 6 December 2016)

A study by Wismans et al. (2009) also points out that lowering congestion and emissions by facilitating a better flow of traffic is largely at odds with the objectives of reducing noise and improving safety.

In a similar vein, a few interviewees voiced concerns over road safety and the stability of the network, given that *''as you exploit more of the network's limited capacity, its resilience is lowered''* (Rijkswaterstaat spokesman, interview, 28 November 2016). One interviewee even went as far as stating *''I'm starting to wonder if one, in light of safety and livability, should even attempt to manage traffic in a network as saturated as that of the Netherlands''* (Rijkswaterstaat spokesman, interview, 2 December 2016).

In spite of these observations, the general opinion was that the solutions developed in the PPA were beneficial and necessary, as *''there never is one panacea to a problem; you always need a palette of several solutions to tackle it. Here, the government has to collaborate with businesses and scientists, who can together realize less toxic asphalt, low-carbon cars and better public transport facilities, which are all part of the solution''* (Consultancy company spokesman, interview, 8 December 2016). Another interviewee argued that *''the measure we implement improves the network throughflow, which directly translates to lower CO2 emissions, and any development that supersedes this is beyond our scope. Quite possibly, the growth we create will be negated over the next two years. But does that mean we should not pursue this solution? No, because the extra capacity is still there''* (Rijkswaterstaat spokesman, interview, 28 November 2016).

6.6 CONCLUSION

In sum, the common theme or key rationale of the PPA projects is cost-effectiveness: curbing the economic costs of congestion by maximizing the network throughflow, and realizing this against the lowest possible costs. The 'optimizing use' rhetoric has proven to be a powerful rhetorical device to mobilize the support of public road authorities, the private sector and motorists alike, to whom it offers the prospects of cost-reduction, new businesses opportunities to be seized, and less congestion.

The PPA projects discussed in this chapter have illustrated several changes in the way in which power is exercised in traffic management. In the PPA, the roadside systems are transforming from being fixed, fragmented, reactive and semi-automated in nature towards dynamic, coordinated, predictive and fully automated systems. This has been made possible by capitalizing on state-of-the-art software, new types of traffic data and GNV models. In this study, these developments are understood as a shift towards algorithmic governmentality, where some of the authority to govern traffic is transmitted to software. Here, roadside systems do not only exert disciplinary power, but also function as mechanisms of control, aiming to confine the values of certain network performance indicators (e.g. traffic density, speed, flow) within certain limits.

Next to the innovations in steering traffic using roadside mechanisms, the PPA has also explored the use of in-car technologies to influence traffic flows. While the discussed in-car apps also make use of automated steering and control mechanisms, an important distinction is that they make use personalization and segmentation to govern traffic, where they use the location or personal preferences of drivers to generate a tailored route advice. Here, the apps deployed in the context of the PPA were unique in the sense that they attempted to balance the individual optimum with the collective optimum. Moreover, as illustrated by ADAM and Livecrowd, in-car apps enable new forms of communication between drivers and operators at traffic control centers. In the PPA trials, individual motorists could request information related to their route from operators at the traffic control center. In turn, operators could request information from motorists, or provided targeted messages to drivers in certain areas.

Last, it is widely believed that private actors will gain a more prominent role within traffic management in the future. Following a positive verdict of 'traffic management as a service' in PPA Zuidoost, public road authorities are now planning to experiment more with outsourcing some of their tasks to private contractors. However, the degree of privatization is uncertain due to significant differences in vision between public authorities on what should be outsourced. Moreover, contractors are currently lacking in viable business cases, and are in disagreement with public road authorities over what their revenue models should look like, as many prefer a business-to-government model over a business-to-business or business-to-consumer model.

7. CONCLUSIONS AND RECOMMENDATIONS

This thesis has posed the following research question: *''How do smart technologies transform the power relations in the governance of road traffic in the Netherlands?''*. It has attempted to answer this question by dissecting it in four subquestions, which will be discussed in the sections 7.1-7.4 below. In this way, it ramps up to the overarching conclusion about transforming power relations in paragraph 7.5. Last, paragraph 7.6 gives several recommendations for further research.

7.1 THE POLITICAL RATIONALITY BEHIND SMART TRAFFIC MANAGEMENT

Primarily, the 'smart' discourse surrounding traffic management seems to have gained momentum in the Netherlands during a time of austerity. In pursuit of more cost-effective traffic management, the national government has opted for optimization rather than expansion of the network capacity (building more roads) or reducing demand (by introducing road pricing). Here, the emphasis of public authorities seems to lie on maximizing the efficiency of the network, since the collected types of data and the metrics used to gauge network performance (e.g. traffic density, lost vehicle hours) seem to be centered around throughflow, instead of, for example, emissions or safety. This observation is corroborated by the PPA case (which also has optimizing the throughflow as its primary objective) and the BGOW and BB programs, where minister of Infrastructure and Environment Melanie Schultz van Haegen particularly stressed the economic benefits of optimizing the network throughflow using smart technologies. As such, the key rationality of smart traffic management is optimizing the network throughflow, which is perceived to be synonymous with economic opportunities.

7.2 MAKING THE MOTORIST KNOWABLE

Since the Foucauldian worldview presupposes that government (i.e. the exercise of power) is only possible by leveraging knowledge, this thesis has taken the developments in traffic surveillance methods as its vantage point for the analysis of the functioning of power. As the automobile gained momentum as a ubiquitous mode of transportation and roads became more crowded, a growing need emerged among public authorities to gauge the performance of the road network and manage traffic flows, in order to mitigate negative externalities of motorized transportation, such as congestion, safety issues and emissions. Hence, the growth of traffic management into an independent discipline over the last decades has been accompanied by the large-scale rollout of a growing variety of roadside surveillance tools, such as vehicle detection loops, (ANPR) cameras, Bluetooth sensors, radar and LIDAR. Parallel to this trend, Floating Car Data [FCD] has recently sparked wide interest among traffic managers. Contrasting roadside sensors - stationary objects which are only able to provide data about a single point in the road network - the mobilization of mobile devices as instruments of data collection theoretically allows the gaze of traffic managers to stretch to any part of the network, thus cloaking it with a seamless web of surveillance. While FCD cannot (yet) fully replace roadside sensors, many expect that (x)FCD will play a greater role in the future, and will render part of the roadside sensing infrastructure obsolete. This development is understood as a move from the modernistic 'disciplinary society' – characterized by enclosed, fixed spaces – towards a Deleuzian 'society of control', which adheres to an open, fluid and networked model. Here, surveillance is no longer just a localized activity (e.g. a highway detection loop that registers the passing of a vehicle), but becomes flexible and near-omnipresent in nature, where vehicles themselves become moving sensors producing a continuous stream of real-time traffic data.

Responding to the deployment of new traffic surveillance technologies and growing volumes of traffic data, road authorities have reorganized some of their data collection, storage and analysis activities in effort to improve the quality and accessibility of traffic data. This development has been referred to as 'professionalization', indicative of a shift from a technology-driven management model towards a more scientific, data-driven model, setting in motion a process of continuous optimization of traffic flows. An important milestone herein was the establishment of a national data bank for traffic information – the NDW – in 2007, signifying a centralization of data collection, processing, storage and analysis. Thus, the first two stages of Rouvroy's stages of algorithmic governmentality are satisfied; 'the collection of big data and the constitution of data warehouses' and 'data processing and knowledge production'.

As indicated in the first chapter, the practices of data collection and analysis in smart cities are inherently linked to privacy concerns. With the growing body of roadside and mobile sensors sending real-time data to the cloud, the establishment of large databases for traffic data and new possibilities in the area of big data analytics, the field of traffic management is no stranger to this debate. Already, there have been several controversies with ANPR cameras in the past, where the national police, several municipalities and the Dutch Tax and Customs Administration violated the privacy rights of motorists by illegitimately using, monitoring and storing their data. Furthermore, road users generally have no means of opting-out of being monitored, thus having to trust public authorities to handle their data responsibly. Attempting to lay such privacy concerns to rest, Dutch traffic managers are now implementing a privacy-by-design approach, where traffic data is aggregated and stripped of as much personally-identifying information as possible in order to protect the identity of drivers. However, given that there are ample examples of 'de-anonymization' through the cross-referencing of multiple datasets, it has been argued that complete anonymization is near-impossible. Hence, along the road towards 'smart' traffic management and intelligent transportation systems, attention should be paid to the means of protecting sensitive personal information.

7.3 HOW MOTORISTS ARE GOVERNED

Much like the means of knowledge production are in a process of transformation, the composition, nature and application of the tools to govern traffic are changing as well. Notably, new technologies have allowed for the centralization of governing. In traffic management, policemen, bridge operators and tunnel operators were largely sidelined by automated systems (e.g. VRIs) and the emergence of control rooms, which allowed for managing from a distance. Moreover, road authorities – each responsible for a different part of the road network – are increasingly cooperating and attempting to manage traffic beyond their administrative borders. Similarly, local traffic management systems are increasingly connected to the cloud and influencing traffic with other parts of the network in mind, a development referred to as 'network-wide traffic management (GNV). In turn, this centralization has made traffic management more cost-effective.

In tandem with centralization, automation has been identified as a development altering how traffic is governed, giving more agency to algorithms. This is understood as a move towards algorithmic governmentality. Increasingly, manual tasks are automated, since computers are more capable of processing the dizzyingly large quantities of data produced by the vast arrays of sensors on the Dutch roads. More than merely reducing manual labor, automation fundamentally alters the nature of traffic management, shifting it from reactive to predictive. This is interpreted as the third and final step of Rouvroy's stages of algorithmic governmentality, where computers act on a combination of historic and real-time data in order to pre-empt undesired events that could happen in the (near) future.

Finally, over the last two decades, mobile in-car information systems have emerged as additional tools to inform and direct traffic flows. In contrast to roadside systems (e.g. DRIPs) aimed at informing drivers, in-car devices are capable of reaching drivers at any point during their trip, allowing for a greater degree of control over their behavior. Furthermore, these devices allow for a greater degree of personalization of the information provided, which, in turn, presumably increases the effectiveness of the information communicated to motorists.

In sum, new 'smart', data-driven technologies have facilitated more cost-effective traffic management through techniques of centralization, automation, prediction and personalization; techniques that are currently implemented in all facets of the smart city, including education policing, and energy, water, waste, and ICT networks. Now, traffic managers are attempting to create a cohesive, integrated system out of the ensemble of roadside systems and in-car devices in order to bring them one step closer to the smart mobility telos they have envisioned: a future characterized by automated cars, connected infrastructure and self-contained algorithms that monitor and predict the situation on the road and implement consecutive measures. Yet, it remains unclear what the growing digitalization and automation will mean for issues such as cyber-security and accountability. First, when cars and roadside infrastructure are connected to the cloud in order to be controlled from a distance, they could become more vulnerable to actors with malicious intentions. Moreover, since the instruments of traffic management grow ever more complex, it seems reasonable to assume that the number of people able to grasp their functioning will decrease. What will the implications be of a situation where the technologies and algorithms that govern us become not only indecipherable to motorists, but also evolve to be so convoluted that even some of the agents tasked with managing them do not fully understand them? Who will be accountable for glitches or other instances of technical malfunctioning?

7.4 SHIFTING PUBLIC-PRIVATE ROLES

For long, public road authorities had a monopoly on the government of traffic flows, and were responsible for both informing and steering traffic. In recent years, this monopoly has been challenged, particularly due to the rise of new technologies and austerity measures. Starting with the commercialization of traffic information, private actors have gained a larger role within traffic management. Navigation systems (and later smartphones) significantly disrupted the existing way of managing traffic, as the information they provided often conflicted with the interests of public road authorities. In order to resolve such conflicts, public actors have stressed the necessity of closer collaboration between public actors and the private sector. However, it remains uncertain how their roles will develop in the future. Although the BGOW program encourages public-private governance and the Praktijkproef Amsterdam has experimented with new roles for private consortia, this study found that there is disagreement on (1) the roles market actors should have and (2) what their business models should look like. First, within the public realm, there are different visions on the degree to which traffic management tasks should be outsourced. While most levels of government are in favor of outsourcing traffic management (viewing it as an opportunity to externalize the associated costs), some public road authorities (notably Rijkswaterstaat) are reluctant of this. Second, this study has found that most private contractors have failed to identify viable business cases within the conditions stipulated by public road authorities. Therefore, they are in favor of a business-to-government model, also referred to as 'traffic management as a service'. However, this option has thus far not been on the table for most public actors, since they are more in favor of business-to-business and business-to-consumer models. Hence, this finding casts doubt on the hypothesis found in the smart city literature that the privatization of urban services is mainly vendor-driven, as the findings presented in this study suggest that public authorities are also driving this development – albeit under strict conditions – since it could allow them to externalize some of the costs of traffic management and make it more cost-effective.

In light of these findings, one may ask what the role of the private sector will be in the future. Although the findings presented seem to suggest that the shifts in public-private power relations are slow and have remained modest, there is reason to believe that this might change in the future. Evidently, TomTom, Google, Apple, Uber and most traditional car manufacturers have already amassed multi-billion dollar investments in autonomous vehicles. When these vehicles become widely adopted by consumers, they will likely render traditional traffic management infrastructure (e.g. traffic lights) obsolete, and with it the agency of public traffic operators. In this scenario, it could be that these corporations become fully responsible for the functioning of the system. On a similar note, if data is indeed the raw material of traffic management, the 'oil of the 21st century' that will fuel the voracious swarm of connected vehicles, the suppliers of this data could soon find themselves in very powerful positions. Therefore, several market actors are now collecting traffic data on a massive scale, and are eagerly investing in expertise to exploit the potential of this data. Consider TomTom: being faced with year-on-year decline in sales of its navigation devices, the company is now pivoting towards revenue models based on the provision of traffic data and services related to big data analytics. In turn, it aims to use its data capture and analysis assets to develop particular products that provide invaluable information to city governments. In the long run, this could possibly create a dependency between these public actors and the commercial service providers, giving these companies a foot in the door in the city governance process.

7.5 FINAL NOTES ON POWER RELATIONS

Based on the findings presented in this study, what can be said about the ways in which power relations are being transformed within traffic management? Altogether, a few developments stand out, which are discussed using Foucault's 5-point framework to analyze power relations: the means of bringing power relations into being, the system of differentiations, the types of objectives, the forms of institutionalization and the degree of rationalization.

First, one can assert changes in the *means through which power relations are brought into being*. Using a growing number and variety of mobile and stationary sensors, the previously fragmented surveillance gaze is becoming near omni-present, making the state of the road network increasingly transparent to traffic managers. Stored in a central databank (the NDW), these growing volumes of data are intrinsically linked to greater degrees of automation. Unable to adequately process such quantities of information due to limitations in their cognitive abilities, traffic managers delegate some of their agency to software, which – using weighting mechanisms and other ingrained rules (i.e. algorithms) – can, at least theoretically, calculate the optimal course of action with respect to the set targets and boundary conditions . Likewise, by leveraging the growing volumes of data, connecting roadside infrastructure to the cloud and retrofitting it with new algorithms, the nature of TDIs, VRIs and other pieces of infrastructure is fundamentally altered: previously functioning as local, standalone units, these instruments of traffic management are increasingly deployed coherently in pursuit of goals on the regional (and even national) level; a development referred to as coordinated network-wide traffic management. Alongside these innovations in roadside infrastructure, in-car devices have opened up new horizons for traffic managers. In contrast to roadside systems, these use techniques of personalization, where the advised route is tailored to the real-time location, profile and other requirements set by the individual. Moreover, since these devices accompany drivers along their journey, road authorities are no longer exclusively bound to a limited set of DRIPs to inform traffic, but can (theoretically) reach the motorist at any given point along his trajectory, in turn allowing for greater control over his or her actions.

Furthermore, there are changes in the *system of differentiations*. As traffic management moves towards a data-driven model, the network starts to manage itself using a collection of quantitative performance indicators. Deconstructing and dividualizing the motorist into a limited set of variables, it can gauge the state of the network, make clear binary judgments (yes/no) about the need for intervention and target drivers in specific areas in order to align their behavior with the objectives of government.

The growing data-drivenness of traffic management also impacts the *objectives of government*. As more information is produced about the state of the network, traffic managers become better able to make judgments about its performance level (in terms of efficiency, the objective of government), and subsequently set corresponding targets. Having knowledge about the network's performance level thus allows them to problematize the behavior of motorists, and legitimizes intervention. Moreover, greater amounts of data allow for evaluation and machine learning. By reflecting on historic data, governing agents – ideally – make more informed decisions in the future, thereby augmenting the *degree of rationalization*. In particular, automated systems can compare the current state of the network to past circumstances, allowing them to predict with reasonable degrees of accuracy how a particular scenario will unfold in the near future. Here, the method of governing shifts from mitigation to pre-emption, where traffic managers preventively respond to events that are expected to happen.

With regards to the *forms of institutionalization*, this thesis has examined which actors are involved in the practices of traffic management and what their respective tasks are. Notably, the findings indicate – in line with other publications on smart cities –that private service providers have assumed a greater role in the process of managing traffic over the years, as they are now responsible for informing drivers. Together with various governmental institutions, the market continues to experiment with new organizational constructions and is trusted with new responsibilities in pursuit of a more cost-effective form of traffic management, a model widely referred to as 'traffic management as a service'. However, there are significant differences between and within the 'public' and 'private' camps in the envisioned telos and how it is to be achieved, in turn slowing down the forces of privatization. For this reason, it remains unclear whether the corporatization of city governance predicted by some will become a reality. Nevertheless, the identified developments do suggest a form of neoliberal governmentality where public agents primarily govern on the basis economic motives (cost-effectiveness), in the process of which they delegate some tasks to the market and to drivers. In a similar vein, the relation between drivers and road authorities is changing, particularly under the influence of in-car devices. These devices have granted motorists greater agency in governing their own actions, understood here as a form of responsibilization commonly associated with neoliberal governmentality. Likewise, they can form a bidirectional communication channel between the motorist and the operator in the traffic control room, where both can request and provide specific forms of information.

In sum, amidst the smart traffic management discourse, significant alterations in the relations of power between government, business and consumers appear to be taking place. Looking back on the utopian and dystopian visions of the smart future, both of these prophecies seem to be grounded in valid criticisms of current developments. On the one hand, smarter forms of mobility can potentially empower drivers through safer and faster journeys, benefit governments by mitigating negative economic and environmental externalities and create new opportunities for the market. On the other hand, several controversies have already occurred that are illustrative of cybersecurity risks associated with digitization and the possible function creep of new forms of traffic surveillance into other, less desirable domains. Moreover, concerning smart traffic management, it remains uncertain if optimization of the network capacity and throughflow will also yield environmental and road safety benefits, given that some theoretical models suggest that this may invoke a 'rebound effect' and lower the resilience of such infrastructural networks. Therefore, as has been shown, the process of translating abstract notions of 'smart' from the drawing board to reality has proven to be challenging, since many unexpected hurdles and points of ambiguity arise along the way. This illustrates that the smart future, is anything but a given: instead, it is a highly malleable concept that is continuously rearticulated. We might be unboxing a techno-utopia or pandemonium, but smart cities will likely evolve into something on the continuum in between. Here, our collective decisions as a society will determine towards which of these ends we will navigate.

7.6 RECOMMENDATIONS FOR FURTHER RESEARCH

Responding to the identified lack of case studies and Foucauldian analyses in the smart city literature, this thesis has attempted to contribute to the database of 'actually existing' smart city projects and to interrogate the shifts in governing and power implied by smart urbanism. Though an attempt has been made to provide both a comprehensive overview of the developments in the field of traffic management in the Netherlands and an in-depth discussion of a 'typical' smart traffic management project, this study remains only a snapshot of a field in rapid transformation, and merely scratches the surface of how smart urbanism is taking form in the Netherlands. In order to further advance the understanding of the ways in which the smart city ideal is articulated and what its implications are for governance and power relations, future studies may analyze other smart city cases using a governmentality framework.

Though case studies can be illuminating, adding nuance to some of the generalized claims made in the smart city literature and showing how the smart city concept is interpreted and realized in different ways, there still is ample room for more general studies. First, in light of the perceived inconspicuousness of environmental considerations within traffic management, researchers could take a wider view and further explore the role of environmental sustainability in the field of smart mobility in the Netherlands. Second, during my research, I found that the mobility sector is still facing many unresolved questions related to privacy and data ownership. Researchers - especially those with a background in law - could therefore examine how regulatory bodies on the local, national and international level cope with the collection, storage, analysis and exchange of personal data by smart infrastructures in order to resolve ambiguities in legislation. On a final note, given the fact that multinational corporations such as TomTom, IBM and Google are involved in numerous smart city projects throughout the world, it would be interesting to take a closer look at the role they have in promoting and shaping the smart city ideal on the European or global level.

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APPENDIX A: LIST OF INTERVIEWEES

Date	Function	Organisation	Interview duration
28/11	PPA project manager	Rijkswaterstaat	1:09:10
2/12	PPA project manager	Rijkswaterstaat	1:25:41
6/12	Traffic policy advisor	Stadsregio Amsterdam	36:43
8/12	Traffic management consultant	Consultancy company	1:39:02
14/12	CEO	Technology company	1:14:10
14/12	Traffic management advisor	Amsterdam municipality	1:04:35
14/12	Traffic management advisor	Amsterdam municipality	40:39
15/12	Project manager	NDW	47:54
19/12	Program manager	Technology company	1:16:09
5/1	Traffic management advisor	Connecting Mobility	1:05:41
24/1	Business developer	Service company	49:35

APPENDIX B: OVERVIEW OF TRAFFIC MANAGEMENT IN THE NETHERLANDS

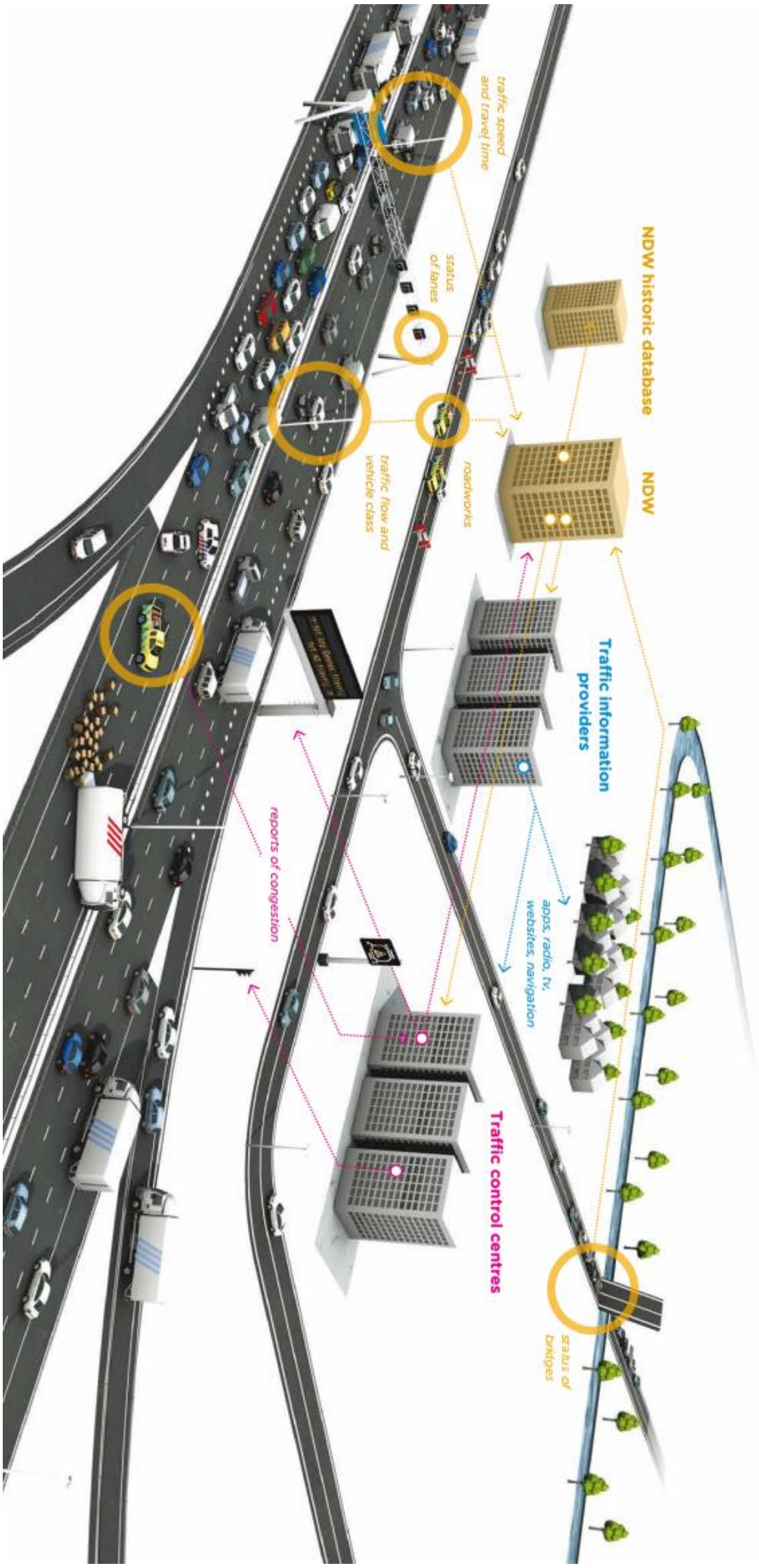

Figure: overview of traffic management in the Netherlands (NDW, 2016)

APPENDIX C: PPA ROADSIDE SYSTEM ARCHITECTURE

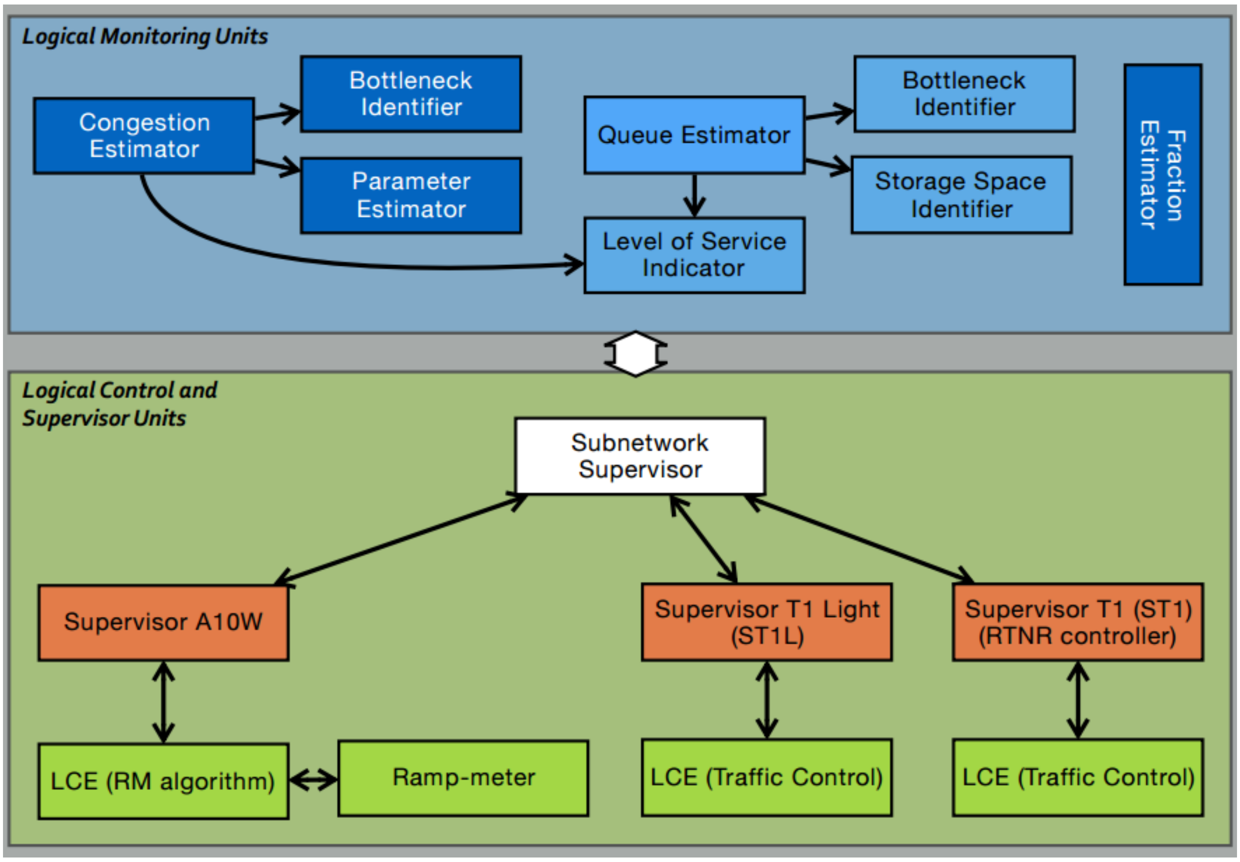

Figure: schematic overview of the monitoring and control functions in PPA Roadside (Hoogendoorn, 2016)

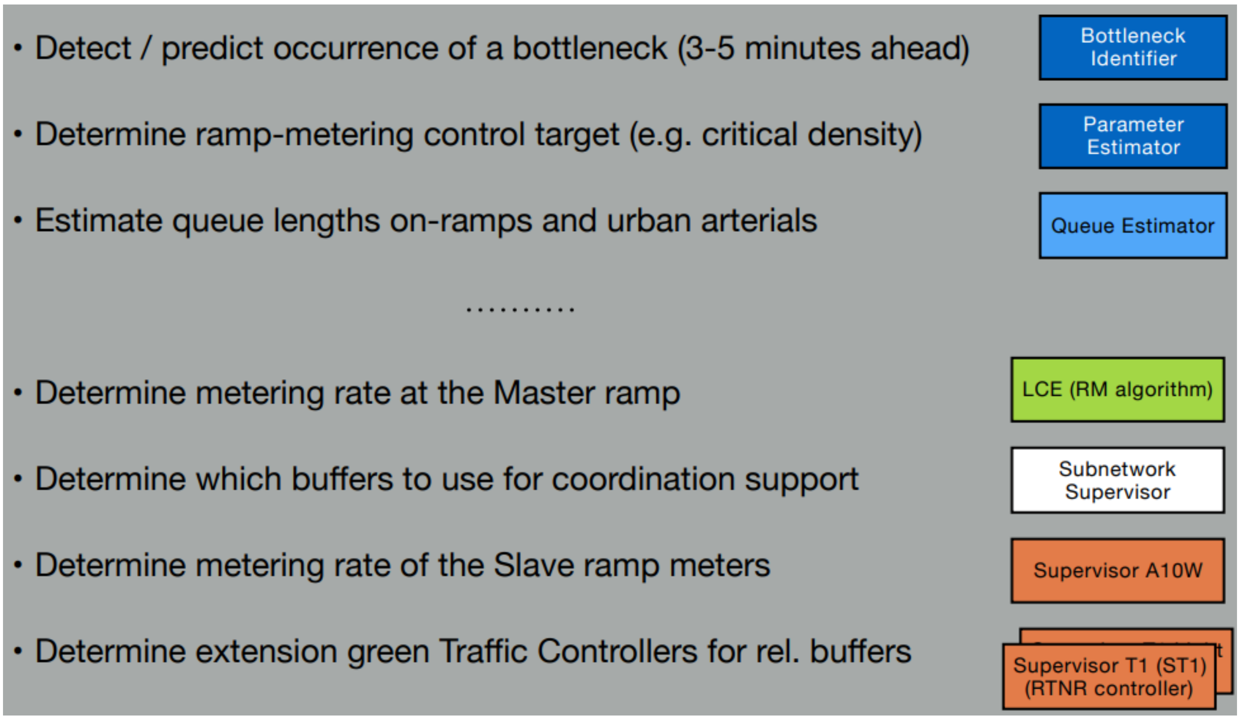

Figure: schematic overview of the monitoring and control functions in PPA Roadside (Hoogendoorn, 2016)