MASTER THESIS| QI AN

FRAMEWORK FOR DETERMINING IMPACTS OF MALFUNCTIONING OF DTM SYSTEMS ON TRAFFIC FLOW:

DEVELOPMENT AND A CASE STUDY FOR THE AMSTERDAM REGION

10TH MARCH 2020

15:00-16:00 (CT-COLLEGEZAAL C)

TU Delft
Delft University of Technology

Rijkswaterstaat
Ministry of Infrastructure and the Environment

Framework for Determining Impacts of Malfunctioning of DTM Systems on Traffic Flow:

Development and a Case Study for the Amsterdam Region

Master Thesis

Delft University of Technology

By

Qi An

To obtain the degree of Master of Science in Civil Engineering
at the Delft University of Technology,
to be defended publicly on 10th March 2020

Composition of Assessment Committee

Prof. Dr. Ir. J.W.C. Hans van Lint	TU Delft, Committee Chair
Prof. Dr. Ir. Serge. P. Hoogendoorn	TU Delft, Supervisor
Dr. Ir. Simeon C. Calvert	TU Delft, Daily Supervisor
Dr. Ir. Henk. Taale	TU Delft, Daily Supervisor
Ir. Martine van den Boomen	TU Delft, External Supervisor
Ing. Zlatan Muhurdarevic MSc	Rijkswaterstaat, Thesis Supporter

This thesis is cooperated by the Department of Transport & Planning (T&P) at the Delft University of Technology (TU Delft) and the Department of Major Projects & Maintenance (GPO) in Rijkswaterstaat, Ministry of Infrastructure and the Environment, under the project of "P-IHP-DVM-II".

TU Delft Delft University of Technology

Rijkswaterstaat
Ministerie van Infrastructuur en Milieu

Abstract

Dynamic traffic management (DTM) plays an important role from Dutch policy perspective to prevent road congestion and has been developed from control strategies to services. Five traffic control centers, 22 different DTM systems with 35 functions and over 50,000 DTM components make up the national traffic management network in the Netherlands. For years, the effects of these DTM systems have been intensively evaluated. It was estimated that around 25% of the congestion growth was reduced from 1996 to 2005 by the implementation of the DTM systems. Since the malfunctioning of the DTM systems is expected to create negative impacts to the traffic, proper maintenance planning is necessary to ensure their availabilities. However, there is less knowledge about the malfunction effects of these DTM systems, which makes it difficult to monetize the effects resulting from DTM malfunctions and therefore to optimally deploy the maintenance budget. Rijkswaterstaat initiated a project named "P-IHP-DVM" to link the function availability of the DTM systems and the maintenance costs. In the first phase of the project, a static queuing model is used to calculate the additional vehicle lost hours introduced by DTM malfunctions, which neglected the route choice behavior of road users in response to the malfunctions, and therefore overestimated the malfunction effects. Also, it is impossible in a static queueing model to know the impacts on other motorway parts. Therefore, a macroscopic dynamic traffic assignment model "MARPLE" is used in the second phase of the "P-IHP-DVM" project, through which relationships among failure function, failure duration, failure location and the associated social costs were built up.

The motorway network around Amsterdam is chosen as the study area in this research, and four DTM systems or measures were evaluated, including the rush hour lane (RHL), the motorway traffic management (MTM) system, the dynamic route information panels (DRIPs) and the ramp metering (RM) system. By conversing the DTM malfunctions into the motorway network, the introduced impacts to the traffic flow both in local and network levels were identified. A methodology is developed in this research to connect the malfunction impacts with the social costs according to the failure function type, the failure duration and the failure location. Varied among different locations, a five-hour malfunction of the RHL are estimated to cost from 936 to 22,069 euros; a five-hour malfunction of the MTM signaling could cost from 323 to 23,438 euros; the malfunction of DRIPs (function of indicating the route travel time) was estimated to produce no cost; while the function of rerouting can cost up to 453 euros per hour; and the costs of the RM malfunctions for 5.5 hours were estimated to produce from 1,011 to 28,710 euros.

This research made the first attempt to modify DTM malfunctions in a macroscopic dynamic traffic assignment model, and a methodology was developed to calculate the malfunction costs both in traffic flow and safety aspects. The outcome of this research answered what-if questions with regarding to DTM malfunctions, it also proved the feasibility of the ambition to translate the DTM malfunction impacts at a network level into its social costs, according to which the maintenance strategy for the DTM systems can be better deployed.

Since there is no prior or parallel study available to provide reference values, and as this project involves multidisciplinary science including risk-based maintenance, asset management, traffic flow science, traffic safety, traffic economics and et cetera, it is hard to calibrate the outcomes at current phase within the scope of this research. Expert judgements are necessary before the products of this research being used in practice.

Overall, the initial goal of calculating the malfunction costs of the DTM systems with a newly developed methodology is met. Through the identified limitations and improvement strategies, the framework developed in this study could offer the possibility to refine the analysis, and/or easily be applied to other DTM systems and road parts.

Key word: Risk-based maintenance, DTM systems, MARPLE, Function failure, Social costs

Preface

Every attempt was worth the effort, when something useful was created. Maybe it is not good enough, at least we made the first step from nothing. The past nine months witnessed the transformation of me from a fresh "master student" who just finished several theoretical courses, to a "master engineer" who can apply the theoretical knowledge into practical implementations.

This transformation process could not be achieved without the tremendous support and help from all my committee supervisors, and here I want to express my sincere gratitude to you all. Henk, we almost meet every week, not only in Delft, but also in Rijswijk. You did not tell me to use Marple in this study, and I did not know you are the farther of Marple when it was chosen, what a coincidence you are one of my daily supervisors! Though "fresh" problems from OmniTRANS and Marple occur over and over again at the beginning, you gave great patience and inspiration, and finally I can apply Marple smartly beyond the content of the manual, it seems that we can attempt to broaden the manual somehow afterwards! Simeon, expect for academic issues, we also talked a lot in other aspects, including my first experience presenting in front of RWS colleagues, self-introduction in Dutch, my first half marathon in Amsterdam, and even my "burning-out" feeling in late November, I always feel encouraged after talking with you, you gave me much confidence to succeed in the upcoming "bottlenecks".

Prof. Hans van Lint, I really appreciate your participation at the final phase of my thesis project, though we only had two short meetings after the green light, your unique insights on the effects of these DTM systems provide me new scopes to rethink about the contributions and limitations of this research, which helps me to deliver this report in a more scientific way. Prof. Serge Hoogendoorn, having you as the promotor has been a great pleasure to initiate this project in a good direction, it is a pity that you could not attend the final thesis defense due to illness, my best wishes for your quick return to good health and see you soon later!

Martine, though we seldom have chance to talk in person, you gave me helpful suggestions to better structure the report, your fast response every time and always positive attitude towards my product gives me more strength to complete the project to a higher quality. It is a pleasure that we will both make our "big" day in March of 2020, I hope everything well for your doctoral defense, and with my great congratulations in advance!

Zlatan, we spent a lot of office time together in Rotterdam. You are the person who introduced me about the Dutch office culture, taught me how to look up Dutch documents, and encouraged me to be active to inquire suggestions and comments from external experts. Though sometimes your practical "ambition" would fight with the academic requirements, which leaves me a challenge to integrate the practical and academic perspectives. Finally we have a product for the POC, and it proves that the methodology we developed is feasible to be further studied and be implemented in practice! Hans van Knotsenburg, I am always happy to work with you, we talked a lot to develop and improve this product to a more robust application at the next phase, I believe that we are at the right position to go forward!

I also want to extend my deep appreciation to Jurgen Koppen (GPO), Jan Helmer (WVL), Rudi Kraaijeveld (WVL), Jon Otten (NIS), Nick Dohmen (VWM) and Wim Wijnen (W2Economics), thanks you all for providing information and valuable comments to this project!

Qi An
29th February 2020, Delft

Contents

List of Tables

Appendix A

Appendix B

Appendix D

Appendix E

Appendix F

Appendix G

Appendix H

List of Figures

1. Introduction

1.1 Research Background

Transportation networks especially the motorway network play a crucial role in supporting economic growth all over the world. It has been widely recognized that the upward trend of personal travel expenditure and worldwide population leads to the growth in travel demand. It is also noted that the increasing travel expenditure mainly takes place on car transport **(Gunn, 1981)**, which induces the problem of increasing congestion on the road.

The congestion contributes to longer travel times and less travel time reliabilities, unexpected delays arise the lost in social-economic efficiency, which are often quantified into monetary units **(KiM, 2013)**. To improve the service quality for the road traffic and social-economic efficiency, congestions should be controlled and limited by road agencies. There are generally three strategies to ease the congestion including road expansion, tolling and traffic management **(Calvert, 2016)**. The expansion of road network often involves huge investment costs, and it is a limited solution due to resource and space availabilities. The introduction of the tolling restricts the entry of vehicles into the network, through which the traffic can be eased. However, there are often political and technical difficulties when implementing pricing for the road system **(Taale, 2009)**. With regarding to the constricts and the feasibility of road expansion and tolling, traffic management has become a more favorable option for transport authorities since the end of 20th century.

Dynamic traffic management (DTM) has become an important part in Dutch policy perspective to ease the negative impacts brought by the growing travel demand since 1990 **(Taale & Middelham, 2000)**, and the traffic management was estimated to reduce 25% of the congestion increase during the period from 1996 to 2005 **(MinVenW, 2008)**. In the Netherlands, around 2,500 kilometers' motorway network is managed and maintained by Rijkswaterstaat. Five traffic control centers, 22 different traffic management systems with 35 functions and over 50,000 DTM components are involved in Dutch motorway network. Rijkswaterstaat operates and manages the traffic via these systems with an annual maintenance budget of around 58 million euros **(Muhurdarevic, 2016)**. Maintenance strategies including corrective maintenance (CM) and preventive maintenance (PM) for these DTM systems are currently in practice by the GPO (*Grote Projecten en Onderhoud*) division of Rijkswaterstaat. Corrective maintenance refers to maintenance tasks performed when the failure in function or system is detected, while preventive maintenance involves regular and periodical maintenance tasks to be conducted. As PM tasks are generally more frequently planned and are often conducted before the failure has been detected, it requires higher maintenance costs compared with CM strategy. However, the "expensive" PM strategy contributes to less unanticipated failures, by which the reliability is pursued and the travel time lost can be saved. A good maintenance plan should make its budget optimally deployed under the premise of ensuring the reliability of each system function within an acceptable level of risks.

As the maintenance on these DTM instruments involves such great amount of investment, improvements on assets management according to system performance and risk analysis are essential to be utilized, in order to reach the optimal balance between performance, risks and costs. The reliability of function availability is greatly influenced by the frequency and quality of system maintenance tasks, which are then affected by the budget on its maintenance planning. Enough maintenance investment should be guaranteed to pursue the system reliability. In the same time, the function availability influences the performance of the traffic managed by these DTM systems, and the affected traffic resulting from the system unavailability would arise the increase in social costs. Previous field evaluations for these DTM systems were often conducted locally, it is difficult to measure the effects to other motorway parts in a larger scale of network. Furthermore, the effects of these DTM systems were evaluated after the implementations, it is unknow how traffic would response to their malfunctions and what would be the costs.

To optimally deploy the maintenance budget for these DTM systems, the ICO (*Instandhouding Constructies en Onderhoud*) department of GPO division wants to build up a relational weighting model between performance, job availability and maintenance costs per function (chain), that can be used for the DTM systems at the whole national network, with the project named in abbreviation of "P-IHP-DVM II (*In Dutch: Prestatiegestuurd Instandhoudingsplan dynamisch verkeersmanagement II*)", the structure of the objective relational model is shown in Figure 1-1, it is expected that the total amount of maintenance costs and societal costs can be minimized.

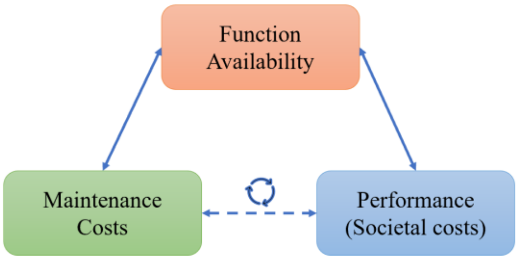


Figure 1-1. Relational weighting model under the project of "P-IHP-DVM II" (Muhurdarevic, 2019*)*

A concept methodology to link the components of the above relational model can be explained by the framework shown in Figure 1-2. A failure probability model is being built to estimate the chance of system malfunctions. By analyzing all components of the DTM systems, interim maintenance plans can be generated with the RCMCost (Reliability Centered Maintenance) analysis. Given a certain interim maintenance strategy (combinations of PM and CM), the number of unforeseen non-availability hours of each system can be determined **(Delta Pi, 2018)**. Through the failure probability model shown in the black dashed frame, the maintenance costs and the malfunction risks can be connected.

Costs of the malfunction risks can be calculated through the performance evaluation model as shown in the red dashed frame. Two aspects of the malfunction impacts might be involved: the impacts to the traffic flow and the impacts to the traffic safety, which make up the total social costs of the DTM malfunction. By implementing the social costs back to the maintenance, the "optimal" maintenance strategy can be derived.

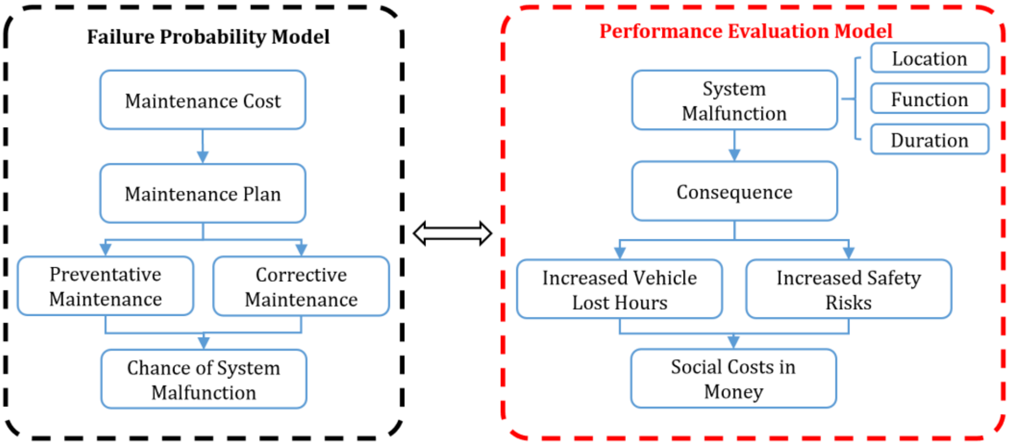


Figure 1-2. Framework for the connection between maintenance cost, risk and performance

1.2 Research Objective

Following the background of the "P-IHP-DVM" project, this research is conducted to build up a model for the performance evaluation, by investigating the relationship between the function availability and the impacts to the traffic, accordingly the societal costs.

In this research, four DTM systems including Motorway Traffic Management (MTM) system, Rush Hour Lanes (RHL), Ramp metering (RM) and Dynamic Route Information Panels (DRIPs) are investigated. It is noted that a system refers to a collection of instrumental components which work together to achieve different functions and applications. Function is one of the properties of the system, one system may contain one or more than one function. System failure and function failure are not distinguished in this research. Either the system failure or function failure mentioned in this report refers to the malfunction at the function level, which assumes that the break-down of one function has no impact to other functions even they are operated in one system.

The function type and the malfunction duration are two important variables that determine the severity level of the malfunction impacts. However, the consequence of the DTM failure would still be varied for the same function with same duration if it happens at different locations (with different demand patterns and physical layout), consequently, it is necessary to put the "location" as an extra control variable to investigate the effects of the DTM malfunctions.

In summary, the objective of this research is to build up a performance evaluation model as shown in Figure 1-2, to **quantify the societal costs introduced by the malfunctioning of four DTM systems** on the motorway operated by Rijkswaterstaat**, according to the function type, the failure duration** and **the failure location.**

The research is expected to provide upstream products to the RCMCost analysis. It helps to link the relation between maintenance planning of the DTM systems and the failure consequences, through which to provide insights into the optimizations of performance, risks and costs for the maintenance planning of the DTM systems.

1.3 Region of Amsterdam

The Dutch motorway network operated and managed by Rijkswaterstaat is classified into four categories, taking administrative boundaries, logical connections and the connection with asset management into consideration (**NIS, 2019**). These categories are shown in Figure 1-3 with different color labels.

- **Red (D).** Rings; crucial links for the circulation of the surrounding road network in the most important urban regions with concentration of main ports;
- **Orange(C).** Connections with high intensities and great importance from a spatial economic policy;
- **Green (B).** Connections with "medium" intensities and importance from a spatial economic policy;
- **Blue (A).** Connections with low intensities and lesser importance from a spatial economic policy.

It is found that the networks are categorized mainly based on intensity levels, as well as political and economic importance. Motorway network in category D is taken as the most critical part, including motorways around four largest Dutch cities in Randstad area (Amsterdam, The Hague, Utrecht, and Rotterdam) and motorway network around the fifth largest city Eindhoven. Among these five regions with motorways in category D surrounded, the motorways at the Amsterdam region shows more complex connections in all four different categories.

The motorway network in Amsterdam region includes **A10** *Ring Road Amsterdam* (D), **A1** *Interchange Watergraafsmeer Amsterdam- German Autobahn BAB 30* (C), **A2** *Interchange*

Amstel Amsterdam - Eijsden Limburg (C), **A5** *Western By-pass Amsterdam* (B), **A8** *Interchange Coenplein Amsterdam-Wormer Zaanstad* (C), **A9** Interchange *Diemen- Ring Alkmaar* (C) and **N200** *Ring Road Amsterdam- Zandvoort* (A). Choosing the motorway network in Amsterdam region as the study area can provide interesting insights into the location difference in severity of malfunction impacts, in terms of the categorization of the motorway.

Figure 1-3. Motorway network categorizations (NIS, 2019)

To specify the range of the study area, the motorway network chosen in this study is limited to the ring road A10 and the six connecting corridors (A1, A2, A4, N200, A5 and A8) to the ring road. The corridor is defined as the motorway section from the interchange on A10 and the next interchange crossing with other motorways, which is shown in Figure 1-4. The defined network is composed of the ring A10 and six connecting corridors, and it is named as "AMS network" for simplicity.

Figure 1-4. Study area of the research (AMS network)

It is noted that the start point of the corridor N200 is beneath the ring road A10, and there is no physical crossing or interchange between N200 and A10. In AMS network, twelve motorway corridors including six connecting corridors and six sub A10 corridors are specified. These A10 sub corridors are mainly separated by the motorway interchanges, for instance, the corridor A10 southwest (SW) refers to the motorway section between the interchanges with A4 and A5.

For the motorway section between interchanges with A8 and A1, two sub corridors A10 (NE) and A10 (NB) are separated at the crossing with S116.

According to the *NIS-Geo Service*, the start & end positions of the defined motorway corridors, and the availability of DTM systems in each corridor are summarized in Table 1-1. Since the MTM signal matrixes are generally placed around every 500 meters of the motorway section, which are used as an integrated signaling system, the specific number of MTM portals in each corridor is not counted.

Table 1-1. Corridor information and DTM availabilities (AMS network)

Location				DTM Availability			
Corridor	**Direction**	**Start**	**End**	**MTM**	**DRIPs**	**TDI**	**RHL**
A1	HRR	A10Re 11.4t & A1Re 4.2	A1 Re7.9	x	1	-	-
	HRL	A1 Li 7.7	A1 Li 3.9 & 4.4f	x	2	-	-
A2	HRR	A10 Li15.8S & A2Re31.0	A2 Re 36.4	x	1	-	-
	HRL	A2 Li 36.4	A2 Li30.9f, 30.5h & 31.0	x	3	-	-
A4	HRR	A1 Re0 & A10 Li21.4s	A4 Re3.4	x	1	-	x
	HRL	A4 Li3.5	A4 Li 0	x	2	-	x
A5	HRR	A5 Re8.4	A5 Re18.9	x	-	-	-
	HRL	A5 Li19.3	A5 Li8.5	x	1	1	-
A8	HRR	A10 Li32.0s & A8Re 0.6	A8 Re5.3r & A8 Re5.4	x	-	1	x
	HRL	A7 Li4.3k & A8 Li5.4	A8 Li0.7	x	2	1	x
N200/A200	HRR	N200 Re 0	A200 Re8.7	-	-	-	-
	HRL	A200 Li 8.5	N200 Li0	-	1	-	-
Sub A10 (SB) Southbound	HRR	A10 Re 15.5	A10 Re21.4	x	1	2	x
	HRL	A10 Li 15.4	A10 Li20.8	x	3	3	x
Sub A10 (SW) Southwest	HRR	A10 Re 21.4	A10 Re26.8	x	2	4	-
	HRL	A10 Li 20.8	A10 Li26.8	x	2	4	-
Sub A10 (NW) Northwest	HRR	A10 Re 26.8	A10 Re31.0	x	-	2	-
	HRL	A10 Li 26.8	A10 Li31.0	x	1	2	-
Sub A10 (NB) Northbound	HRR	A10 Re 31.0	A10 Re4.7	x	1	2	-
	HRL	A10 Li 31.0	A10 Li4.6	x	1	2	-
Sub A10 (NE) Northeast	HRR	A10 Re 4.7	A10 Re11.1	x	3	3	-
	HRL	A10 Li 4.6	A10 Li11.2	x	3	3	-
Sub A10 (SE) Southeast	HRR	A10 Re 11.1	A10 Re15.5	x	3	3	-
	HRL	A10 Li 11.2	A10 Li15.4	x	3	3	-

1.4 Research Questions

As this research is conducted to investigate the impacts resulting from malfunctions of the DTM systems, the *type of failed functions*, the *failure location* and the *failure duration* are three specified crucial variables that determine the severity of the impact to the malfunction location and to the rest part of the motorway network.

In order to fill up the knowledge gap in the connections between function failures of the DTM systems and the social costs of corresponding impacts, research questions are formulated in this section, by answering which the research objective could be achieved.

- **Main Research Question**

What are the costs when functions of the dynamic traffic management systems fail at different locations on the motorway network?

- **Sub Research Questions**

1) What are the recognized benefits of the selected dynamic traffic management systems?

2) What method is applicable to determine the effects of system or function failure? Which method or tool is used in this research, and why?

3) What would be the impact if one function breaks down at one or more locations at the local level? And at the network level(s)?

4) How could those impacts resulting from the malfunctions of the DTM systems and functions be converted into monetary costs?

1.5 Framework of the Research Process

A framework is set up to provide an overview of the research structure, as shown in Figure 1-5. The whole research process can be divided into three main phases. The first phase defines the method and tool for the modifications of DTM malfunctions through literature study, after which the first two sub research questions can be answered. In the second phase of this research, the malfunction scenarios with different locations and durations in AMS network are modified with the method/tool selected in the first phase, and then the effects are compared and discussed. Based on the malfunction effects obtained in the second phase, the associated societal costs can be calculated in the last phase of this research.

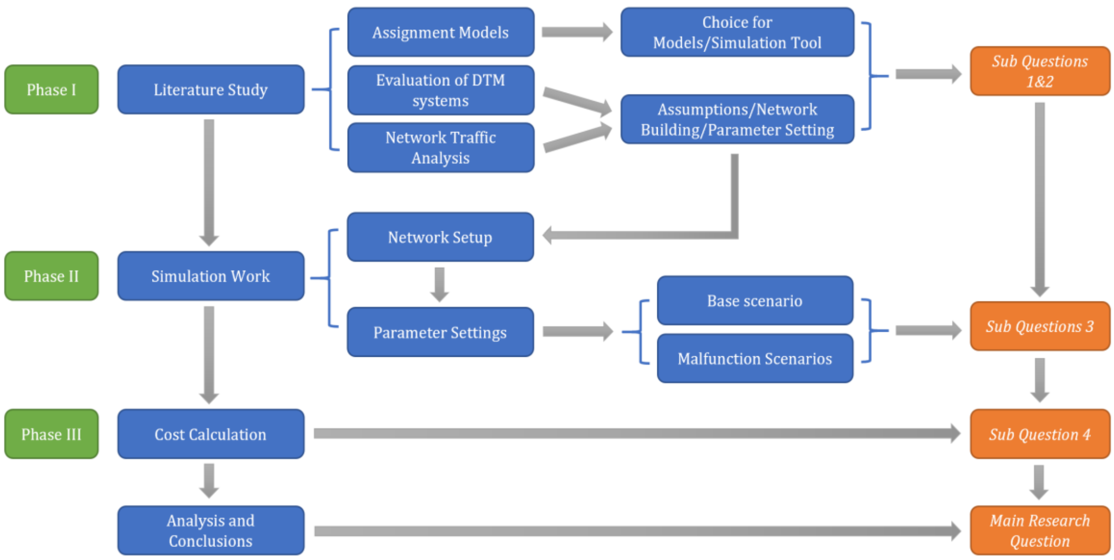


Figure 1-5. Schematic overview of the research structure

2. Literature Study

The literature study is summarized in this chapter, which include previous research on failures of the DTM systems, a broad state-of-art study for traffic assignment and simulation models, as well as practice of evaluation tools implement by Rijkswaterstaat for the traffic management measures. Typical applications and limitations of each type of assignment models are identified through the literature study, and a proper tool/model for the evaluations of DTM malfunctions can be determined.

Introductions and summaries of the DTM evaluations based on RWS internal documents (RHL in section 2.4, MTM in section 2.5, DRIPs in section 2.6 and RM in section 2.7) are also included in this chapter. The internal documents include design manuals, directives, evaluation reports and investigation surveys. In section 2.8, the identified effects of the DTM systems at the AMS network are summarized accordingly, combined with overview report of 210 practical evaluations in the Netherlands **(Taale, 2018)**.

Identifying the effects of these DTM systems could provide insights and expectations for the traffic situations with DTM malfunctions, also help to set and adjust the input parameters in the simulation models according to actual situations.

2.1 Failures of the DTM Systems

The component failure or system malfunctions could lead to considerable effects and loss. Few literature could be found for the study of DTM malfunctions. While the system malfunction in other fields could also provide insights into its considerable effects and the importance of risk analysis for the system malfunction.

In the field of aviation, the recent Boeing trouble raised a great concern of system robustness. The failure of the AoA[1] sensor leads to the malfunction of MCAS[2] stall-prevention system on Boeing 737 MAX airplanes, which would push down the plane's nose repeatedly and undercut pilot's ability to regain the control manually **(Pasztor, Tangel, Wall & Sider, 2019; Johnston & Harris, 2019)**. The MCAS malfunction caused two severe aviation crashes and a total number of 346 deaths (Lion Airlines Flight 610 in Oct 2018 & Ethiopian Airlines Flight 302 in March 2019).

In automotive industries, the brake defects would make the brake fail to react effectively during its application and could arise risks of vehicle crashes **(Mudd, 1972; Oduro, 2012).** The failure in lane detection can lead to the swerving and veering of the automated vehicles for no reason, and the failure in identifying obstacles on the road environment can cause sudden braking or uncomfortable acceleration and deceleration, which are negative in maintaining the safe driving operation **(Dikmen & Burns, 2016)**.

In the cold-chain process of perishable goods, failures in temperature control lead to the growth of pathogens and spoilage microorganisms, which would cause quality loss of the goods during the warehouse storage and transportation **(Mercier, Villeneuve, Mondor, Uysal, 2017).**

[1] AoA: Angel of Attack
[2] MCAS: Maneuvering Characteristics Augmentation System

2.2 State-of-art of Traffic Assignment Models

Since no study was found for the evaluation of DTM malfunctions, and thus no experience could be acquired in the selection of simulation tools. Traffic assignments models are used to predict the flows in a road network, which can be used for the evaluation of the effectiveness of traffic management strategies. Based on the way how traffic flows are determined, the traffic assignment models can be classified into macroscopic, microscopic and mesoscopic categories **(Taale & Van Zuylen, 2006)**. In this section, a state-of-art study for traffic assignment models is conducted, to identify the features and limits of each type of model.

Calvert et al. (2016) summarized existing traffic assignment and simulation models, including the categorization and their characteristics, implementations and corresponding commercial or research models in practice worldwide and in the Netherlands. In their report, the traffic models are classified into six categories, including Demand Models, Macroscopic Models, Mesoscopic Models, Microscopic Models, Hybrid Models and Data-driven Models. Figure 2-1 presents the summary of these traffic models. A brief introduction of these model categories and the application is then illustrated.

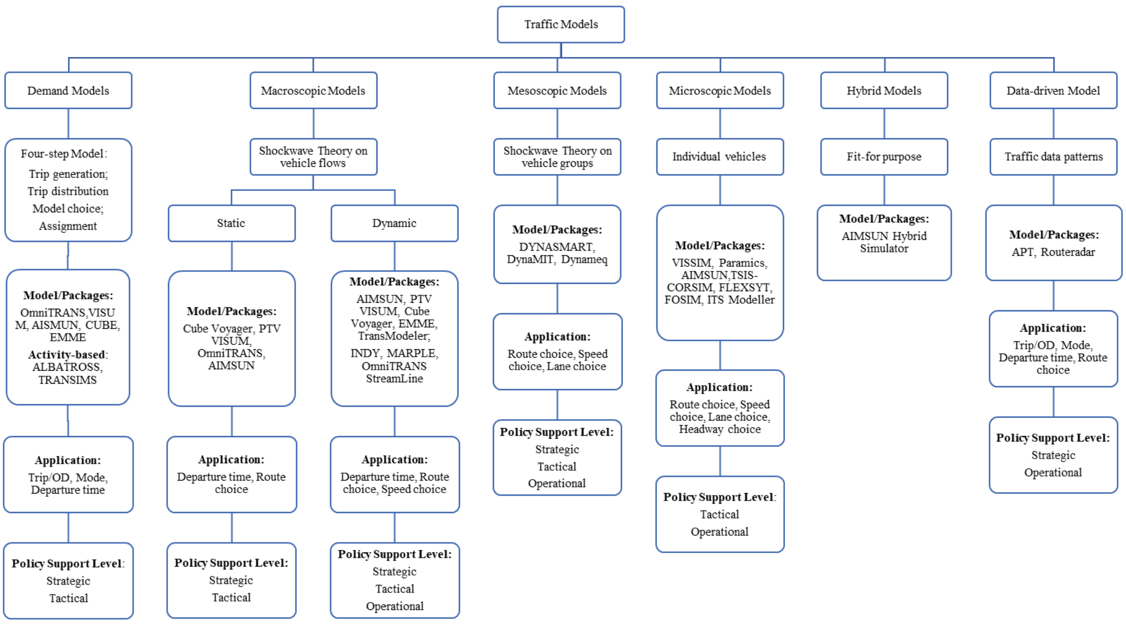


Figure 2-1. Summary of state-of-art of traffic assignment models and packages
(based on Calvert et al., 2016)

■ Demand Model

A demand model is named so as to forecast the number of trips between pairs of origins and destinations with a specific transport mode at a certain area. It is a part of the classical four-step model including trip generation, trip distribution, mode choice and route assignment. While the route assignment can be done with macro-, meso-, microscopic models and any other assignment models in different categories.

■ Macroscopic Model

A macroscopic model is used to investigate the aggregate traffic properties including the flow, density, mean speed of traffic streams and so on. With or without consideration of time dependency and spill-back effects, macroscopic models can be classified into dynamic and static models.

- **Mesoscopic Model**

Mesoscopic model is in between macroscopic model and microscopic model in terms of scale of modelling, which takes vehicle groups as the agent to calculate the traffic flow conditions. The predication for movement of vehicle groups is based on macroscopic relations. Since individual vehicles are also modelled, individual vehicle speed, lane change and car-following headway can be predicted as well.

- **Microscopic Model**

In microscopic models, individual vehicles are the basic units to be modelled. It provides the highest level of detail for traffic properties of vehicle units, including the position, velocity, and lane usage at any time at any location within the network. However, microscopic models cause great amount of computation times and computer memory in the meanwhile.

- **Hybrid Model**

Hybrid Model is a combination of different types of traffic models, these different models are used under different conditions and objectives for the network. A typical implementation of hybrid model is to model the traffic flow on motorway with macroscopic models and model the traffic condition on intersections or road sections with microscopic models.

- **Data-driven Model**

Data-driven model is applied to make predictions purely based on statistical analysis with data of traffic patterns. The prediction is strongly influenced by the 'quality' of data. Data of unstable traffic conditions and complex road settings makes data-driven models hard and inadequate to be used to derive reliable forecasts for traffic conditions.

2.3 Practice in the Netherlands, RWS Models & Tools

- **FLEXSYT-II & FLASH**

FLEXSYT-II is a microscopic simulation traffic model used to investigate the effects of traffic flow on network level, which simulates the movement of individual vehicles with a stochastic process.

FLASH provides the simulation environment for FLEXSYT-II microscopic model, it supports the test and visualization for traffic controllers and regulations. Various modules are included in FLASH, files can be managed by project management module, traffic networks can be built graphically with network editor module, and tests can be operated by simulation module.

- **MARPLE (Model for Assignment and Regional Policy Evaluation) & OmniTRANS**

The sustainable traffic management process (Gebiedsgericht Benutten, GGB) brings all parties involved to cooperate for a broadly supported traffic management architecture (TMA). The Regional Utilization Explorer (Regionale BenuttingsVerkenner, RBV) was a tool used in GGB process, with which a macroscopic dynamic assignment model "MARPLE" is implemented for calculating the effects of traffic management measures in regional network.

MARPLE is the abbreviation for "Model for Assignment and Regional Policy Evaluation", which was developed to study the interaction between route choice and signal control, and has been implemented by Rijkswaterstaat in supporting regional planning and evaluation process for traffic management **(Taale, Westerman, Stoelhorst, & Van Amelsfort, 2004; Taale & Westerman, 2005)**.

MARPLE is a route-based macroscopic dynamic traffic assignment model, which generates a priori route choice sets to propagate the traffic through the network according to travel time functions. The use of generated priori route sets is based on a behavioral point of view for road users, which has the advantages of easy treatment of non-linearities present in the generalized cost function as well as great flexibility in choice model types, it can effectively reduce the computation time for the dynamic fastest paths during the model simulation **(Taale & Pel, 2019)**.

Three components are included in the MARPLE model package: route set generation model, dynamic route choice model and dynamic network loading model, the framework of MARPLE is shown in Figure 2-2. The routes in a given transportation network are generated with the set of origin-destination (OD) pairs by the route set generation model, the available routes between OD relations are maximized and determined with Monte Carlo simulations with free flow travel times and Dijkstra's shortest paths **(Taale, 2009)**. In the dynamic route choice model, the choice proportions are computed per OD relation based on the generalized route costs, and the route flow are obtained by multiplying the dynamic OD demand with these proportions. With the dynamic network loading model, route flows are propagated along each route through the whole network, taking spill back effects into consideration **(Bliemer & Taale, 2006)**.

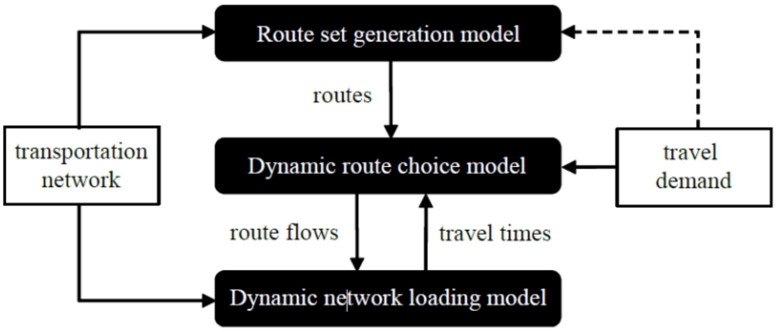


Figure 2-2. Framework of MARPLE (Taale & Hoogendoorn, 2012)

OminTRANS is a well-practiced transport modelling platform developed in the Netherlands, which provides a toolbox for developing and calculating traffic models. It can be served as the user interface of MARPLE. The MARPLE plug-in contains the functionality to estimate and quantify the effects of the DTM measures and services **(Taale et.al, 2004)**. The simulation results can be exported in a user-friendly manner, and also be visualized with the OmniTRANS environment.

2.4 Rush Hour Lane (RHL)

The rush hour lanes are available at two locations of the AMS network, one at the ring south and corridor A4 in both directions, and another one at the corridor A8 connected with motorway A7 in both directions. Much smaller than the regular lane (2200 veh/h), the capacity of a rush hour lane at the right hard shoulder is assessed around 900 veh/h according to the capacity manual **(WVL & Grontmij, 2015)**. The operational opening times of the rush hour lanes are inquired from the traffic control center North-Holland, according to which the capacity supply in regular situations is identified. Detailed information about the rush hour lane practice can be found in this section.

2.4.1 Introduction

The rush hour lane (RHL) is designed to achieve rapid and temporary extra capacity at relatively low costs on road sections with an upcoming traffic bottleneck **(GPO, 2017)**. Two types of the RHL are implemented in the Netherlands, namely "*spitsstrook rechts*" and "*spitsstrook links (also called as plusstrook)*". The "spitsstrook rechts" are placed at the right hard shoulder separated by a solid lane marking, as shown in Figure 2-3; the "spitsstrook links" are placed on the left of regular lanes, separated by an interrupted lane marking, as shown in Figure 2-4.

The RHL is opened depending on the volume of traffic, which can temporarily create additional capacity to prevent congestions. Therefore, the RHL is only available when the traffic is busy (especially during the peak hours) as well as at events or road works. However, there are also risks involved due to the disappearance of right hard shoulder and narrowed crossing sections, therefore, compensatory safety measures are implemented together with the opening of the rush hour lane, such as traffic signaling with built-in function of jam protection, dynamic maximum speed, cameras, AID (automatic incident detection & congestion warning) and et cetera.

Figure 2-3. Spitsstrook links (GPO, 2019)

Figure 2-4. Spitsstrook rechts (GPO, 2017)

The RHL is taken as a traffic management measure instead of a structural solution **(GPO, 2017)**. The opening and closure of the RHL have following typical conditions:

- ***Regular open***. Opening according to the intensity criterion or routes based on time windows.
- ***Regular closing***. Closure according to the intensity criterion.
- ***Irregular opening***. In work-in-progress (WIP), incidents, poor weather conditions and with emergency plans.
- ***Irregular closing.*** In work-in-progress (WIP), incidents, poor weather conditions and with emergency plans. In addition, when required by a vehicle in a refuge, technical problems or bad weather.
- ***Incidents on rush hour lanes.*** Each route is arranged with emergency plans.
- ***System failure.*** No opening of the rush hour lane or partly under strict conditions.

2.4.2 Evaluations of the rush hour lane

The effects brought by the opening of RHL were proved to be positive during the pilot projects carried out in 1996, it was found that the vehicle speeds become more homogeneous, with less serious conflicts and shorter headway times **(GPO, 2017)**. Based on the results of pilot projects, the construction of RHL was speeded up with the *Road Widening Emergency Act* released in 2003, as well as additional legislations including *Acceleration of Decisions on Road Projects: The Crisis and Recovery Act.*

Road sections with opened RHL could not be taken same as road sections with one more regular lane, since the capacity value was estimated around 900 veh/h for spitsstrook rechts, 1700 veh/h for spitsstrook links (3.10 m) and 1400 veh/h for spitsstrook links (2.50-2.75 m), these values are determined by field measurements and expert judgments **(WVL & Grontmij, 2015)**.

- **Flow Improvement**

In the report of the second evaluation for the RHL **(Poorterman, Brandt, Kijk in de Vegte & Nijenhuis, 2011)**, the benefits brought by the implementation of the RHL were calculated and estimated for six consecutive projects under road expansion programs, including A2 (Urmond - Het Vonderen), A4 (Badhoevedorp - Nieuwe Meer), A10 (Nieuwe Meer - Amstel), A1/A6 (Diemen- Muiderberg - Almere), A1 (Watergraafsmeer - Diemen) and A28 (Ommen - Lankhorst; Hattemerbroek - Lankhorst). Their evaluation results for the project A4/A10 are summarized in Table 2-1.

Table 2-1. Evaluation results of vehicle lost hours (VVUs) and travel time (TT) RHL A4/A10

Period	Direction	Pre-test		Post-test		Difference	
		VVU	TT	VVU	TT	VVU	TT
Morning Peak	A4-A10 (L)	1857	23.8 min	600	20.2 min	-67.7%	-3.6 min
	A10-A4 (R)	668	15.0 min	599	14.6 min	-10.3%	-0.4 min
Evening Peak	A4-A10 (L)	3204	30.9 min	1489	23.9 min	-53.5%	-7.0 min
	A10-A4 (R)	2403	22.7 min	620	15.3 min	-74.2%	-7.5 min
Day Rest	A4-A10 (L)	874	19.2 min	661	19.6 min	-24.3%	+0.3min
	A10-A4 (R)	666	14.1 min	391	13.6 min	-41.3%	-0.5 min
Total	A4-A10 (L)	5934	21.9 min	2750	20.4 min	-53.7%	-1.5 min
	A10-A4 (R)	3737	15.7 min	1609	14.0 min	-56.9%	-1.7 min

Based on the decrease in vehicle lost hours per day and a total of 56 effective days opened for the evaluation, the economic savings for the rush hour lanes on A4/A10 in both directions can be up to 4.74 million euros per year (with 10.14% of freight vehicles traveled on A4/10, and the value-of-time of 13.27 and 44.10 euros applied for passenger vehicles and freight vehicles).

- **Safety Effects**

Safety issues regarding the rush hour lane were also evaluated. In the research conducted by **Arcadis (2007)**, the rush hour lanes were analyzed based on the accident data with a three-year period before and after the opening of the rush hour lanes. The study shows that the number of accidents reduced in 12 out of 14 rush hour lanes. However, the development of the road safety differs a lot among each RHL stretch since the local circumstance is believed to have greater influence on the consequences for the road safety. In a follow-up research by **Grontmij (2010)**, the relationship between the number of accidents and the opening and closure of the RHL was investigated. It is found that the average number of accidents with the rush hour lanes opened remains same when they are closed, despite of the fact that there was more traffic during the opening of the rush hour lanes. A step-further research was conducted by **VIA (2011)**, in which the risk rates on the same routes focused in the **Grontmij (2010)** study were investigated. The risk rates at road sections with closed RHL were found to have no significant difference with road sections (with similar intensity/capacity ratio) without implementations of the rush hour lane; however, the risk rates when the rush hour lanes are opening vary dramatically per rush hour lane due to the influence of local conditions. No clear conclusion was drawn in previous studies with regarding to the relationship between the number & type of accidents and the opening & closure of the rush hour lanes, which requires further pre- and post- examinations.

In the study of **Grontmij (2015)**, the road safety level of RHL stretches was determined and compared with regular road sections with hard shoulder lane, based on safety-related variables and the risk developments. Routes with “spitsstrook rechts” were found to have a considerably higher road safety risk when the traffic is relatively low and high (I/C < 0.3 or I/C > 0.7), compared with regular routes with the same number of lanes; routes with “spitsstrook links” would also have a significantly higher safety risks when the traffic is not busy (I/C < 0.3). Also, the accident risk around connections was found to be higher on routes with the rush hour lane regardless opening and closure. It can be concluded that the creation of the RHL is not always a desirable solution in too high or too less demand conditions and at specific locations from traffic safety perspective.

The road safety for extended opening hours was also investigated by **Antea Group (2016).** By changing the criterion (1,350 vehicles per lane per hour) in the activation of rush hour lanes to be opened, a 26% longer opening time was realized per month on average. The road safety was found to be improved as more traffic is served with the extended opening time of rush hour lanes, with an acceptable risk level (when the I/C is in between 0.3 and 0.7).

- **Limitations**

Though the implementation of the RHL is a cost-effective measure to increase the capacity for desired road sections, it is not a desirable and suitable solution at heavily loaded road sections (if the I/C ration is still greater than 0.7 after the realization of rush hour lanes). As evaluated by **Grontmij (2015)**, the RHL with high intensity level will cause higher safety risk than routes with regular lanes and the hard shoulder lane. Since the safety is compromised, the congestion on the road sections would be exponentially reinforced when incident happens especially when the hard shoulder is used as the rush hour lane.

Furthermore, it is not always true that the realization of rush hour lanes would be cheaper than the expansion with a regular lane, when taking the costs of associated DTM systems as well as the maintenance into account.

2.4.3 Rush hour lanes in AMS network

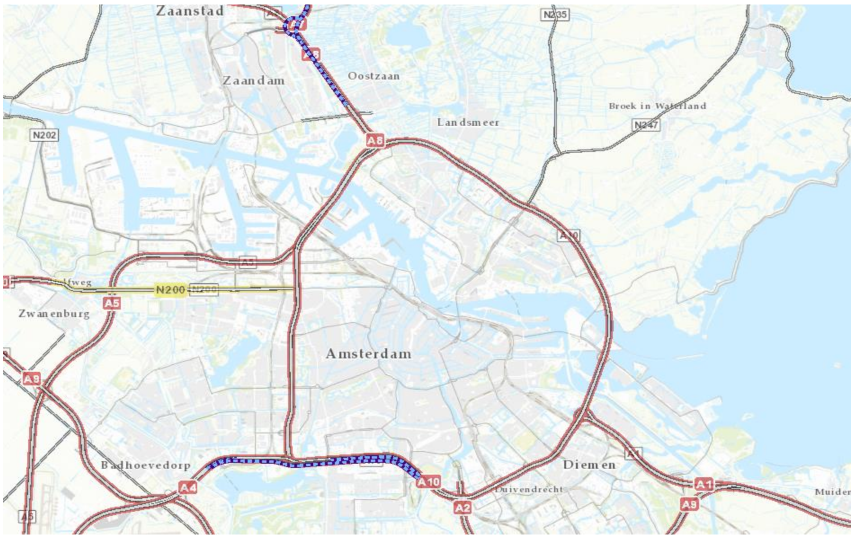


Figure 2-5. Rush hour lane availability in AMS network (NIS, 2019)

As shown in Figure 2-5, there are two motorway stretches with the RHL implemented at the AMS network: A8/A7 in the north and A4/A10 in the south. Detailed information regarding the directions, start & end locations as well as lengths of the RHL are shown in Table 2-2.

As the RHL is not opened all the time, only malfunctions during the opening time of the RHL are expected to cause actual effects to the traffic. Therefore, when the RHL are generally opened and closed during the day is important for the analysis of time effects. The opening times for the two RHL stretches in AMS network are summarized in Table 2-3, which are inquired from the traffic control center in North Holland.

Table 2-2. Properties of rush hour lane stretches in AMS network (NIS)

	Motorway	Direction	from	to	Start	End	Length(km)
a	A4	HRR	Nieuwe Meer	Badhoevedorp	1.80	2.72	0.92
b	A10	HRR	Amstel	Nieuwe Meer	17.30	20.00	2.70
c	A4	HRL	Badhoevedorp	Nieuwe Meer	2.60	0.00	2.60
d	A10	HRL	Nieuwe Meer	Amstel	20.90	17.28	3.62
e	A8	HRR	Zaandam	Zaandam	4.15	5.50	1.35
f	A7	HRR	Zaandam	Purmerend-Zuid	5.10	12.93	7.83
g	A7	HRL	Purmerend	Zaandam	12.93	4.10	8.83
h	A8	HRL	Zaandam	Oostzaan	4.89	3.50	1.39

Table 2-3. Opening times in current operations (Traffic control center in North Holland)

Route section	Length	Opening Weekday	Opening Saturday	Opening Sunday
a	0.92	6:00-20:00	8:00-21:00	8:00-21:00
b	2.70	6:00-20:00	8:00-21:00	8:00-21:00
c	2.60	6:00-20:00	8:00-21:00	8:00-21:00
d	3.62	6:00-20:00	8:00-21:00	8:00-21:00
e	1.35	14:00-19:00	15:30-17:30	14:30-17:00
f	7.83	14:00-19:00	15:30-17:30	14:30-17:00
g	8.83	5:30-10:30	-	13:30-16:30
h	1.55	5:30-10:30	-	13:30-16:30

2.5 Dynamic Route Information Panels (DRIPs)

The DRIPs implemented in the Netherlands can be typically divided into two types according to physical shapes & installation positions: the standard DRIPs and the berm DRIPs. According to the type of the displayed information, the DRIPs can also be classified into textual DRIPs and graphical DRIPs (or GRIPs). No available evaluation was found with regarding to the possible different effects brought by the standard DRIPs and the berm DRIPs, surveys were only conducted for the comprehensibility of graphical messages displayed by the berm DRIPs. Furthermore, most of the studies are not up to date, especially those comprehensibility surveys would have limited helpfulness nowadays, as the surveys were conducted at the time when the berm DRIPs just started to be used. It is unclear if road users have better understanding of the graphical DRIPs nowadays, after years of adaptation.

2.5.1 Introduction

The Dynamic Route Information Panel (DRIP) is a digital information panel with the function of providing road users with information on the downstream traffic situations **(AVV, 2005)**. The DRIP is also called as Variable Message Sign (VMS).

According to the purposes of the displayed information, the applications of the DRIPs include information on *Dynamic traffic*, which is automatically generated based on the collected traffic information; *Work-in-Progress (WIU)*, which is intended for situations where the roadway has to be completely or partially closed as a result of road works; *Unforeseen circumstances*, when substantial traffic jams are caused by unplanned events such as an accident, lost cargo, strong winds, road damages and so on; *Supporting traffic measures*, which is intended to guide and explain the DTM measures to road users; *References at events (including parking)*, which often involves the parking information near stadiums and P+R (park and ride) facilities; *National and regional announcements*, which are always scheduled and determined by the traffic center of the Netherlands (VCNL).

The DRIPs implemented on Dutch motorway networks can be classified into two main types according to the information types and installation positions: standard DRIPs and berm DRIPs. The standard DRIPs are normally placed on the portal above the motorway (as shown in Figure 2-6), which are primarily used to indicate the traffic situation on several (alternative) routes and occasionally for other messages. The berm DRIPs are placed on a single pile at the roadside (as shown in Figure 2-7). The "berm" is a Dutch word with the meaning of "shoulder/roadside". A typical difference among two types of the DRIPs is that the berm DRIPs can display both textual and graphical traffic (especially the jams) information **(VWM, 2017)**.

Fig. 3.1.1 DRIP met informatie in tekst

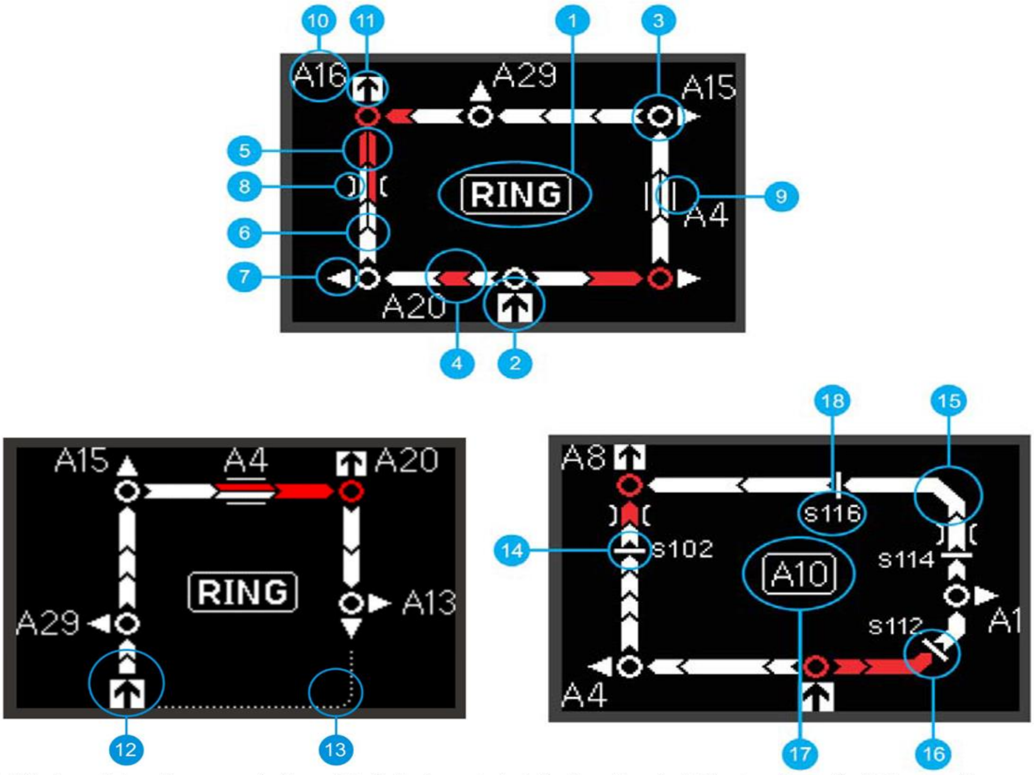
Figure 2-6. Standard DRIPs (VWM, 2017)

Fig. 3.1.2 BermDRIP met grafische weergave van informatie

Figure 2-7. Berm DRIPs (VWM, 2017)

2.5.2 Application of Graphical-DRIPs (GRIPs)

To implement graphical information on existing DRIPs, several types of GRIPs were tested at the Transport Advisory Service (AVV) center since 1990. A uniform GRIP with more free-programming possibilities has been established by Rijkswaterstaat since 2005. In the PIM (*Partner program Infrastructure Management*) project in 2007, the queuing information was added into berm DRIPs' graphical presentation at the ring Amsterdam, it indicates the locations of queues. Examples of such graphical information displayed by berm DRIPs are explained in Figure 2-8.



1. Title ring 2. Location arrow starting point 3. Node symbol 4. Section of road 5. Road section split 6. Road section gap 7. Road section from node 8. Bridge symbol 9. Tunnel symbol 10. Road number (main road) 11. Location arrow (end point) 12. Location arrow (road section spacing) 13. Road section without traffic information 14. Connection in the right road section 15. Oblique road section 16. Sloping road section 17. Title road number 18. Road number local road (s-nr)

Figure 2-8.Typical graphical applications of berm DRIPs (VWM, 2017)

The main applications of the GRIPs can be varied in different road network structures.

- TYPE II: GRIPs along connection route to a closed network (such as a ring)
  These GRIPs are stylized at the entire network and adjacent main roads. The graphical information is mainly used to support the textual information on the standard DRIPs into more detail.

- TYPE II: GRIPs on a closed network
  These GRIPs show the traffic information for the remaining part of the network to the exiting points, and the traffic information is summarily presented for the network part.

- TYPE III: GRIPs along connection route to an open network
  These GRIPs display a stylized graphical representation for the whole network and the main connecting roads.

In the defined AMS motorway network, all three types of applications are included. Those berm DRIPs on the ring belong to Type II; berm DRIPS at connecting corridors in the direction to the ring belong to Type I and those berm DRIPs in reverse direction belong to Type III.

2.5.3 Evaluations of the DRIPs

The DRIPs are mainly intended to achieve a more efficient, safer and more comfortable road use by eliminating part of the uncertainty. The observed benefits for the traffic on the Diemen-Badhoevedorp corridor with a before & after measurement conducted in 1998 show its biggest gain in travel time saving, which is mainly because drivers choose other routes to avoid the traffic jams with the message from the DRIPs. In the evaluation report RIA-4, a cost-benefit analysis was made for the installation of 14 new DRIPs on the ring road Amsterdam, and the intensity was found to be increased by 0.8%, the vehicle lost hours decreased around 20%. Instead of directly reducing the traffic jams, it is more often found that the DRIPs lead to a reduction in the variation in traffic congestion **(Goudappel Coffeng, 1998)**.

In the research of Amsterdam berm DRIPs in 2007, the effects of the provided information were proven to be significant, around 40% of road users have their route choice affected **(Grontmij, 2007)**. The experiences with the berm DRIPs are generally positive according to the discussion with those road users. However, the link between the travel time information on standard DRIPs and jam information on berm DRIPs was not made spontaneously by the respondents **(Ergo, 2010).** In another survey "*Hoofdlijnen enquête Noordwest Nederland*" on the comprehensibility of the graphical information provided by berm DRIPs, less than a quarter of respondents indicated that the information of GRIPs could be fully understandable, while less than half of the respondents (47%) were unclear about the graphical information **(Grontmij, 2007)**.

2.5.4 DRIPs in Amsterdam region

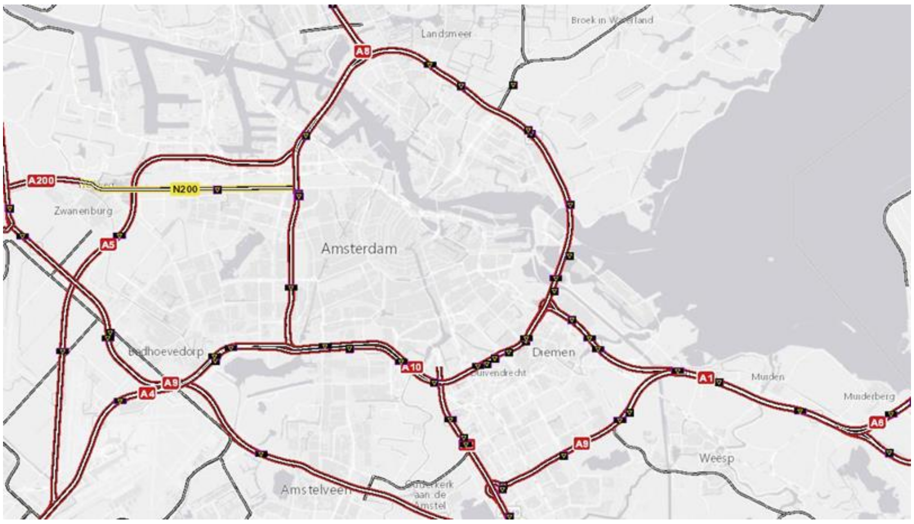


Figure 2-9. DRIPs availability in AMS network (NIS, 2019)

A total number of 23 DRIPs have been installed on the ring road A10, including 7 standard DRIPs and 16 berm DRIPs. There are 9 DRIPs on the inner ring and 11 DRIPs on the outer ring. Additionally, three berm DRIPs are placed on the access ramps. Detailed information about these DRIPs can be found in Appendix D.

2.6 Motorway Traffic Management (MTM) Systems

As one of the most important and widely implemented systems on the Dutch motorways, the MTM has slight contribution to the flow improvement. Nowadays the MTM is integrated with various functions and works in association with other DTM systems. The basic and permanent function of AID (automatic incident detection & congestion warning) was evaluated with a 2% capacity gain on average of the motorway sections. In comparison, the MTM signaling system has more significant benefits to the road safety, an average of 19 % less accidents ranging from 15 to 45% has been realized after implementations of the MTM system **(Taale, 2018)**. However, regardless of the flow or the safety effects to the traffic, the benefits brought by the MTM systems are proved to be varied from location to location, and no generic effect was identified for the MTM signaling systems that can be applied to any motorway sections.

2.6.1 Introduction

In the Netherlands, a traffic signaling system named as Motorway Traffic Management (MTM) has been implemented on motorways since 1981 with aims of improving safety and efficiency of the traffic **(AVV, 1994)**. This signaling system is working cooperatively with the detection system, by which the disruptions in the flow of traffic can be detected, road users are warned of these disruptions by means of maximum speed limits displayed on signal matrix signs above the road. In the event of work-in-progress, arrows and crosses are shown to guide and clear the traffic on certain lanes to be closed, shown in Figure 2-10. In most cases, the operation of the signaling system is an automatic process achieved by advanced control algorithms.

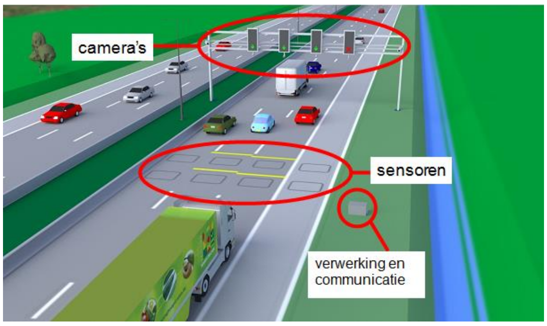


Figure 2-10. Components of the MTM system

Figure 2-11. Photo MTM signal matrix (AID)

2.6.2 Applications

Typical applications of the MTM system including *automatic incident detection and congestion warning (AID)*, *work in progress (WIP)*, *flow homogenization* and *fog signaling*.

The automatic incident detection and congestion warning (AID) is taken as the basic and permanent function of the MTM system, of which the purpose is to warn the incoming traffic about the approaching congestion. A maximum speed of 50 km/h is automatically shown once slow movement (under 18 km/h) is detected, and a maximum speed of 70 km/h is indicated for the upstream traffic, as shown in Figure 2-11; Work-in-progress (WIP) is another basic and permanent function of the MTM system, red crosses and expulsion arrows are used to indicate the unavailable lanes, by which extra space can be created for the maintaining works or the handling of an accident. At road sections when the traffic is highly loaded, an adjusted speed limit can be applied to road users to homogenize the traffic, by which less shock waves can be achieved. Depending on the average speed at the road section, a speed of 90 km/h or 70 km/h would be shown on the signal matrix installed on the portal. The MTM system was also used for vehicles approaching fog areas, a lower speed limit together with additional text information "MIST" would be given to road users, the severity and chance of accidents can be reduced by a lower driving speed.

Nowadays, functions of flow homogenization and fog signaling are less used, and the MTM has been developed as a basic system integrated with other DTM systems (inclduing monitoring system, DRIPs, ramp metering systems, cameras…), measures and functions are achieved by the coordination between systems.

2.6.3 Evaluations of the MTM systems

- **Flow Effects**

The main objectives of the MTM system are to increase the road safety, improve the flow of traffic and to support the role of road managers and polices in blocked barriers. The AID function was extensively evaluated and showed positive effects to the traffic. A 4-5% flow improvement in terms of travel time reductions, and a 15-25% of reduction in accidents and 40-50% decrease in secondary accidents resulting from less (50%) shock waves were observed. These effects were further explained by improvement of traffic flow stability, since the speed distribution were found to be more homogenous, and drivers' attention were also increased. As a result, the road capacity could be better and longer utilized by 1 to 2 % **(de Kroes, Donk & de Klein, 1983).**

The MTM signaling were further investigated with the speed and intensity data collected at the ring road A10, the signaling in the south of the Coentunnel was evaluated in **EAVES (1994)** project. A "standard product-limit method" together with the "Van Aerde method" were carried out to compare the control difference before and after the implementation of the MTM signaling system. It was found that the capacity increased around 2.5%, and the travel speed was slightly higher with the signaling system **(McKinsey & MinVenW, 1994)**.

Additional research was also conducted with the analysis of intensity and congestion data from 21 fixed counting points **(AVV & BGC, 1994)**. The observed maximum hourly intensity or the highest peak intensity were taken as the proxy of the capacity. By comparing comparative road sections with and without the signaling system, a 5% higher in the capacity of road sections with the signal system was utilized. The capacity value is estimated around 2,330 veh/h per lane, compared with a capacity of 2,220 veh/h per lane at road sections without signaling system.

- **Safety Effects**

The road safety is another important aspect that was also evaluated in the research of **de Kroes et al. (1983)**, a reduction of 24% in the number of accidents (with a 90% confidence interval in between 12% and 34%), and a reduction of 46% in the number of secondary accidents (with a 90% confidence interval in between 37% and 57%) were identified by the signaling system. **Verbokkum et al. (2002)** compared the number of accidents after the implementation of AID function, and it was found that 15% of accidents and 22% of serious accidents were decreased.

According to **Elvik (2009)**, signaling on motorways can reduce 16% of the follow-up accidents (crashing into vehicles at an accident location) and a reduction of 44% of accidents in traffic jams (crashing into the tail of jams). In the overview report based on 210 practical evaluations **(Taale, 2018)**, it is summarized that the signaling system contributes to 19% (ranging from 14% to 45%) less accidents on average, also with a realization of 35% fewer secondary accidents.

2.6.4 MTM signal matrixes at Amsterdam region

The MTM signal matrixes are almost uniformly placed on the portals above the motorway every 500 meters. All corridors in AMS network are equipped with the MTM system except for the corridor N200, since it is a non-motorway stretch signposted with a "N".

2.7 Ramp Metering System (RM)

The ramp metering is one of the mostly studied systems in the Netherlands, various control algorithms were tested and compared. However, it is still hard to judge the effects of the ramp metering system, which are varied from location to location. One of the most common features after the implementation of the ramp metering, is the speed increase on the main road. In this section, the introduction, control algorithms as well as the evaluations of the ramp metering are provided. Additionally, the availability and the distributions of the 35 ramp metering systems in AMS network are illustrated in section 2.7.4.

2.7.1 Introduction

The ramp metering systems was firstly implemented in the Netherlands since 1989 with the aim of reducing the disruptions and congestion effects to the main road network, by regulating the supply to the motorway in response to the current downstream or upstream traffic situation on the motorway. Besides, the ramp metering system is also used to combat rat-running drivers (motorists using side streets to avoid the congestion on the intended main road) **(WVL, 2018)**. The ramp metering systems are usually applied at on-ramps close to a bottleneck or on-ramps which can cause disruptions to the main road traffic, for instance by the merging process of vehicle platoons. A typical installation of the ramp metering systems on the Dutch motorway is shown in Figure 2-12. The first practice of the ramp metering system was implemented at the last on-ramp before the Coentunnel to the A10 west in March 1989, and proved its positive effects to the motorway traffic, after which the number of rat-runners decreased, the average speed and the total number of vehicle kilometers on the A10 increased **(Taale, 2009)**.

Figure 2-12. Photo ramp metering at A10 Basisweg (location A10Re 27.3b)

The activation of the metering systems is based on the traffic conditions (intensity and speed) on the ramp and motorway sections upstream and downstream the ramp measured by induction loops. Dynamic signal actions are taken whereby the metering frequency is determined in every measurement period (usually every green-yellow-red cycle) **(WVL, 2018)**. The ramp metering system is activated when the detected flow and speed exceed the predefined thresholds, in each green phase, a maximum of one or two vehicles per lane are allowed.

The maximum and minimum green times are the basic properties of a metering system. The maximum green time is adjustable as it actuates according to the detected flow intensity. In Dutch motorway practice, a default value of 15-seconds for the maximum green is defined, taking into considerations of road users' acceptance, and 12-seconds is chosen in most regular circumstances. The minimum green time is theoretically around 4.5 seconds, which depends on factors including the warranty red time, minimum yellow interval and vehicle accelerations.

2.7.2 Algorithms of Ramp Metering Control

Several algorithms for the control of the ramp metering system were tested and compared, including the RWS strategy, the ALINEA strategy, Fuzzy logic **(Middelham & Taale, 2006)**, HERO algorithm **(Yuan, Daamen, Hoogendoorn & Vrancken, 2009)** and so on.

The RWS strategy is conducted to smooth the motorway flows and better utilize the capacity based on the on-ramp flows as well as speed and flows of the motorway. The number of vehicles allowed to enter the motorway in a time interval is determined, according to the difference between the pre-specified motorway capacity and measured upstream flow of the on-ramp in previous time interval. It is called as feed forward control. The cycle time of the metering is calculated according to the number of on-ramp lanes and the determined number of allowed vehicles. When a queue is detected on the on-ramp, the predefined minimum cycle time would overrule the calculated cycle times to release the pressure at the on-ramp.

The ALINEA strategy is developed with the aim of remaining the downstream occupancy of the on-ramp at a pre-specified setpoint, based on which to determine the switch-on and switch-off of the metering system. It is a feedback control.

The Fuzzy logic is based on the classification of the speed values upstream and downstream of the on-ramp, and the time a queue formed at the on-ramp. The membership degrees are determined by the rules and then are transferred to a value of cycle time. According to the comparison of the calculated cycle time and the defined upper and lower thresholds, the metering system then is activated or deactivated.

Although the ALINEA and Fuzzy logic strategy produced comparable and even better control performance, in practice, the RWS strategy is chosen as the standard application for the ramp metering in the Netherlands to generalize the tuning process **(Knoop, Taale, Meulenberg, van Erp & Hoogendoorn, 2019).**

2.7.3 Evaluation of the Ramp Metering System

It is difficult to judge the effects of ramp metering system, even it is one of the most studied DTM measures **(Middelham & Taale, 2006 & Taale, 2009)**. The most common effect with the implementation of metering systems retrieved from various assessment studies is the speed increase on the motorway, ranges from 4 km/h to 30 km/h, varying from location to location. Besides, the control dilemma raised by the red-light ignorance were also studied, the red-light violations are around 6% when a clear bottleneck exists, and the percentage increases to around 15% when there is no clear bottleneck. **(BGC, 1990; Grontmij, 1990, 1991, 1994, 1995 and 1998; Heidemij, 1996; Witteveen+Bos, 1999; Goudppel Coffeng, 1998**), as summarized in Table 2-4.

Table 2-4. Summary effects of ramp metering systems (retrieved from Taale, 2009)

	capacity bottleneck	speed motorway	use of on-ramp	total delay (veh.hours)	travel time motorway	ignoring red light
Coentunnel (1 on-ramp)	=	+30 km/u	-50%	-	-	5-6%
Coentunnel (4 on-ramps)	+1-2%	+20 km/u	≈	-20%	-	-
Delft-Zuid (1st assessment)	+5%	-	=	<	-	15%
Delft-Zuid (2nd assessment)	+4%	-	=	<	-	15%
Zoetermeer	+3%	-	=	-	-6%	13%
Schiedam-Noord	>	+20 km/u	-8%	-	-6%	3%
Barendrecht	+5%	+20 km/u	-35%	-	-10%	2%
Kolkweg	=	+4 km/u	-10%	-	-3%	6%
Vianen	+5%	+5 km/u	-36%	-	-	5%
Muiden/Muiderslot	-	-	≈	-	=	6-7%

'=' means equal, '<' means decrease, '>' means increase, '≈'means variable and '-' means not studied

The project "Improving traffic flow A10 (In Dutch: Verbeteren Doorstroming A10 -VDA10)" was developed as part of the *FileProof* program launched by the MinVenW from 2006 to 2008, in which the effects of the ramp metering systems at the ring A10 together with a number of VMS (DRIPs) were evaluated. The evaluation results of the VDA10 project indicated the positive effects on the flow of the ring road with a 10% reduction in vehicle lost hours on an average working day; and the statistical results indicated a 3-10% increase of travel speeds at the majority of ring road sections, while the speed decreased 3% at the western part of the outer ring during the evening peak hours; the safety was also estimated based on the incident reports in the before- and after- surveys, resulting in 50% less incidents during the morning peak and 25% less during the evening peak **(Van der Veen & Taale, 2011)**.

2.7.4 Ramp Metering Systems in AMS Network

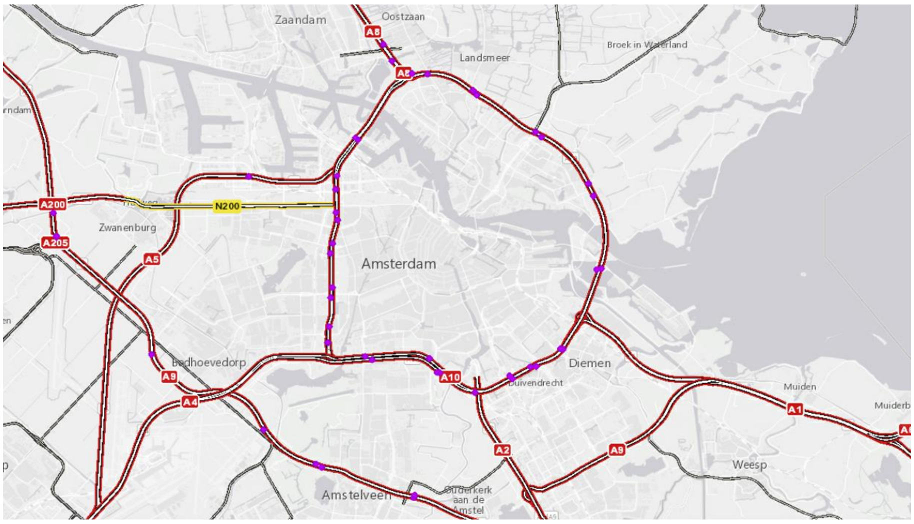


Figure 2-13. Ramp metering availability in AMS network (NIS, 2019)

The ramp metering systems are installed at every interchange of the urban road network with the ring road. There are 32 ramp metering systems in total at all on-ramps of ring road A10, 2 at the corridor A8 and 1 metering at the corridor A5 in the northbound direction. Information of all these ramp metering systems including the default minimum and maximum green are summarized in Appendix E.

2.8 Overview Effects of the DTM systems in AMS Network

In this section, the overviews effects of the DTM systems in AMS network are summarized, listed in Table 2-5 to Table 2-8, the figures are retrieved from previous evaluation reports for these systems, combined with the overview reports from **Taale (2018)**.

Table 2-5. Practical evaluations available for the RHL in AMS network

<table>
<tr><th>Location</th><th>Intensity</th><th>VVU</th><th>Queue length</th><th>Travel time</th></tr>
<tr><td>A4-A10 Badhoevedorp-Amstel</td><td>+2.9%</td><td>- 53.7%</td><td>-</td><td>-2.0min (-6.8%)</td></tr>
<tr><td>A10-A4 Amstel- Badhoevedorp</td><td>+2.6%</td><td>- 56.9%</td><td>-</td><td>-2.0min (-10.8%)</td></tr>
<tr><td rowspan="4">A4-A10 (L) Morning Peak
A4-A10 (L) Evening Peak
A10-A4 (R) Morning Peak
A10-A4 (R) Evening Peak
(Poorterman et al. 2011)</td><td>-</td><td>- 1257hrs (-67.7%)</td><td>-</td><td>-3.6min (-15.1%)</td></tr>
<tr><td>-</td><td>- 1715hrs (-53.5%)</td><td>-</td><td>-7.0min (-22.7%)</td></tr>
<tr><td>-</td><td>- 69hrs (-10.3%)</td><td>-</td><td>-0.4min (-2.7%)</td></tr>
<tr><td>-</td><td>- 1783hrs (-74.2%)</td><td>-</td><td>-7.0min (-33.0%)</td></tr>
</table>

Table 2-6. Practical evaluations available for the DIRPs in AMS network

Location	Intensity	Changing route	Queue length	VVU	Message understood
A10 (1st DRIP in Netherland, RIA-1)	-	13%	-34%	-	-
A10 (4 DRIPs, RIA-3, 1st Evaluation)	-	2%	-20%	-13%	97%
A10 (4 DRIPs, RIA-3, 2nd Evaluation)	-	-	-25%	-25%	-
A10 (11 DRIPs, RIA-4)	+0.8%	Yes	-23%	-14%	-

Table 2-7. Practical evaluations available for the MTM in AMS network

Location	Capacity	Accidents	Secondary Accidents	Shock waves
A10 West	+5%	-	-	-
EAVES (1994)	+2.5%	-	-	-
de Kroes et al. (1983)	+1-2%	-24%	-46%	-50%
AVV & BGC (1994)	+5%	-	-	-
Verbokkum et al. (2002)	-	-15%	-22%	-
Elvik (2009)	-	-16%	-44%	-
Taale (2018)	+2%	-19%	-35%	-

Table 2-8. Practical evaluations available for the RM in AMS network

<table>
<tr><th>Location</th><th>Capacity</th><th>Speed</th><th>VVU</th><th>Travel distance</th><th>Travel time</th></tr>
<tr><td>A10 Coentunnel (1st RM in NL)</td><td>=</td><td>+20 km/h</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>A10 Coentunnel (4 RMs)</td><td>+2%</td><td>+20 km/h</td><td>-20%</td><td>-</td><td>-</td></tr>
<tr><td rowspan="4">A10 All RMs
A10 Inner Ring
A10 Outer Ring
Urban Road Network</td><td>-</td><td>+2.2 km/h</td><td>-1.8%</td><td>-13%</td><td>-5%</td></tr>
<tr><td>-</td><td>+2.6 km/h</td><td>-2.1%</td><td>-19%</td><td>-10%</td></tr>
<tr><td>-</td><td>+1.9 km/h</td><td>-1.5%</td><td>-9%</td><td>0%</td></tr>
<tr><td>-</td><td>-</td><td><</td><td>-</td><td>></td></tr>
<tr><td>VDA10 (2011)</td><td>-</td><td>+3-10%</td><td>-10%</td><td>-</td><td>-</td></tr>
</table>

3. Methodology

The research methodology is illustrated in this chapter. Based on the literature study in previous section, a macroscopic dynamic traffic assignment model MARPLE via OmniTRANS platform is selected, as explained in section 3.1. In section 3.2, conceptual conversions from the DTM malfunctions to model inputs are determined, according to the measured effects of these DTM systems and the features of MARPLE. In section 3.3, a methodology to transfer the malfunction effects of the four DTM systems to monetary costs is developed.

3.1 Selection of Simulation Tools

Since DTM malfunctions are not regular events at the operational phase of motorway network management, substantial data over years might be required to derive empirical evidence of the malfunction effects. Accordingly, data-driven model is not a proper option as it relies on extensive data collection and preparations, constricted of the available data size recorded and the data quality. Besides, the predication capability of data-driven model is limited due to the inability in reassigning flows with changed network conditions as well as less considerations in drivers' anticipation **(Van Toorenburg, 2003; Van Toorenburg & Kijk in de Vegte, 2011; Nijenhuis, Elbers & Kijk in de Vegte, 2006-2010**).

Owing to the size of motorway network at Amsterdam region, microscopic simulation models becomes cumbersome and unfeasible considering the network setup and the computation time. A macroscopic model then becomes the best option to achieve the research goals in the light of present knowledge, as the effect at the network level is more emphasized in this research.

Based on Rijkswaterstaat's practice, MARPLE can be a good option fitting for this research to evaluate the impacts of traffic management measures and services at the network level, the model outcome consists of performance indicators such as total travelling distance (TTD), total travel time (TTT), total delays (TD) in terms of vehicle lost hours (VVUs), average speed at network level; indicators including flow, travel time, delay per time period at route level; and link level indicators such as flow, speed and density per time period **(Taale, 2009)**. Furthermore, MARPLE was implemented and tested in previous evaluation projects for DTM measures at Amsterdam region such as the "*FileProof (Improvement Traffic Situation of Ring A10) project and Praktijkproef Amsterdam (Field Operational Test Integrated Network Management Amsterdam) project*", which makes the modelling of road network at Amsterdam region is already available. Previous contributions can save us quite a lot time in building the roads network (both HWN[3] and OWN[4]) and updating the demand profiles.

Taking into account the considerable time and labors required for the setup for other simulation models, MARPLE (PM project from 14:30 to 20:00) is chosen in this study.

3.2 Conversions of the DTM Malfunction

In general, evaluations for the DTM systems are conducted before their wide implementations, and MARPLE was used to determine the effect of certain measures on route choice behaviors, as well as determine control strategies to eliminate the bottleneck according to policy objectives with different criteria **(Taale, 2005)**. Since there is no literature found for the impacts of the DTM malfunctions, and MARPLE has never been used to calculate the malfunction effects, a methodology should be built up to convert the malfunctions in terms of inputs of MARPLE.

[3] HWN: National road networks (In Dutch: Hoofdnetwerken voor wegen)
[4] OWN: other non-national road networks (In Dutch: onderliggend wegennet)

Since the DTM systems are expected to provide no service during the malfunction period, it is assumed that the DTM malfunctions would take away its “positive” effects brought to the traffic. The RHL malfunction can be modified by removing the extra capacity provided by the right hard shoulder, which is estimated around 900 veh/h. The MTM signaling was also estimated to have increased the motorway capacity with 2 to 5%, thus the malfunction of the MTM system can also be modified by capacity constricts to the network. In MARPLE, the capacity constricts can be achieved in terms of adding events to the network, with the properties of the start/end time of the event, changes in lane numbers, changes in free flow speed, and percentage of the remaining capacity. The stochastic equilibrium assignment should be applied for all scenarios, taking the overlap possibility into consideration **(Cascetta, Nuzzolo, Russo& Vitetta, 1996)**. By adjustment of the start & end time of the capacity event, malfunction impacts with changes of failure durations can be estimated.

There is no such type of event that can be allocated in MARPLE to modify the unavailability of DRIPs and RM systems. It is assumed that the performance differences in situations with and without corresponding DRIP or RM, are the effects introduced by its malfunction. However, since no timing elements that can be evaluated for these two systems, the comparison is based on network difference during the whole simulation period. In this study, the type of the DRIPs is not distinguished since no firm conclusion was found for the effect difference between textual DRIPs and berm DRIPs with graphical information. The ramp metering system applied with the RWS strategy can be added into the network via the OmniTRANS in the process of network setup.

Unlike the function type and the failure duration which can be easily distinguished to describe the properties of a malfunctioning event, a “location” can be defined at a point level, a route stretch level or even a network level, therefore, the detail level of a failure location should be firstly defined, and then malfunction scenarios with different locations can be specified.

For the rush hour lane, the malfunction of which makes no sense at either point or network level, it can only be realized at a route level. For the MTM system, the malfunctioning of a single MTM signal matrix at a specific location point can hardly have impact on the traffic since road users can still receive the MTM signal information at the next portal after a 20-second driving (with a speed of 90 km/h). In comparison, the malfunctioning of all MTM signal matrixes in an area can cause strongly different effects depending on its physical and even demographic characteristics. Given these constraints introduced by defining the failure location at a point or a network level, a route stretch level is chosen to specify the location properties for the RHL and the MTM system. Those defined corridors (in both directions) in Section 1.3 can be taken as the failure stretches in different location scenarios, the traffic state is assumed to be homogeneous within the same stretch.

However, the malfunction of a corridor of DRIPs would lead to different route choice behaviors with the malfunction of a single DRIP, since there are also decision points (e.g. the off-ramps) in between two adjacent motorway interchanges. Also, as a local control measure, the operation of the metering system at one on-ramp is independent with other metering systems. Therefore, simulations for the DRIPs and the RM based on a point (DTM unit) level can give more accurate results. Considering amount of work, the DRIP malfunctions are conducted at the corridor level, and only the RM malfunctions are conducted at the point (RM unit) level.

3.3 Cost Calculation of the DTM Malfunction

Based on the experience from the second evaluation for the rush hour lane **(Poorterman et al.,**

2011) and the first phase of P-IHP-DVM project, the social costs of the DTM malfunction can be calculated based on the values-of-time (VOT) and changes in vehicle lost hours (VVUs). The VVUs can be obtained from MARPLE output, and the malfunction effects in this research are mainly referring to the changes in VVUs with and without the corresponding DTM system.

Since the MTM system was identified to have created more safety benefits (19% less accidents on average) than the flow benefits (2% capacity gain on average) **(Taale, 2018)**, the costs due to the rise of safety risks with MTM malfunction should also be considered for the total social costs. A conceptual framework to determine the malfunction effects and transfer to costs is shown in Figure 3-1. It is noted that the calculation of the safety costs for the MTM system is independent form the MARPLE simulation.

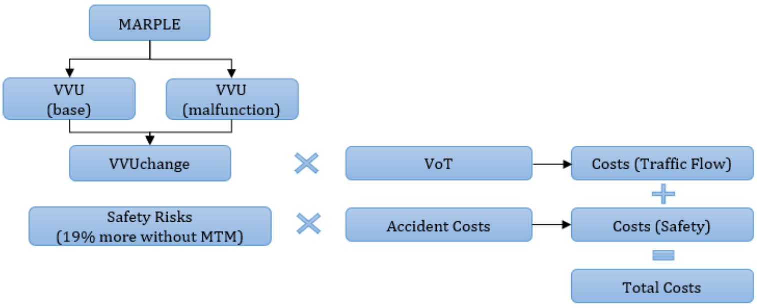


Figure 3-1. Framework for cost calculation of DTM malfunctions

4. Simulation Module I: Network Preparation and Model Setup

The model simulation requires network adjustments in selected simulation tool. Road networks at the Amsterdam region had already been modeled in OmniTRANS environment in previous *FileProof* (*Improvement Traffic Situation of Ring A10; Traffic Management Trail Amsterdam*) project. Situations in 2007 were modified, of which the physical structure of the network and the traffic conditions differ a lot from current situations. Therefore, adjustment of the network structure and calibration of the network performance are required to make the model analysis consistent with the ongoing traffic conditions.

The network and model setup are illustrated in this chapter, through which a revised network is obtained to represent the current traffic conditions on an average weekday, and it is taken as the base situation with all DTM systems functioning properly.

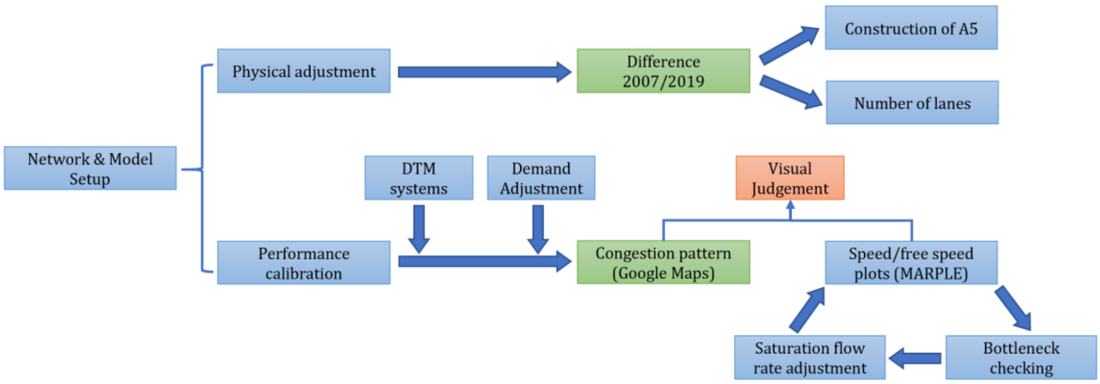


Figure 4-1. Flowchart for the network and model setup process

Shown in Figure 4-1, the setup strategy is divided into two layers: the physical adjustment and the performance calibration. In the process of physical adjustment, motorway stretch A5 was modified into the network, and the number of lanes of each motorway section in AMS network was also checked and adjusted to provide proper capacities. Other than physical adjustments, the DTM systems were also added into the network, and the total demand in the network was scaled to modify the intensity growth over the past ten years. In the process of performance calibration, the congestion pattern retrieved from Google maps on 18th October 2019 (Figure 4-4) is taken as the reference of current situation. It is matched with the speed plots generated from MARPLE, by adjusting the saturation flow rate of inconsistent parts in the network. The model represents the traffic with a comparable agreement with the reality. Detailed descriptions for the setup process are illustrated in section 4.1 and 4.2.

4.1 Physical Adjustment

A main difference in the motorway structure which can be easily noticed is the construction of the motorway A5 trajectory from A10 at the south of *Coentunnel* to the interchange *Raasdorp* connecting with A9 (*Haarlem- Badhoevedorp*). Accordingly, a total length of 12.7 kilometers in the southbound direction and 13.2 kilometers (including the length of diverging sections and ramps) in the northbound direction of the A5 motorway stretch are added into the network. To allocate proper traffic on the revised A5 stretch, an important parallel urban road connection between S103 (*Seineweg*) and the roundabout (*Sierenborch- Luvernes*) was also updated with a length of 1.75 kilometers (Appendix A). The number of lanes per motorway corridor in AMS network is also checked in the process of physical adjustment, which has direct impact to the route capacity and therefore modifications of the motorway bottlenecks.

4.2 Performance Calibration

4.2.1 Implementations of the DTM systems

Before the process of checking the network performance, currently implemented DTM systems were firstly added into the network. Among four studied DTM measures, the rush hour lanes and the ramp metering can be directly added via the OmniTRANS interface.

- **Rush Hour Lanes (RHL)**

The rush hour lanes currently implemented at the motorway network in Amsterdam region include the A8/A7 stretch and A4/A10 stretch in both directions, as introduced in section 2.4. As each motorway corridor is composed of a series of links, the capacity of these links is mainly determined by the number of lanes, which has already been checked in the process of physical adjustment. For road sections where the hard shoulder is used for the RHL, the extra lane was not counted in the lane numbers and the capacities.

Taking that the rush hour lanes are generally open the whole simulation period (14:30 to 20:00) into account, the extra lane could be taken as the permanent capacity to the traffic. Therefore, to modify these RHL stretches, the default lane numbers of those involved links were adjusted to the actual effective lane numbers (number of regular lanes plus one RHL), and the capacity values of these road sections were also improved with extra 900 vehicles per hour as suggested from the capacity manual **(WVL & Grontmij, 2015)**. Detailed adjustments for these rush hour lane stretches can be found in Appendix B. It is noted that the RHL stretch on A7-A8 in the direction from Purmerend to Oostzaan is not modified, since it is only opened in the morning (5:30 to 10:30).

- **Ramp Metering (RM)**

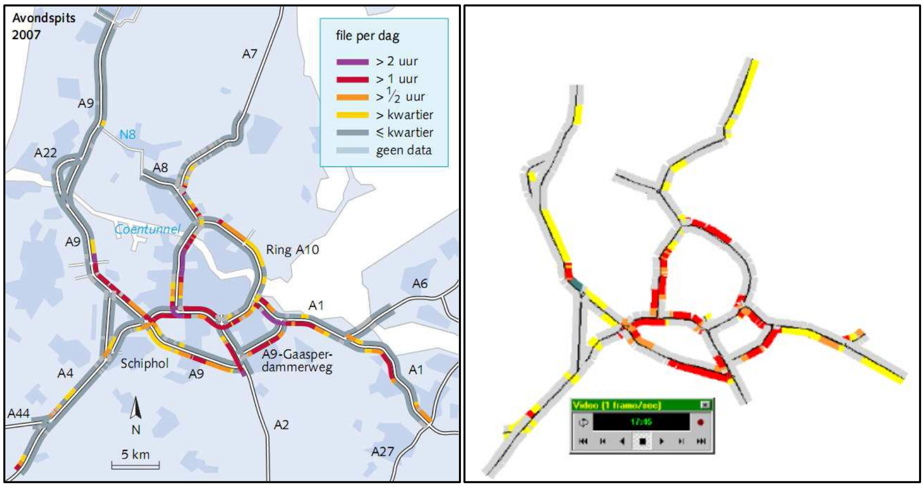
There are 32 ramp-metering systems in total implemented at every on-ramp towards the ring road A10, two ramp-metering systems on A8 and one on A5. All ramp metering systems were modified in OmniTRANS environment via the MARPLE plug-in function, with a 2% capacity improvement of the downstream bottleneck **(Taale & Middelham, 2000)**, the locations of these modified ramp metering systems are shown in Figure 4-2. The detailed information for the flow threshold and signal timing can be found in Appendix E.

Figure 4-2. Implementations of the ramp metering systems (OmniTRANS interface)

4.2.2 Modification of Current Situations

The current situation in the model should reflect actual traffic conditions in the region to make consistent analysis for traffic management measures **(Taale, 2005)**. In the traffic management trail Amsterdam project, the calibration of the motorway is based on the average congestion pattern measured in 2007 **(Transpute, 2008)**, as shown in Figure 4-3, the model simulation produced good consistence with the measured traffic. Since measurement of current traffic requires much work to be processed, the Google maps is used for the reference of current traffic situation.

After the process of physical adjustment and implementations of the rush hour lanes and ramp metering systems, a global scaling factor of 114% was used to modify the intensity growth from 2007 to 2018 **(RWS, 2019)**. A pilot simulation was then conducted with MARPLE plug-in to modify the current traffic situation. The performance calibration is conducted based on the visual comparison of the congestion pattern between simulation results and the Google maps.



(a) Measured traffic (b) Model simulation

Figure 4-3. Evening congestion pattern in North Holland (Taale & Transpute, 2008)

The Google maps provide both the continuously updated live traffic condition and the recent typical traffic condition, shown in Figure 4-4 is the typical traffic near the retrieving date. The traffic situation derived from MARPLE plug-in can also be visualized by the analysis of the ratio of speed and free flow speed.

It is found that the congestion of the MARPLE results is most serious at the simulation time of 17:30 (shown in Figure 4-5), which is consistent with day pattern of the average intensity shown in Figure 4-6 **(RWS, 2019)**. It is also found that the traffic at 17:30 in Google maps is busiest on a Tuesday basis. Therefore, the traffic situation on Tuesday at 17:30 retrieved from Google maps is chosen as the reference of current traffic from a worst-case point of view.

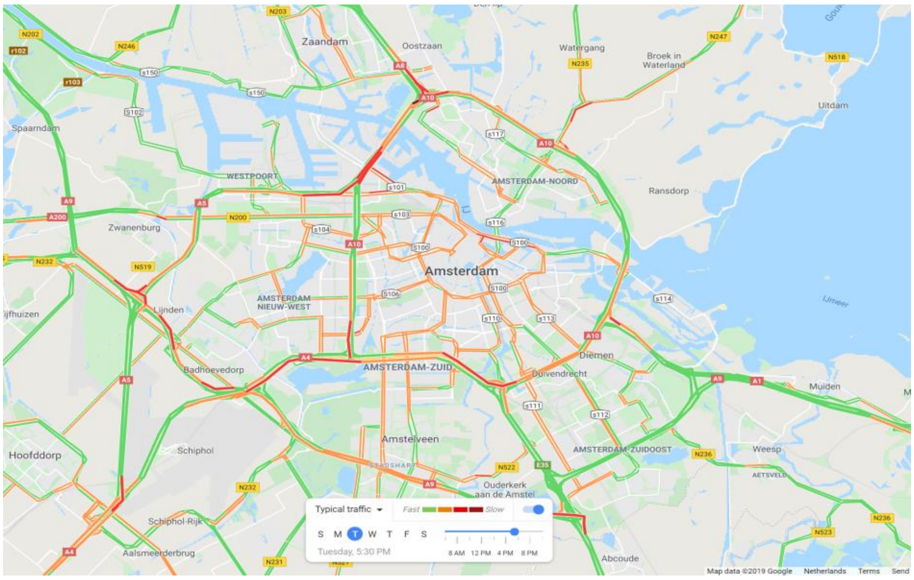


Figure 4-4. Typical traffic Amsterdam region at 17:30 (Retrieved on 18/10/2019)

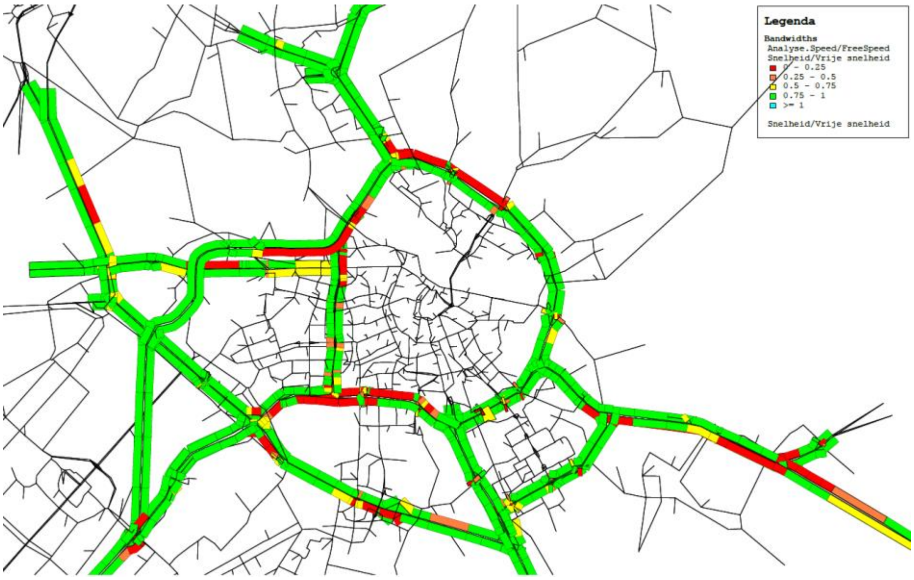
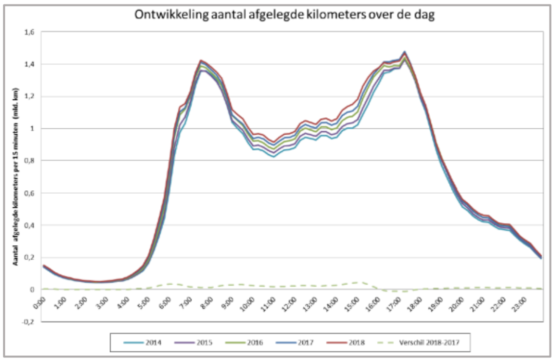


Figure 4-5. Speed/free speed plot from MARPLE at 17:30 (Retrieved on 31/10/2019)

The bottlenecks in MARPLE simulation were compared with bottlenecks in the Google maps, and the saturation flow rates of the bottlenecks and the upstream traffic were adjusted (with a maximum constraint of 2200 veh/h, based on the capacity manual) to keep the consistency between model and reliability. The revised speed plot in regular condition shown in Figure 4-5 mimics a “comparable” congestion pattern with Google maps retrieved on 18th of October 2019.

It is noted that even though the baseline traffic was determined from a worst-case perspective. The seasonal effects were not considered in this study. According to the periodical mobility report **(RWS, 2019)**, the congestion severity over the Netherlands in November and December is highest from 2017 to 2018. The traffic from August to October (shown in Figure 4-7) is less congested as of holiday seasons, which reveals that the congestion pattern would vary and become more serious when retrieving the typical traffic condition from Google maps at the end of the year. Since all simulation works should be based on a same “reference”, it is not possible, with the scope of this research, to wait until more congestion patterns have been obtained and set multiple network baselines to take seasonal effects into consideration. Therefore, the process of performance calibration was stopped after weeks of work, and the revised congestion pattern derived from MARPLE is regarded to be comparable with the current situation, based on the practice of **Transpute (2008)**.



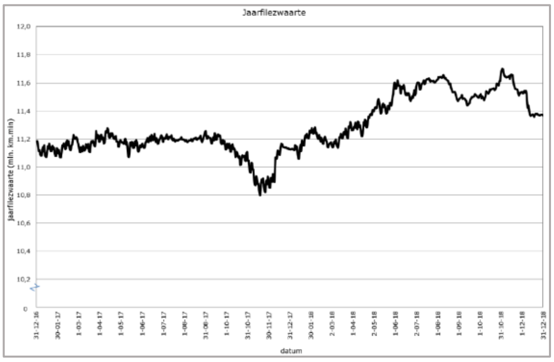


Figure 4-6. Average traffic intensity over a day from 2014 to 2018 (RWS, 2019)
Figure 4-7. Congestion severity over the whole Netherlands from 2017 to 2018 (RWS, 2019)

The adjusted links for the aim of physical adjustment and performance calibration can be found in Appendix A, B & G. Additionally, speed plots derived from MARPLE in each time window (with a half-hour interval) are also provided to represent the modified traffic behaviors, shown in Figure B-1.

5. Simulation Module II: Modification of DTM Malfunctions

Following the methodology described in Chapter 3, this chapter deals with the simulations of the DTM malfunctions in different location scenarios. The RHL and MTM malfunctions were evaluated by allocating capacity-constrict events into the network with different start/end times. The malfunction effects of DRIPs and RM are obtained by comparing the traffic state after their removal from the initial network condition. Changes in vehicle lost hours is taken as the main performance indicator for the effects of DTM malfunction, according to which the social costs can be further calculated.

Detailed methodology for the malfunction modification of four DTM systems is illustrated in each sub section, through which the simulation answers the sub question (3) at the end of this chapter. Detailed simulation results are attached in Appendix F.

5.1 Malfunctioning of the Rush Hour Lanes

The RHL malfunctions are modified by applying incidents on the involved MARPLE links, with the start/end time as well as the remaining capacities resulting from the "incident". The closure of the RHL due to malfunctions is treated as capacity loss at corresponding road sections, with a lane unavailable during a certain period. The process of the RHL malfunction is shown in Figure 5-1.

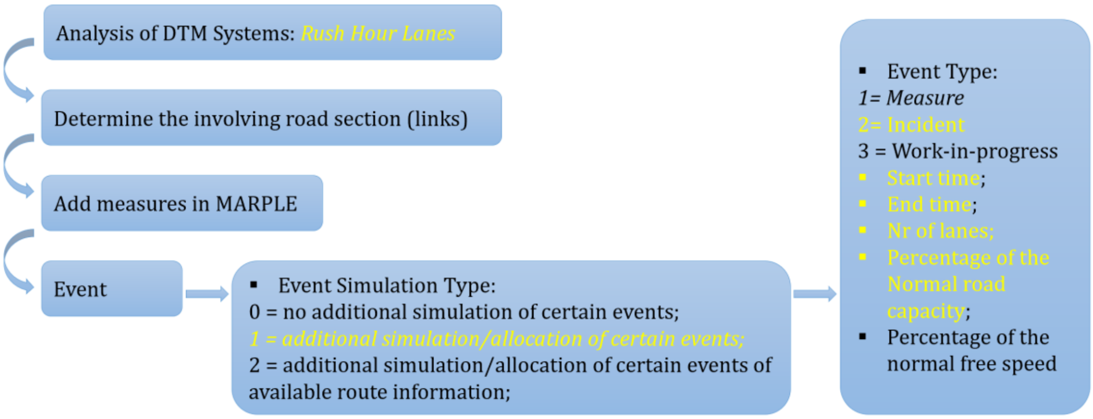


Figure 5-1. Framework of the malfunctioning modification for the rush hour lane

The involved links for the malfunction event are determined by lengths and locations of the RHL stretches. The summed length of all involved links is matched with the actual opening length of the RHL. The failure duration is modified by the inputs of the start and the end time, during which the number of lanes is reduced by 1. The transferring effects of the RHL closure is achieved by the percentage of remaining capacity, and it is calculated by subtracting a 900 veh/h from the original capacity. Detailed input scripts for the malfunction modification can be found in Appendix C-1.

It is expected that the RHL malfunction outside the regular opening times would cause no effect to the traffic, because it is always closed regardless of the malfunction. In this sense, the RHL malfunction at A7-A8 stretch in the direction from Zaandam to Oostzaan is excluded in this research, as it only opens in the morning from 5:30 to 10:30 on weekdays and the model is only prepared for an extended evening peak period from 14:30 to 20:00.

In order to have a stable traffic pattern allocated in the network before the malfunction occurs, a five-hour period from 15:00 to 20:00 is taken as the range of malfunction time windows. As the malfunction with same duration but at different time periods is expected to cause different levels of disruption to the traffic, four timing series with different starting times (from 15:00 to

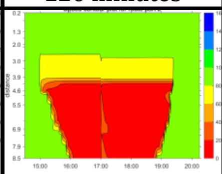
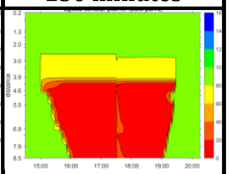
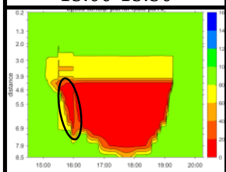
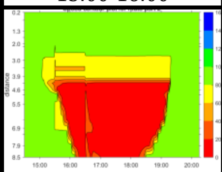
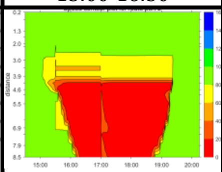
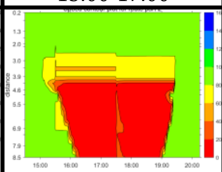
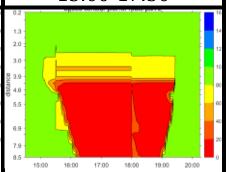
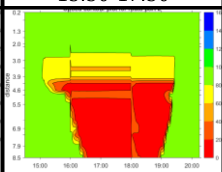
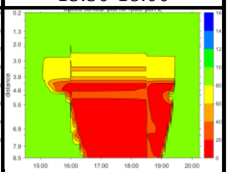
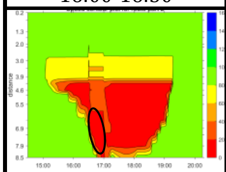
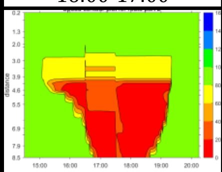
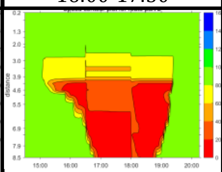
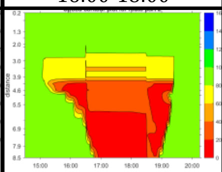
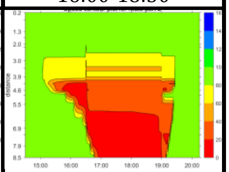
16:30) were conducted with every half-hour movement. In this way, the critical downtimes of half-hour, one-hour, two-hour and so on with the most VVU increment could be determined, according to which a checklist of all worst cases with different malfunction durations can be obtained.

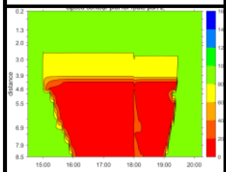
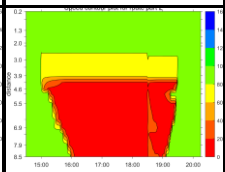
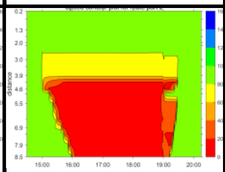
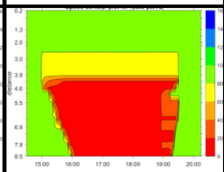
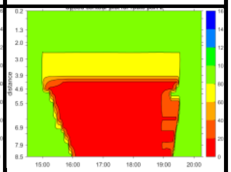
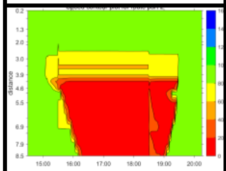
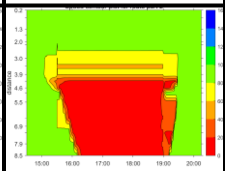
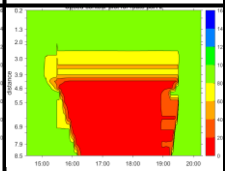
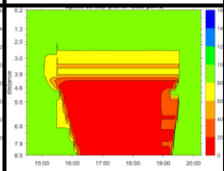
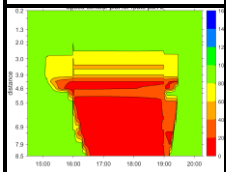
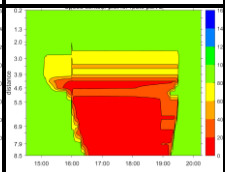
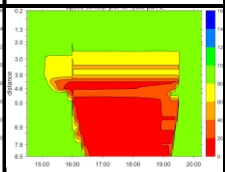
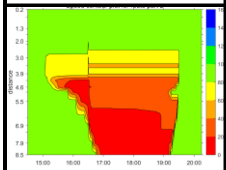
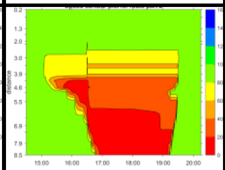
The RHL stretch on A4L and A10L in the direction from west to east was firstly tested, it is found that the malfunction starting from 15:00 generally leads to the most VVU increment, in situations when the malfunction is longer than 1 hour. With practical considerations of required recovery time of the RHL malfunction within four hours, and time feasibility in this research, the malfunction series starting from 15:00 is taken as the baseline for the malfunctions of all three RHL stretches (RHL stretches on A4/A10 in both directions and on A8/A7 in northbound direction)

5.1.1 Rush Hour Lane A4L-10L (Direction Badhoevedorp to Amstel)

The contour plots for the route from the interchange A4/A9 to the interchange A10/A2 (corridor A4L plus corridor A10SBL) are given with every half-hour increment. The yellow-orange-red area in the plots represents the jams through the simulation period. It can be seen from the contours that the maximum queue length is around 6 kilometers from 8.5 km (A10 Li 20.2) to 2.3 km (A4 Li 1.2) of the route, the queue is formed at different times among each malfunction scenario. It can also be observed that the affected traffic with the malfunction is moving from the route upstream to the route downstream with the delay in malfunction starting times. Take the half-hour malfunction as an example, the affected traffic (marked by the black circle in the first column of Table 5-1) would form a queue from 6.9 km (A10 Li 18.8) to 3.0 km (A4 Li 0.5) of the route when the malfunction starts at 15:00, a queue from 7.9 km (A10 Li 19.8) to 2.8 km (A4 Li 0.7) when the malfunction starts at 15:30, and a queue from 8.5 km (A10 Li 20.2) to 2.7 km (A4 Li 0.8) when the malfunction starts at 16:00 or 16:30.

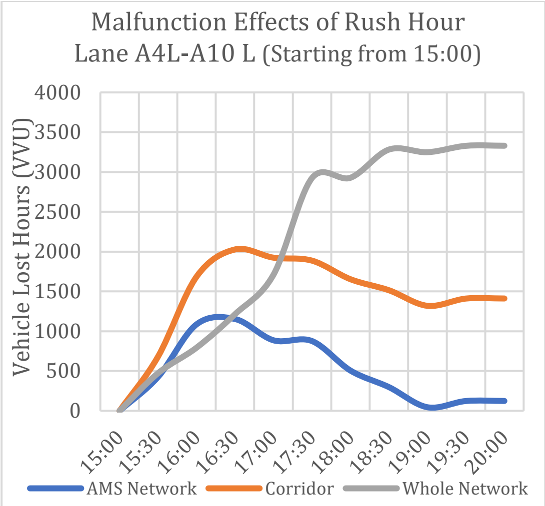
Table 5-1. List of speed contour plots of the RHL stretch A4L-A10 L

30 minutes	60 minutes	90 minutes	120 minutes	150 minutes
 15:00-15:30	 15:00-16:00	 15:00-16:30	 15:00-17:00	 15:00-17:30
 15:30-16:00	 15:30- 16:30	 15:30-17:00	 15:30-17:30	 15:30-18:00
 16:00-16:30	 16:00-17:00	 16:00-17:30	 16:00-18:00	 16:00-18:30
 16:30-17:00	 16:30-17:30	 16:30-18:00	 16:30-18:30	 16:30-19:00

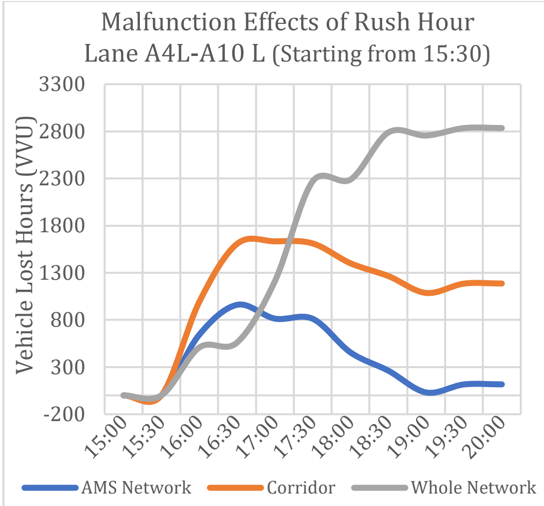
180 minutes	210 minutes	240 minutes	270 minutes	300 minutes
 15:00-18:00	 15:00-18:30	 15:00-19:00	 15:00-19:30	 15:00-20:00
 15:30-18:30	 15:30-19:00	 15:30-19:30	 15:30-20:00	-
 16:00-19:00	 16:00-19:30	 16:00-20:00	-	-
 16:30-19:30	 16:30-20:00	-	-	-

The size of the congestion area in the contour plots also indicates the severity of the jam. With a half-hour malfunction, the congestion area of malfunction scenario from 15:30 to 16:00 is largest compared with other time periods. Therefore, it can be inferred that the worst half-hour malfunction lies in the time series of 15:30. Similarly, the worst one-hour malfunction can be expected with a downtime between 15:00 to 16:00, by direct visual judgement according to the contour plots.

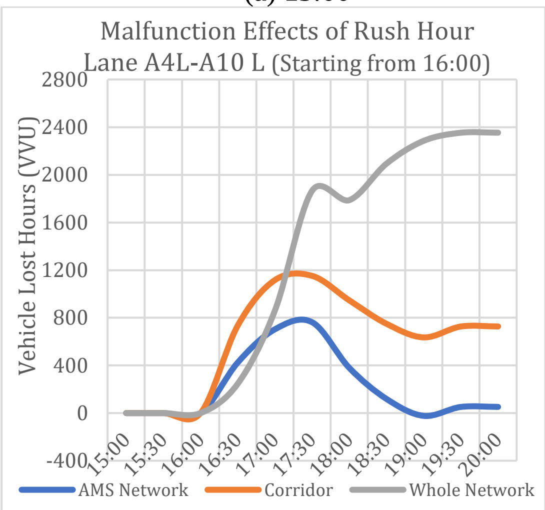
Based on the performance figures of each network part, the delay curves (in terms of changes in vehicle lots hours) are generated at different aggregatation levels: the corridor level, the AMS network level and the whole regional network level. The corridor level refers to the failure trajectory where the malfunction occurs, since the RHL stretch from Badhoevedorp to Amstel involves 2 corridors (A4L and A10SBL), the failure trajectory in this case is defined as the sum of two involved corridors. The AMS network refers to the motorway network defined in this study, including the ring road A10 and 5 motorway connecting corridors A1, A2, A4, A5, A8 and a non-motorway corridor N200. The whole network refers to the total regional network including other motorway parts as well as the urban road network. In the model environment, the whole regional road network is composed of 4,637 links, 2,549 nodes, 350 pairs of origin-destination, and a total number of 107,014 routes are formulated for the traffic through the network. The delay curves under four malfunction time series at three different aggregation levels are shown in Figure 5-2 from (a) to (d).



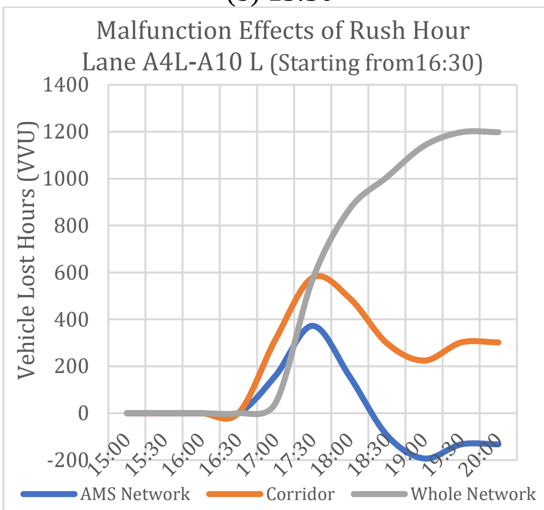
(a) 15:00



(b) 15:30



(c) 16:00



(d) 16:30

Figure 5-2. VVU effects of the RHL malfunction A4L-A10L
(starting from 15:00, 15:30, 16:00 and 16:30)

It is observed from Figure 5-2 that the RHL malfunction on stretch A4L-A10L could lead to an overall delay increase at the whole regional network level with the increase of failure durations. In comparison, the total delay changes at the AMS network level and at the corridor level are expected to increase to a peak and then fall back to a stable value. The growing phases are generally from the first 60 to 90 minutes of the malfunction regardless the starting times (the delay curve reaches its peak at 16:30 when the malfunction starts at 15:00 and 15:30, the delay curve reaches the peak at 17:30 when the malfunction starts at 16:00 and 16:30). It is noticed that there is always a pit from 19:00 to 19:30 on delay curves at both corridor and AMS network level, and a pit from 18:00 to 18:30 on delay curves at regional network level, route choice behaviors of road users are the main cause of the VVU drop since less intensities are observed as the response to the capacity reductions.

As the product of the RCMCost analysis applied for the DTM systems is the unforeseen non-availability hours **(Delta Pi, 2018)**, exactly when the malfunction would start in practice is not predictable, the worst-case strategy is adopted to compare the effects with the same malfunction durations. The delay curves were reconstructed according to the absolute malfunction durations, which was done by moving the delay curves in Figure 5-2 to the same start point. Shown in Figure 5-3, 5-4 and 5-5 are the reconstructed delay curves at the failure corridor level, the AMS network level and the regional network level, respectively.

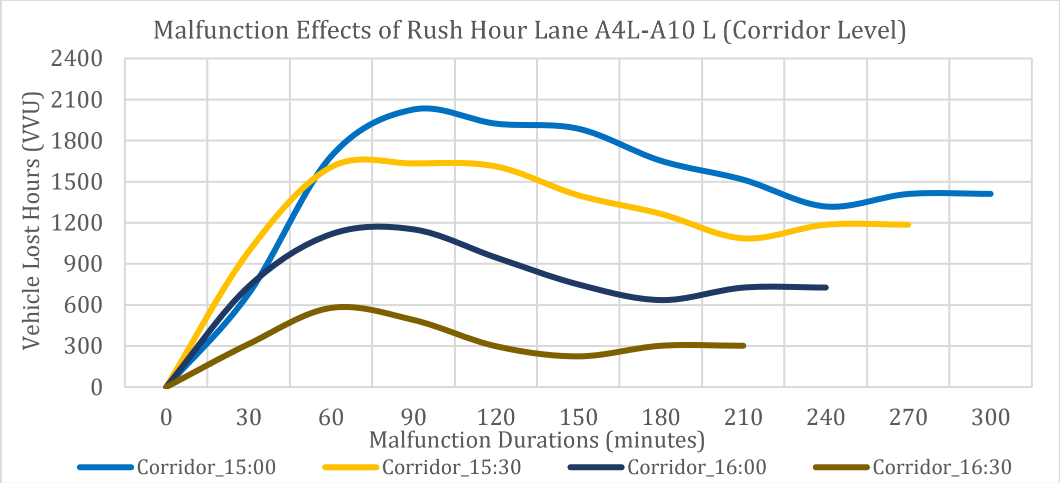


Figure 5-3. VVU effects of the RHL malfunction A4L-A10L (Failure corridors)

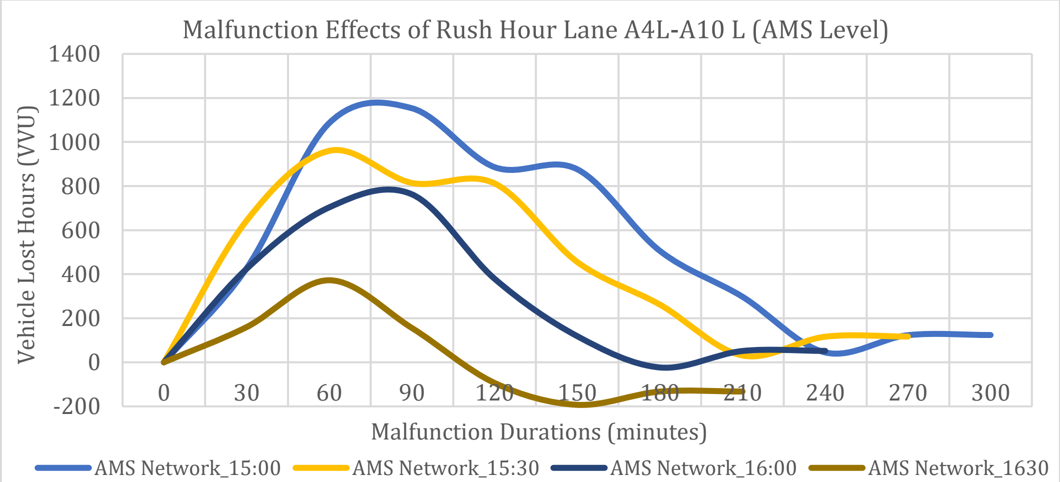


Figure 5-4. VVU effects of the RHL malfunction A4L-A10L (AMS network)

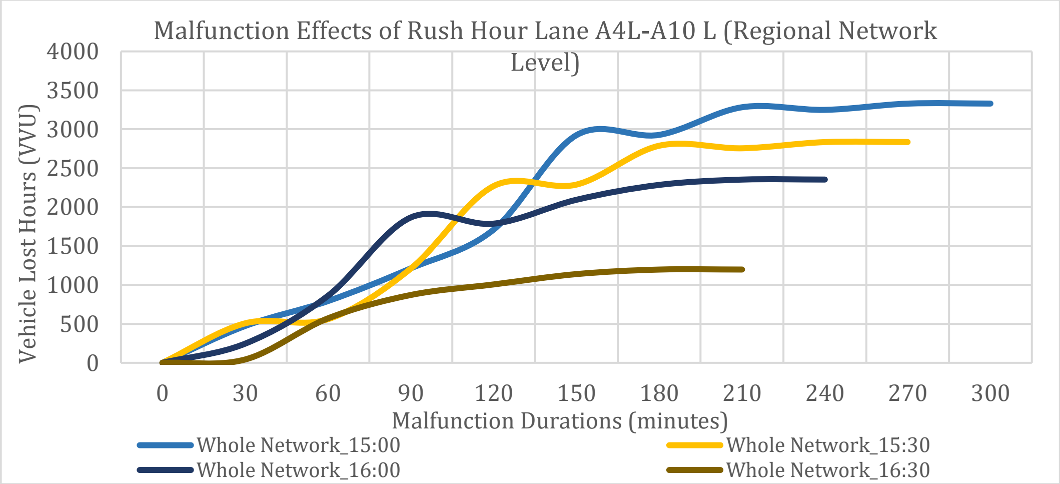


Figure 5-5. VVU effects of the RHL malfunction A4L-A10L (Regional network)

It can be observed that the total delays are generally highest when the malfunction starts from 15:00, compared with the delay curves at AMS network level and at the corridor level. The exception is that the malfunction from 15:30 to 16:00 causes more VVU increase than the malfunction from 15:00 to 15:30, which confirms the visual judgement according to the size of the congestion area in contour plots. However, when the malfunction duration is longer than 1 hour, the most delays would still be expected at the curve with the malfunction starting from 15:00.

With regarding to malfunction effects at the regional network level, the conclusions derived from the AMS network and corridor levels do not hold anymore. The worst half-hour and 2-hour malfunction were observed at the delay curve starting from 15:30, and the worst one-hour and 1.5-hour malfunction were observed at the 16:00 series. When the malfunction lasts longer than 2 hours, the highest delay would be expected at the 15:00 time series. As the focus of this research is on the motorway network, the effects at the AMS network and the failure corridor levels are preferred. For the malfunction effects at these two levels, the delay curve starting from 15:00 could be taken as the worst-case curve as it is generally higher than other time series.

Effects on each motorway corridor in AMS network are also checked, and the simulation results can be found in Appendix F-1. Most of the increased VVUs are at the corridor A4L, the VVUs at corridor A10SBL are not changed much, and even less than the regular condition when the malfunction is longer than 4 hours, which is resulting from the reduction in total travel distance (TTD) of 9,798.8 vehicle kilometers at this corridor. There are two main reasons for the TTD reduction at this corridor, the blocked traffic upstream and the route choice behaviors. The TTD changes as a result of the RHL malfunction at corridor A4L and A10SBL are shown in Figure 5-6, it is found that the downstream corridor A10SBL is always with higher TTD reduction.

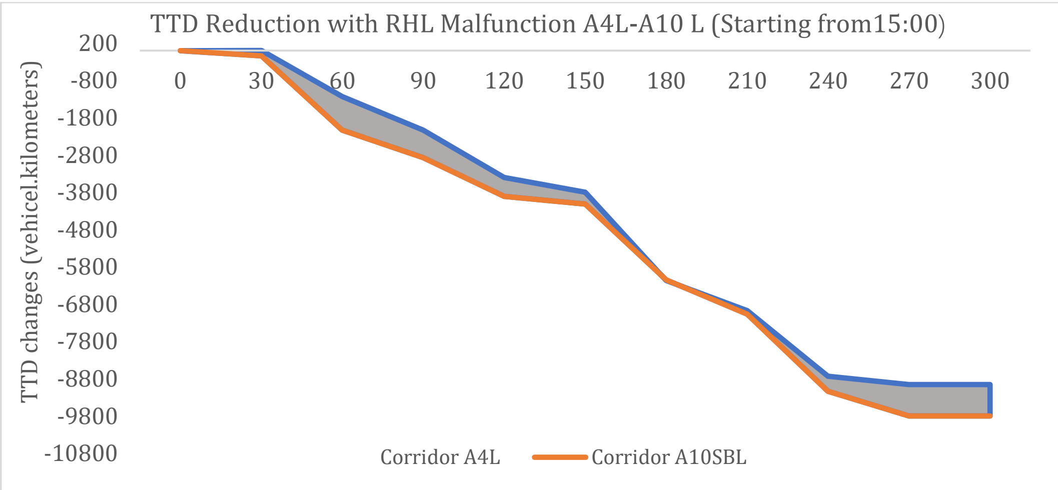


Figure 5-6. TTD changes at failure corridors (A4L & A10SBL)

The reduced intensity at the corridor A4L can roughly represent the blocked traffic to corridor A10SBL, since another downstream corridor A10SWR was less affected by the blocked traffic on A4L. Therefore, the shadowed area in Figure 5-6 can also roughly indicate the extra demand decrease due to route choice behaviors, since the TTD on another upstream corridor A10SWL increased 671.7 veh.km and thus the traffic on A10SWL did not contribute to the TTD reduction on corridor A10SBL.

5.1.2 Rush Hour Lane A10R-A4R (Direction Amstel to Badhoevedorp)

The total length of the RHL stretch on corridor A10R and A4R in the direction from east to west is 3.62 kilometers, while the hard shoulder is not continuously used for the RHL through the whole motorway stretch. At the location of "*A10 Re20.0 km*", the RHL is merged into the right-hand direction to the ring west "Leeuwarden Zaanstad / Amsterdam Slotervaart (s107)". From the location of "*A4 Re1.80 km*", the hard shoulder is again available for the RHL after the merging with traffic from A10 west, until the off-ramp to "Amsterdam-Sloten (*A4 Re2.72 km*)". Though these two separate parts of the RHL stretch are not with the same hard shoulder, and it is possible that one is closed while the other one remains open. In this research, it is assumed that the malfunction will lead to the closure of all these two RHL parts together.

Following the findings from the malfunction scenario of the RHL stretch in reverse direction and for simplicity, malfunction simulations were only conducted for the time series starting from 15:00. Shown in Figure 5-7 and Figure 5-8 are speed contour plots for the RHL part at corridor A10SBR (inner ring), and the VVU changes across the time at different network levels.

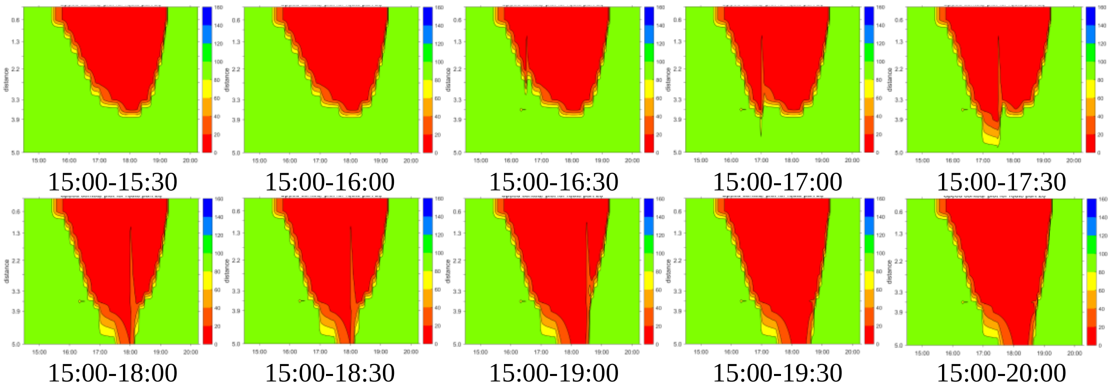


Figure 5-7. Speed contours corridor A10SBR (RHL malfunction A10R-A4R)

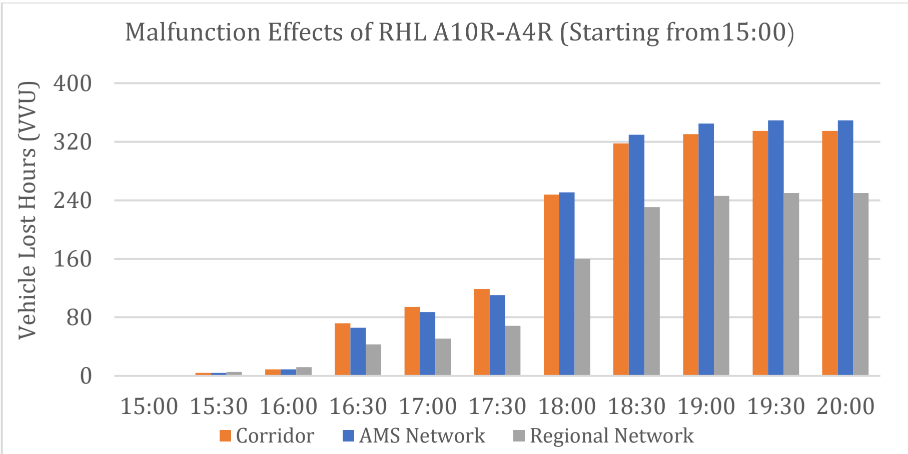


Figure 5-8. VVU changes with the RHL malfunction (A10R-A4R)

With a five-hour malfunction starting from 15:00, a total 334.6 VVUs are increased at the corridor level (sum of corridor A10SBR and corridor A4R), the malfunction effects are almost same both at the corridor level and the AMS network level. The aggregate effects are generally smaller at the regional network level, caused by the decrease of the intensity at the rest parts of the whole regional network, and therefore less calculated delays at those network parts. The variation between the curves at different network levels represents the propagation of the malfunction effects. The closer of the curve values at the corridor level and the AMS network level indicates that the effects are more restricted locally; the closer of the curves at the AMS network level and at the regional network level represents the affected traffic are more accommodated within the AMS network.

As shown in Figure 5-8, there is almost no added effect to rest parts in AMS network, only the corridor A2L are affected by the RHL malfunction, which is one upstream corridor of the RHL stretch. The increased delay on corridor A2L is mainly caused by spillback effects (the intensity at this corridor remains unchanged). The VVU changes at corridor A2L remain stable at the first two malfunction hours, and the VVUs suddenly increased from 7.3 to 19.2 vehicle hours when the malfunction still lasts at 18:00, which is consistent with the contour plots shown in Figure 5-7: the jam length keeps growing with the increase of malfunction hours, it propagates to the end of corridor A10SBL at 18:00, and since then the upstream corridor A2L starts to be affected by the malfunction.

Similar with the RHL malfunction in the reverse direction, most of the increased VVUs were observed at the upstream of the RHL stretch. The VVUs increased 301.3 veh.hrs at corridor A10SBR and 33.3 veh.hrs at corridor A4R. The intensity was less affected at the failure section, a total of 264.6 vehicle kilometers reduced at these two corridors with the malfunction from 15:00 to 20:00.

5.1.3 Rush Hour Lane A8R-A7R (Direction Zaandam to Purmerend-Zuid)

As the general opening time of the RHL A8R-A7R in northbound direction during weekdays is from 14:00 to 19:00, which indicates that the extra capacity provided by the RHL could not be taken as permeant during the whole simulation period. At the same time, the malfunction from 19:00 to 20:00 is believed to produce no effect to the traffic since the RHL is supposed to be closed during this period. Therefore, the malfunction of the RHL A8R-A7R is analyzed with a four-hour (15:00 to 19:00) period.

In addition, as the RHL parts on A8 and A7 are using the same hard shoulder, it is not realistic for the case in which only the A8 part is closed due to malfunctions while the A7 part remains open. Even though the defined AMS network ends at the interchange A8 and A7, it is still necessary to close the whole RHL section in malfunction scenarios. The VVU changes on A7 are provided as the reference of the malfunction effects not included in AMS network, while the VVU changes at the corridor level refers to the sum effects at both corridor A8 and A7.

It is found that the malfunction of the RHL stretch A8R-A7R has limited impacts to the AMS network, the model results are logical as the RHL starts downstream of the bottleneck identified in MARPLE simulation and in google maps. Furthermore, the simulation results also indicate that this malfunction has no effect to other parts of the AMS network, as the traffic on A8R and A7R is leaving the AMS network and no blocked traffic was produced due to the malfunction.

It can also be found that the increased vehicle lost hours are mainly at the A7 trajectory with an average speed decrease of 4.9 km/h. With a four-hour malfunction, the delay increased 52.8 VVUs on A7 and 1.7 VVUs on A8, the route choice was not affected by the closure of the RHL. As the A7 motorway is not included in the defined AMS network, most of the increased VVUs could only be observed at the corridor level, thus Figure 5-9 only presents the VVU changes at the corridor level.

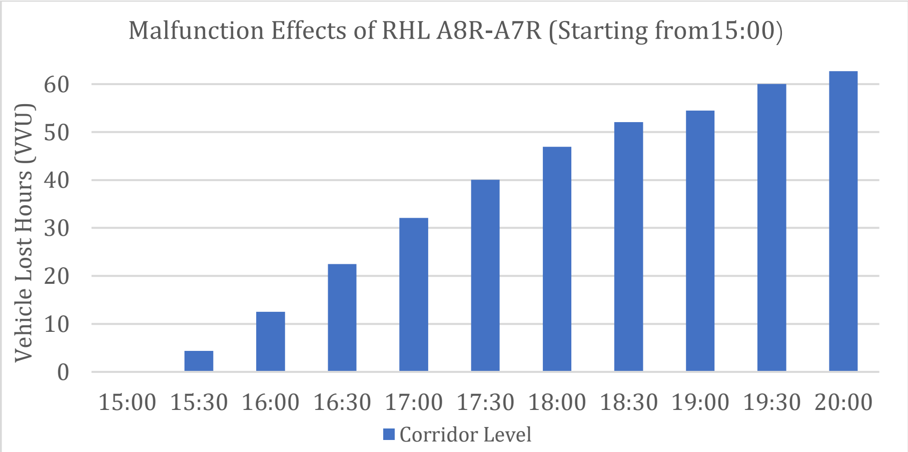


Figure 5-9. VVU changes with the RHL malfunction (A8R-A7R)

5.2 Malfunctioning of the MTM (AID function)

The MTM malfunctions are modified with the same process of the RHL malfunction, while the remaining capacities are different. In this section, only flow effects of the MTM (AID function) are investigated, the modification process is shown in Figure 5-10.

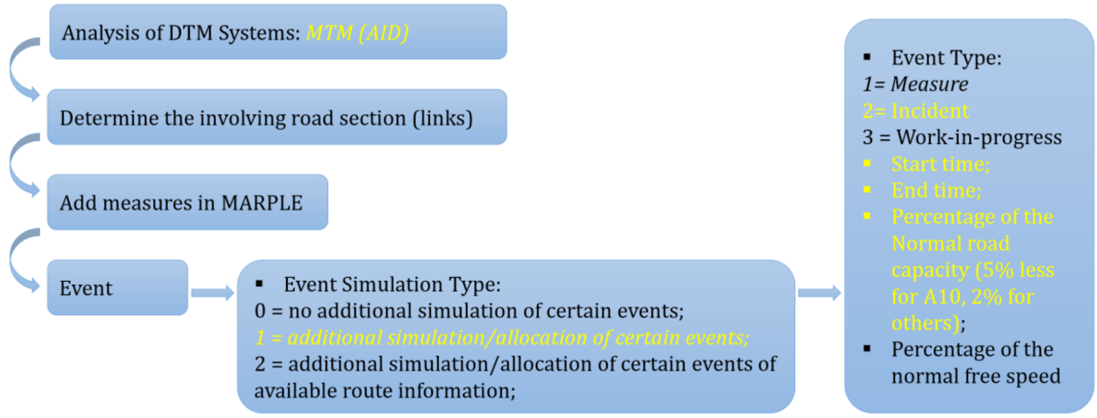


Figure 5-10. Framework of the malfunctioning modification for MTM (AID function)

According to previous evaluations for the MTM signaling system, especially for the *Automatic Incident Detection & congestion warning* (AID) function, a 5% capacity gain was observed at the western part of motorway A10, and a 2 % on average increase in capacity was utilized from the evaluations of other motorway parts, as illustrated in Chapter 2. It is assumed that when the MTM system is not in service, the road capacities would reduce 5% on A10 and 2% on other motorway segments.

In this section, the MTM malfunction at five connecting corridors (A1, A2, A4, A5, A8) and two A10 sub corridors (A10SB & A10SW) in both directions are investigated, as illustrated in each sub section.

5.2.1 MTM on A1 corridor

- **A1 L (Direction to Ring Amsterdam)**

The MTM (AID) malfunction in terms of 2% capacity drop at A1 corridor in the direction to Amsterdam almost has no effect to the traffic. With the increase of malfunction durations, only 6.6 vehicle lost hours have been increased with a 0.4 km/h speed decrease at this corridor.

- **A1 R (Direction leaving Ring Amsterdam)**

The vehicle lost hours only increased at the failure corridor (A1R) itself. With the increment of malfunction hours, the VVUs at the failure corridor showed a steady growth. A total of 111.5 more vehicle lost hours were produced without the AID function for 5 hours, accompanied by 224 less vehicle kilometers at this corridor. Shown in Figure 5-11, the delay changes are always negative at the regional network level, it is because of the greater intensity reduction outside the AMS network.

The VVU changes at the AMS network level increased slightly at the first malfunction hour, and started to decrease from 16:00 to 17:30 with less intensity at the AMS network, since when the VVU increase at the failure corridor A1R could not compensate the VVU decrease at other parts of the AMS network. The overall delay again showed a growing pattern after 18:00, which reveals that the intensity reduction after three hours' malfunction was not significant compared with the increased VVUs resulting from the capacity loss.

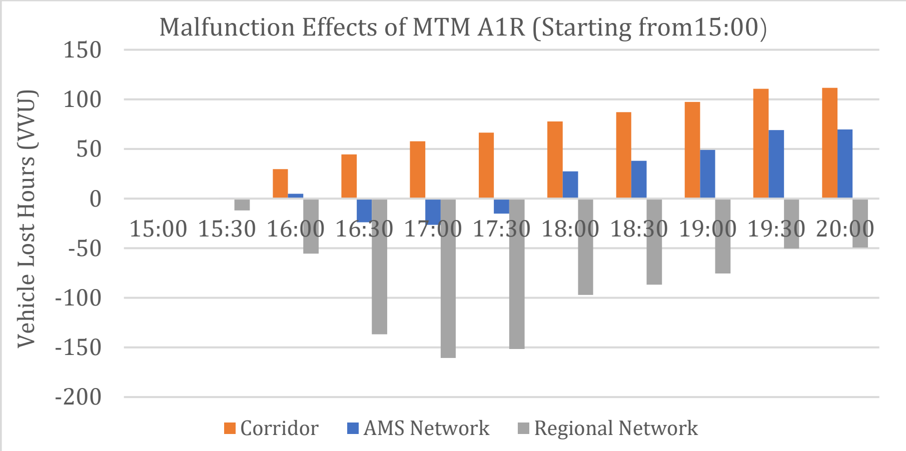


Figure 5-11. VVU changes with MTM (A1R) malfunction

5.2.2 MTM on A2 corridor

- **A2 L (Direction to Ring Amsterdam)**

The malfunction of MTM (AID) at the corridor A2 in the direction to the ring is expected to contribute negative effects only at the failure corridor, while only 0.3 VVU is increased with a 5-hour MTM malfunction.

- **A2 R (Direction leaving Ring Amsterdam)**

A 2% of capacity drop at the corridor A2 in the direction of leaving the ring A10 can have slight spread effects at adjacent corridors A10SBR and A10SEL. The delays increased 6.3% from 122.4 to 130.1 VVUs at the failure corridor, and the overall delay development in the AMS network is 101.5 vehicle hours, of which corridor A10SEL contributed most with 49.3 VVUs.

5.2.3 MTM on A4 corridor

- **A4 L (Direction to Ring Amsterdam)**

The MTM malfunction at the corridor A4R has limited impacts on the total vehicle delays, the VVUs are observed to increase only at the failure corridor, which increased 2.2% from 1,786 to 1,825 vehicle hours with a five-hour malfunction.

- **A4 R (Direction leaving Ring Amsterdam)**

The increase of the VVUs at the failure corridor A4R is not significant with MTM malfunction, a total of 10.2 more VVUs at corridor A4R were observed with a 5-hour malfunction.

It is noticed that upstream of the failure corridor A4R, corridor A10SBR contributed the most delay increment with the MTM malfunction, where the delays increased 6.3% from 2,955 to 2,757 VVUs. The speed contours for the route following the A10SBR are shown in Figure 5-12, the MTM malfunction caused extra queue length of one kilometer from 18:00 when the malfunction is longer than 90 minutes.

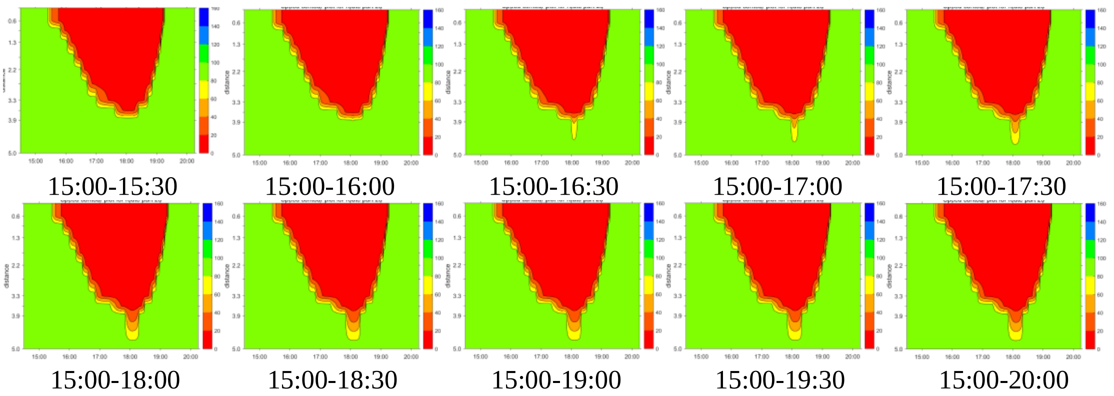


Figure 5-12. Speed contours corridor A10SBR (malfunction of AID function at A4R)

5.2.4 MTM on A5 corridor

A 2% capacity drop at corridor A5L can hardly have effects on the traffic, a slight delay change from 10.6 to 11.1 VVUs was observed at the failure corridor. The MTM malfunction at the corridor A5R also only contributed the delay increase at the corridor itself, the VVUs increased 24.6 vehicle hours in the 5-hour malfunction scenario.

5.2.5 MTM on A8 corridor

- **A8 L (Direction to Ring Amsterdam)**

The VVUs only increased 4.5% at the failure corridor A8L, it could be taken as no effect at all considering that only 0.4 VVUs increased with a 5-hour malfunction.

- **A8 R (Direction leaving Ring Amsterdam)**

Compared with the malfunction at A8L, the malfunction in reverse direction A8R produced more delays to the traffic. At the failure corridor, the VVUs got slightly increased with 11 vehicle hours, accompanied by 1,743 veh.km of less travel distance. The increased VVUs are mainly at corridor A10NER and upstream corridor A10NBL. The total delays increased 170 VVUs at the AMS network, together with 842 more vehicle travel kilometers.

It is not surprised that the upstream corridor suffered from the MTM malfunction at corridor A8R, as the bottleneck is located at the beginning of the failure corridor, a slight capacity drop could leave considerable negative effects to the upstream traffic. While corridor A10NER also suffered from the malfunction at A8R, which was not expected before the simulation.

In order to find explanations for this phenomenon, the TTD changes at adjacent corridors were also checked. The traffic comes from corridor A10NER is also upstream of the traffic at A8, and it is noticed that the TTD at A10NER slightly increased 21 veh.km, while the TTD at downstream corridors A10NBR and A10NER increased 793 and 1,144 veh.km respectively. Based on the TTD changes, it could be inferred that part of the traffic continued the movement at the inner ring instead of entering A8R in MTM malfunction scenarios, and the increased traffic at the corridor A10NER is the main attribute to the VVU increase.

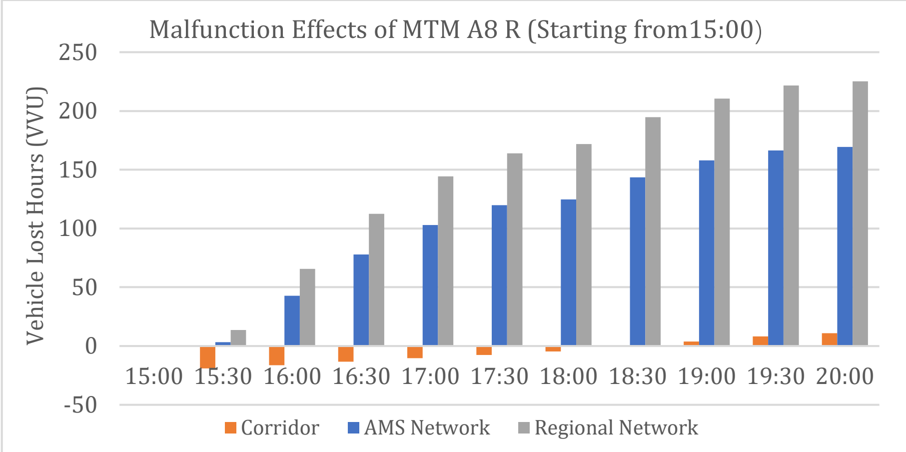


Figure 5-13. VVU changes with MTM (A8R) malfunction

5.2.6 MTM on A10 Southbound

- **A10 SBL (Outer Ring)**

The MTM malfunction with 5% capacity drop at corridor A10SBL led to considerable effects to the failure corridor and also upstream corridors A4L and A10SWL. The downstream corridor A2R was also affected, the vehicle lost hours reduced 31.0% as the result of 1.24% less traffic intensity at this corridor, the decreased traffic was blocked by the upstream bottleneck at the failure corridor. The speed contours for the most affected upstream corridor A4L are provided in Figure 5-14 to indicate the congestion pattern across the time.

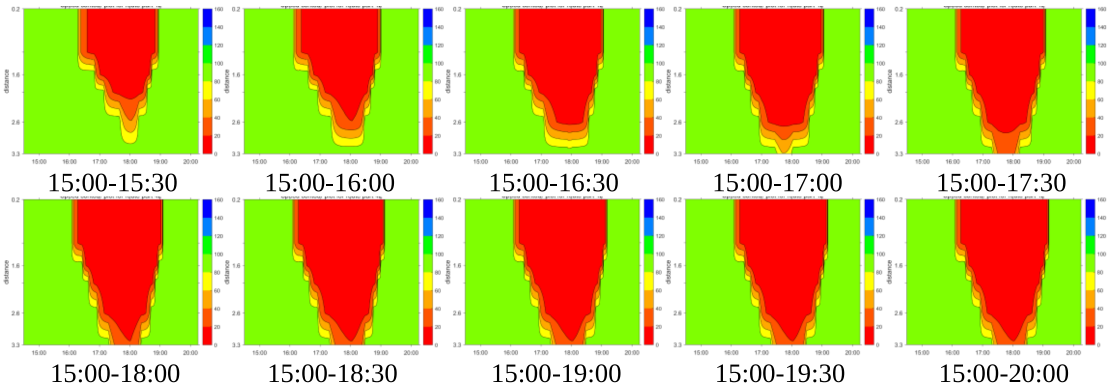
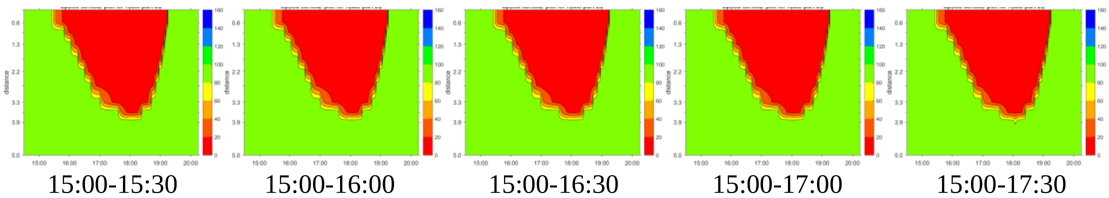
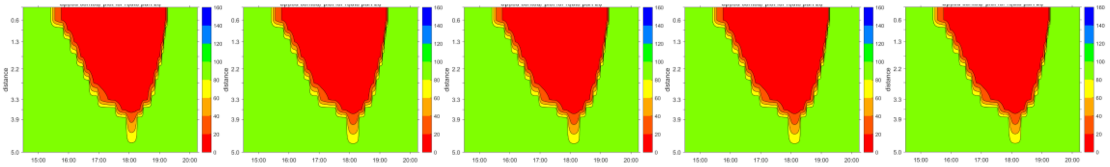


Figure 5-14. Speed contours corridor A4L (malfunction of AID function at A10SBL)

- **A10 SBR (Inner Ring)**

In comparation, the MTM malfunction at the same motorway corridor but in reverse direction A10SBL, contributed less impacts to the traffic. Other parts of the AMS network were almost not affected at all, only the VVUs at the failure corridor increased 8.9% (230.5 veh.hrs) with a 5-hour malfunction.





15:00-18:00 15:00-18:30 15:00-19:00 15:00-19:30 15:00-20:00

Figure 5-15. Speed contours corridor A10 SBR (malfunction of AID function)

As of the substantial effects with the malfunction at both sides of corridor A10SB, the VVU changes with the increase of malfunction durations at different aggregation levels are visualized, shown in Figure 5-16 and 5-17. Owing to the particularity of ring corridors, the inner ring and the outer ring levels are also provided as for reference of the propagation within the ring.

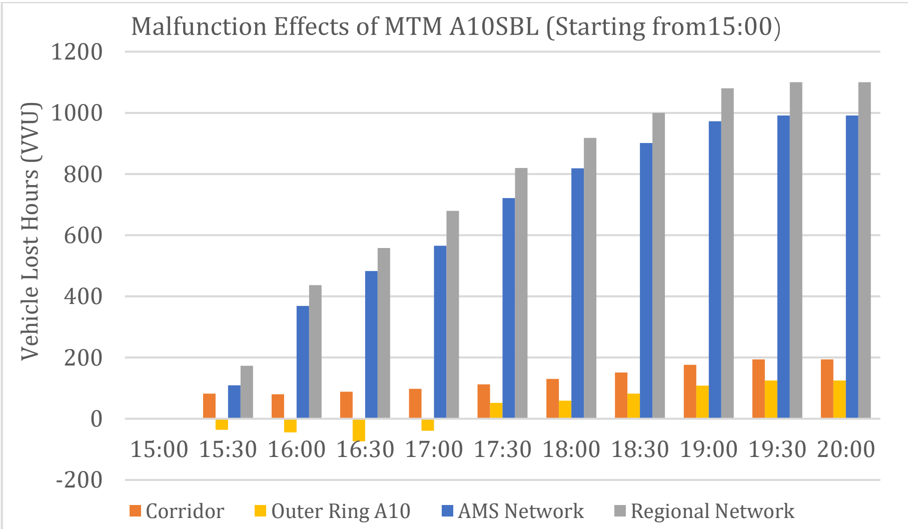


Figure 5-16. VVU changes with MTM (A10SBL) malfunction

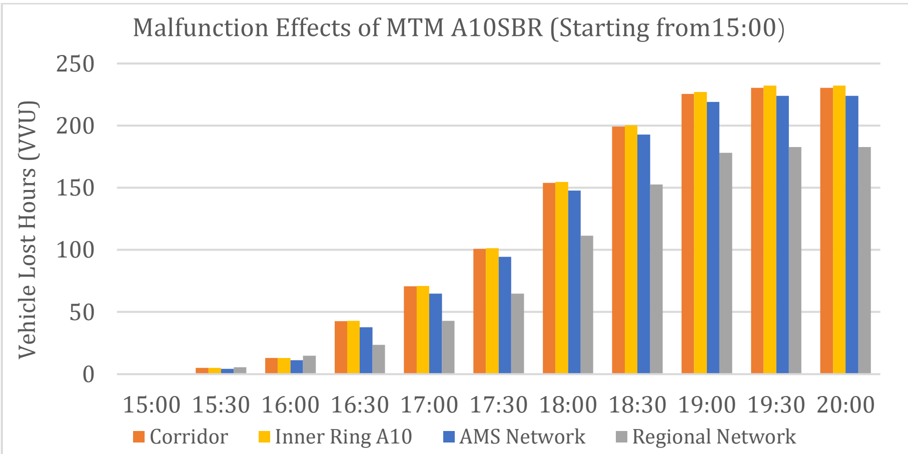


Figure 5-17. VVU changes with MTM (A10SBR) malfunction

5.2.7 MTM on A10 Southwest

- **A10 SWL (Outer Ring)**

The MTM malfunction at A10 SWL with 5% capacity less only produced negative effects on the corridor itself. With five hours' malfunction, the delays at the failure corridor increased 29.6 veh.hrs with unaffected traffic demand, and the average speed was slightly lowered with 0.89 km/h.

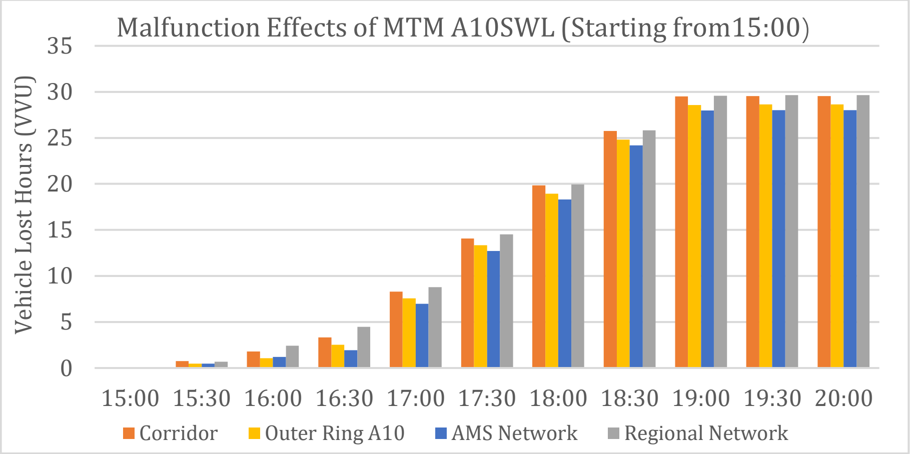


Figure 5-18. VVU changes with MTM (A10SWL) malfunction

- **A10 SWR (Inner Ring)**

The MTM malfunction at corridor A10SWR almost had no effect (2.8% less delays) on the corridor itself, but introduced negative impacts on upstream corridors. The corridor A4L was affected most with 25.7% of delay increase, and corridor A10SBR was also greatly affected with 7.0% more delays in the situation of a 5-hour malfunction.

The increased delay at the AMS network is close to the total delay change at the regional network, which indicated that the MTM malfunction at the corridor A10SWR had been mostly accommodated by the connecting corridors within the AMS network.

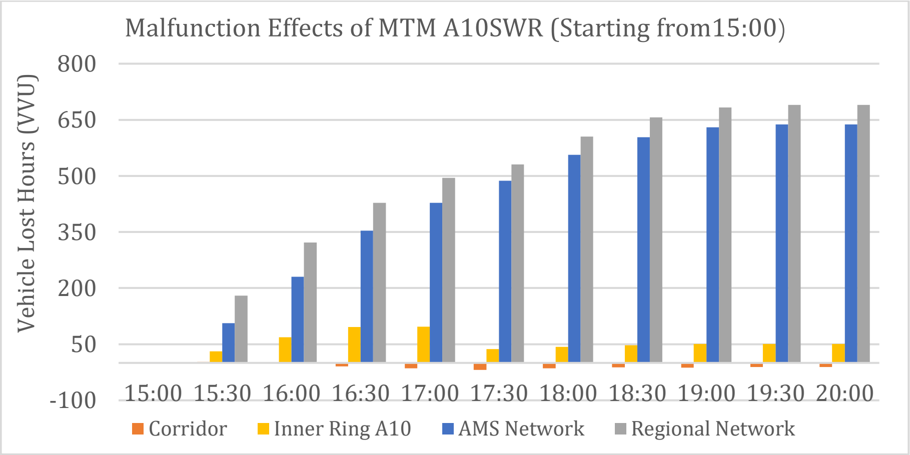


Figure 5-19. Vehicle lost hours with the MTM (AID) malfunction at A10SWR

5.2.8 MTM Ring A10

Malfunctions of the MTM system at multiple locations were also evaluated by reducing 5% of the capacity values of all inner ring and outer ring links, the VVU effects and the TTD changes are also presented in progressive network levels, ranked by the range and size of the network.

- **A10 L (Outer Ring)**

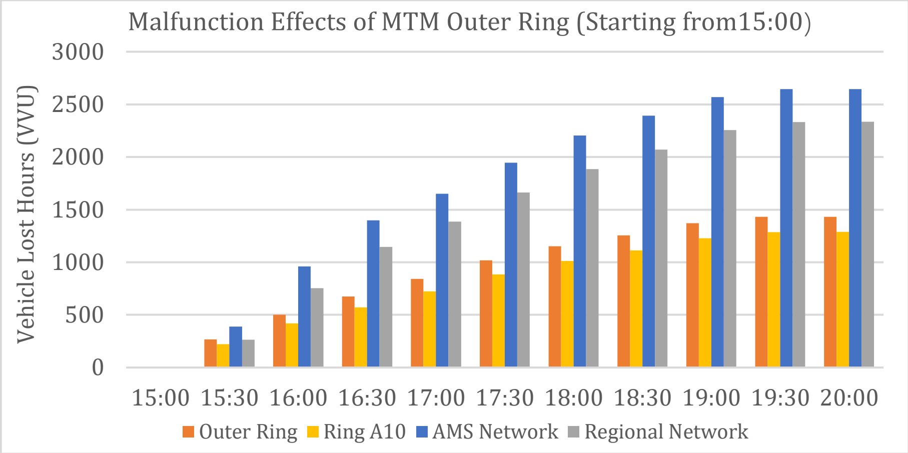


Figure 5-20. VVU changes with outer ring MTM malfunction

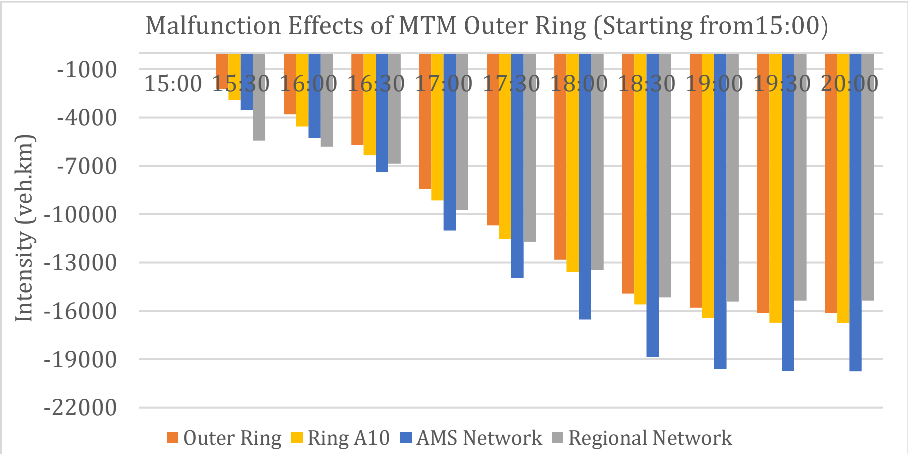


Figure 5-21. Intensity changes with outer ring MTM malfunction

As shown in Figure 5-20, the capacity loss at the outer ring left most delays at the AMS network level, where the increased VVUs at the outer ring are comparable with the increased VVUs at six connecting corridors. The VVUs at the outer ring are generally 11.23-20.0% higher than the VVUs at the whole ring, and the VVUs at the AMS network are generally 13.3-47.7% higher than the regional network, which indicates that the VVUs at the inner ring and the VVUs at the road network outside the AMS network are decreased, as shown in Figure 5-21, those decreased VVUs are mainly resulting from the reductions in intensity.

With the increase of the malfunction hours, the VVUs presented a growing pattern along with the intensity drop at all four aggregation levels. The AMS network level proved to be the most suffering level, where both the intensity drop and the VVU increase are the highest among other aggregation levels.

- **A10 R (Inner Ring)**

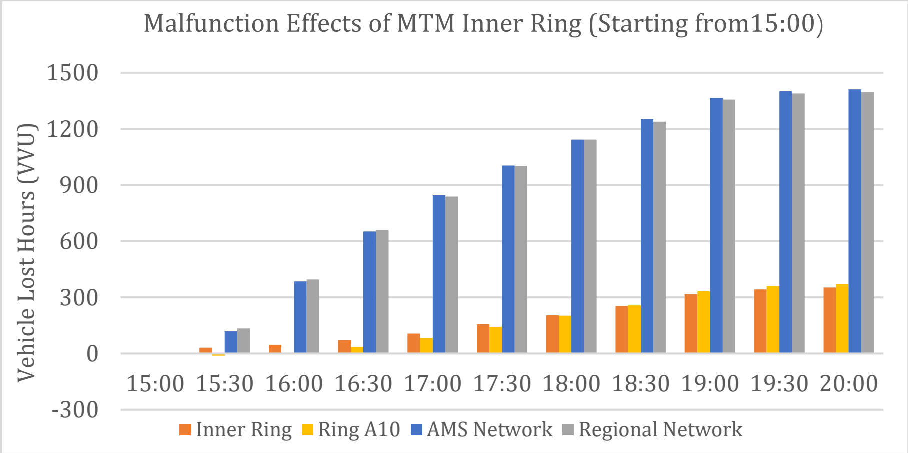


Figure 5-22. VVU changes with inner ring MTM malfunction

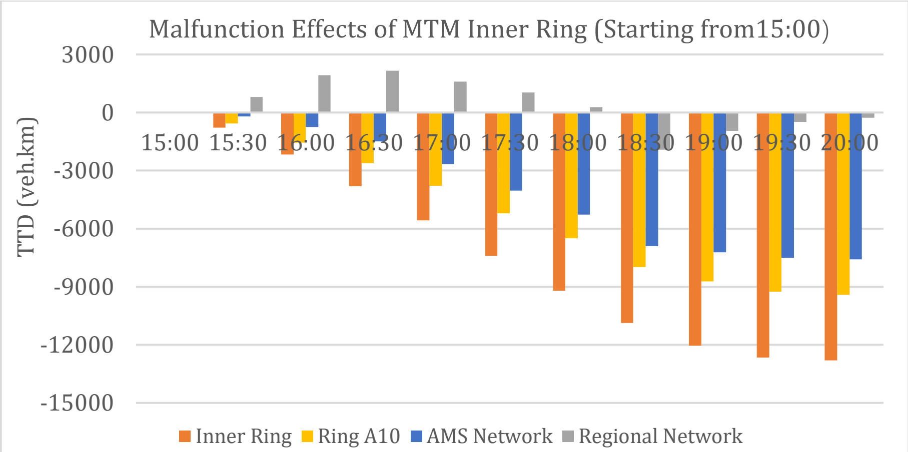


Figure 5-23. Intensity changes with inner ring MTM malfunction

The capacity loss at the inner ring indicated the different responses compared with the outer ring. More than 73.7% of the increased VVUs were observed at the connecting corridors, and the increased VVUs are comparable at both the AMS network level and the regional network level, which revealed that the road network outside the AMS network was less affected by the MTM malfunction at the inner ring, and the TTD change at the regional network level shown in Figure 5-23 confirmed the limited effects to the rest parts of the regional network.

5.3 Malfunctioning of the DRIPs

Two functions are evaluated for the DRIP malfunction, the *dynamic traffic* and the *work-in-progress* introduced in Section 2.5. To specific the aims of the displayed information, these two functions are renamed as the *route travel time indication* and the *rerouting*. As illustrated in Chapter 3, the effects of the DRIP malfunctions are assumed to be equal with the difference after its removal from the initial network condition.

Since different actions would be made among road users even with same informed messages, the user classes should be firstly distinguished in the evaluation of DRIPs, to represent the degree and compliance of the route information among different user types. **Haaijer, Quite & Maaskant (2019)** collected the inquiries and self-reports about the development of roadside information usage and the use of personal navigation devices in the Netherlands from 2015 to 2018. Based on the type of information sources and how much the information is used, **Taale (2019)** sorted the user classes with the percentage of each class fitted for MARPLE simulation, including:

- Road users who are not affected by the route information (26%);
- Road users who are moderately affected by the information (14%);
- Well informed users (33%);
- and road users with in-car navigation (27%)

It is assumed that 26% of the road users would maintain their original routes regardless the availability of the roadside information, and 74% of the users have the possibilities to alter to other routes. And the possibility for each user class is determined by the route choice parameters from 1.0 to 2.0 with a 0.5 increment **(van der Mede & van Berkum, 1993; Taale, 2019)**.

5.3.1 Function of Travel Time Indication

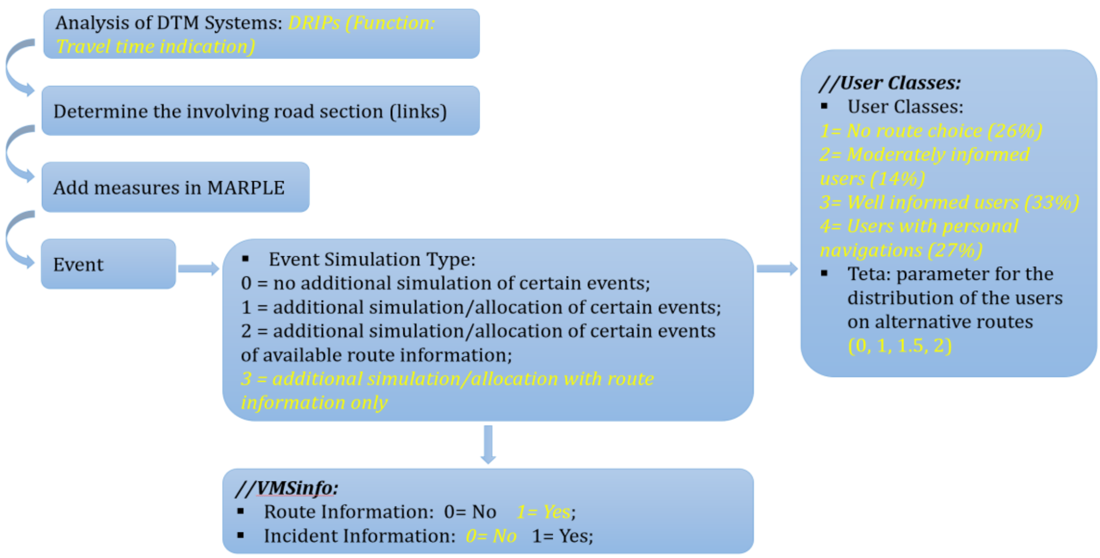


Figure 5-24. Modification process of DRIPs (travel time indication)

The determination of the involved road section (links) depends on the DRIP availability on that link. As summarized in Appendix D, there are 37 DRIPs in total placed at the AMS network, and the modification of these DRIPs is to provide information for the routes passing through the links at corresponding locations. It is assumed that those links in the simulation model where DRIPs are located are the links where the route information is available. Comparing the actual DRIP locations and the corresponding link locations in the model, 36 links are defined for the

37 DRIPs (there are two DRIPs located at the same link). By applying route information at those involved links and switching the event simulation type to 3 in model input files, the effects with these added DRIPs can be determined.

In the first simulation, all 36 involved links were added into the network, which can be taken as the base condition with all DRIPs functioning properly. Situations with and without all these DRIPs were compared, it is assumed that those corridors which benefited most with the DIRPs would suffer most when the DRIPs are not available. Therefore, by converting the impacts from positive to negative values, the proposed malfunction effects at the AMS network are visualized in Figure 5-25. The red corridors are the victim locations where the vehicle lost hours would increase, and those blue corridors are locations where less vehicle lost hours would be produced without the DIRP information, the bandwidth indicates the severity level of the malfunction impacts, and the numbers are the deviation from the base scenario as a percentage.

It is found that the total vehicle delays decreased 11.0% from 20,879 to 18,573 VVUs after the implementation of all 37 DRIPs at the AMS network. The corridor A4L is the most benefited section where the total vehicle delays reduced most (1,124 VVUs), with 14.2 km/h increase of average speed. The corridor A10NER suffered most with 86.4% of delay increment (187VVUs).

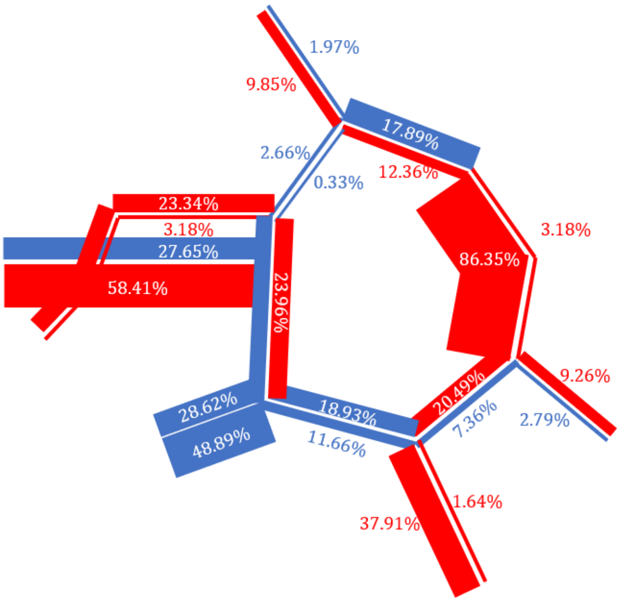


Figure 5-25. Effect map of AMS network (DRIP-route travel time malfunction)

The malfunction of DRIPs is modified on a corridor basis. Situations without DRIP information can be simply modified by removing be corresponding route information link(s). All DRIPs at the same corridor stretch would be switched off as a corridor failure case, regardless the amount of DRIPs at that stretch. For instance, the A1L malfunction refers to the situation all two DRIPs on A1L do not function. Following the division of DRIPs at a corridor stretch level, location scenarios were conducted per corridor. It is found that the traffic remained unaffected in all location scenarios, which indicates that the DRIP malfunction at one corridor almost have no impact to the network. The detailed simulation results can be found in Appendix F-3.

Though the integrated effects with all DRIPs are significant, and it is assumed that the benefits brought by DRIPs are equal to the malfunction effects. While this assumption would only hold when all DRIPs are malfunctioning together. Since the malfunction effects in location scenarios are determined by comparing the traffic at the situation with all DRIPs available instead of the situation with no DRIPs at all. It is argued that the harmfulness with one DRIP malfunction can be much smaller than the benefits with only this one DRIP functioning in the network.

5.3.2 Function of Rerouting

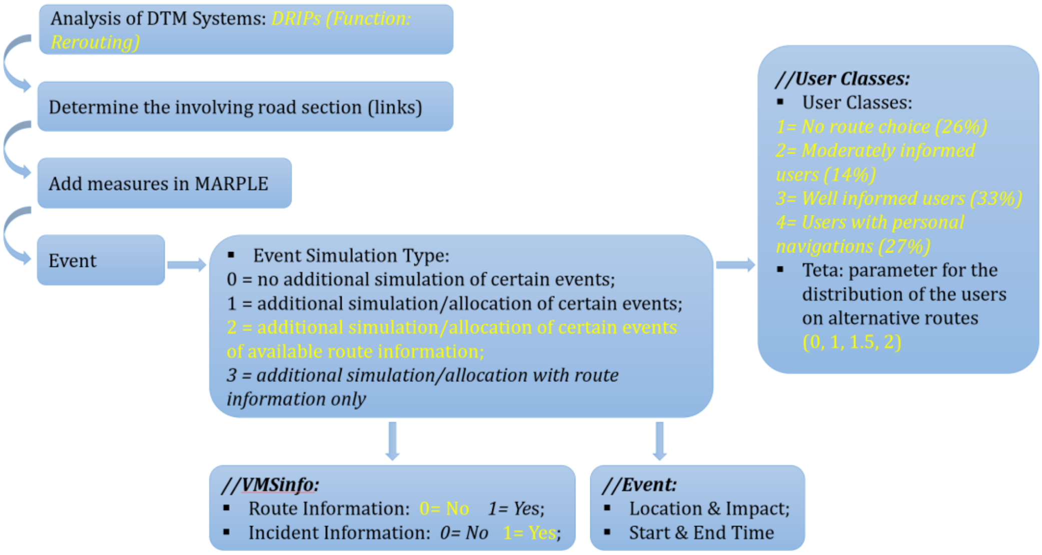


Figure 5-26. Modification process of DRIPs (Rerouting)

Malfunctions of the rerouting is expected to produce great impacts, since rerouting event is less anticipated by road users. In the situation of DRIP malfunction with rerouting event, road users will not be informed when an incident happens downstream (work in progress, accidents, events, heavy congestions and so on). Those uninformed road users would maintain the original routes, then the traffic would condition become worse and the congestion is enforced with more delays. As such incidents are always unique and not pre-planned, the type of incident and the effects can be strongly different from case to case.

In practice, the DRIP rerouting is responsible to all downstream corridors in any direction, and the rerouting message can also be displayed by DRIPs on all upstream corridors in any direction. In this research, it is assumed that the rerouting information would only be displayed by DRIPs on adjacent upstream corridors. Take the A1L DRIPs at an accident as an example, either the information on accident A10NEL or accident A10SER would be displayed by all the two A1L DRIPs. With regarding to one specific accident on A10NEL, both DRIPs on corridor A1L and on corridor A10SEL would be used to inform road users, as shown in Figure 5-27.

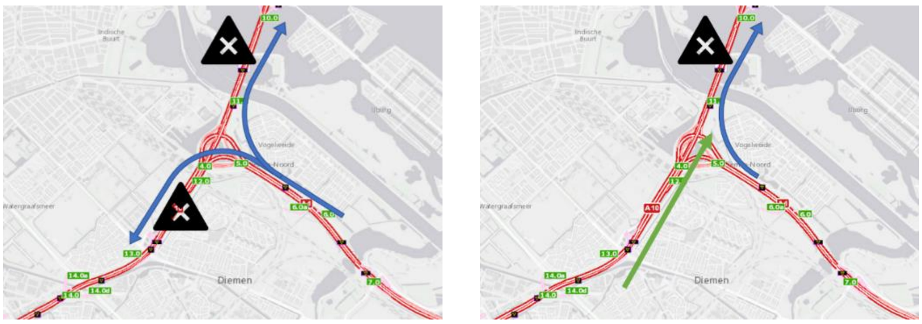


Figure 5-27. Incident simulation for DRIP rerouting

To investigate the situation when the rerouting is not available to guide the traffic, a predefined "typical" accident is allocated downstream of the route decision point. It is assumed that two lanes are closed for 2 hours (take "15:00-17:00" as the reference), one lane where the accident locates, and one lane for handling the accident (at 2-lane trajectories, only one lane is closed).

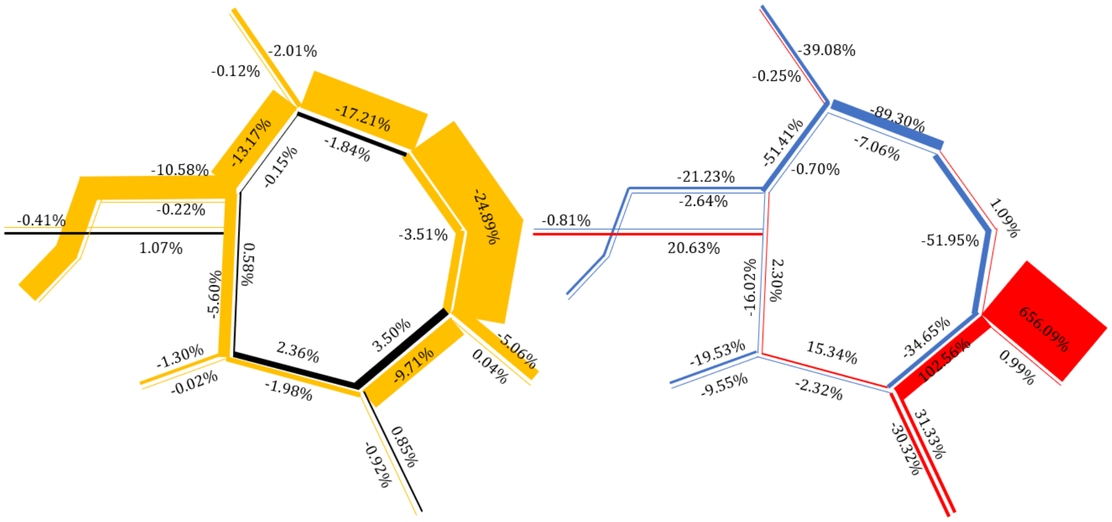


Figure 5-28. Effect map (Intensity & VVU change) with accident A10NEL (No DRIPs)

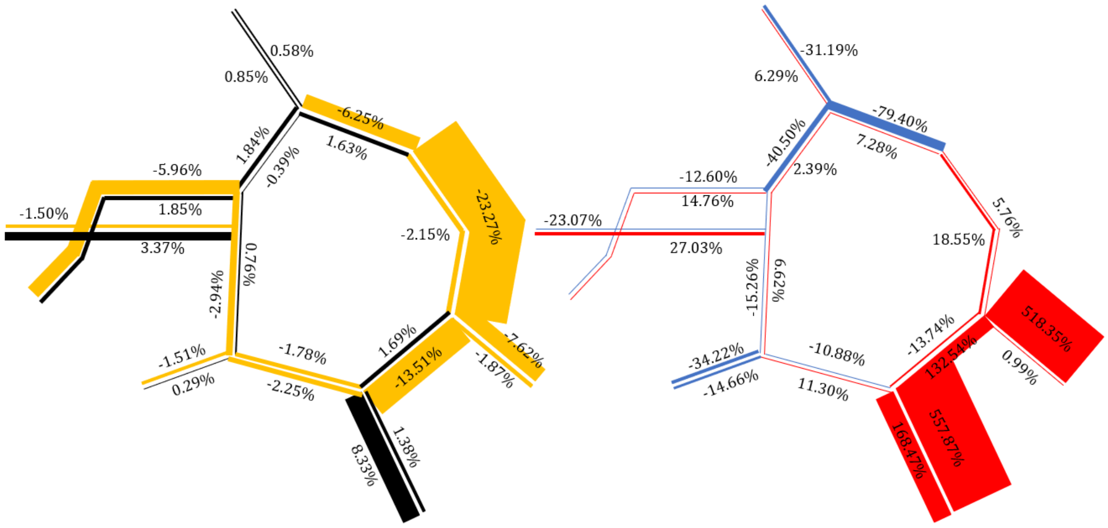


Figure 5-29. Effect map (Intensity & VVU change) with accident A10NEL (A1L DRIPs)

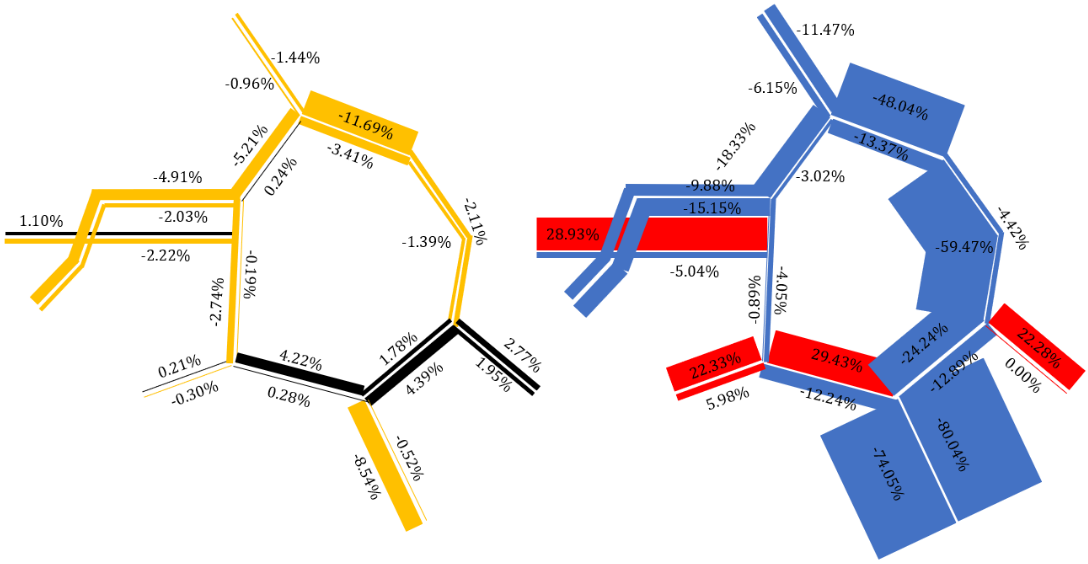


Figure 5-30. Comparison of effects with and without the A1L DRIPs in case of accident A10NEL

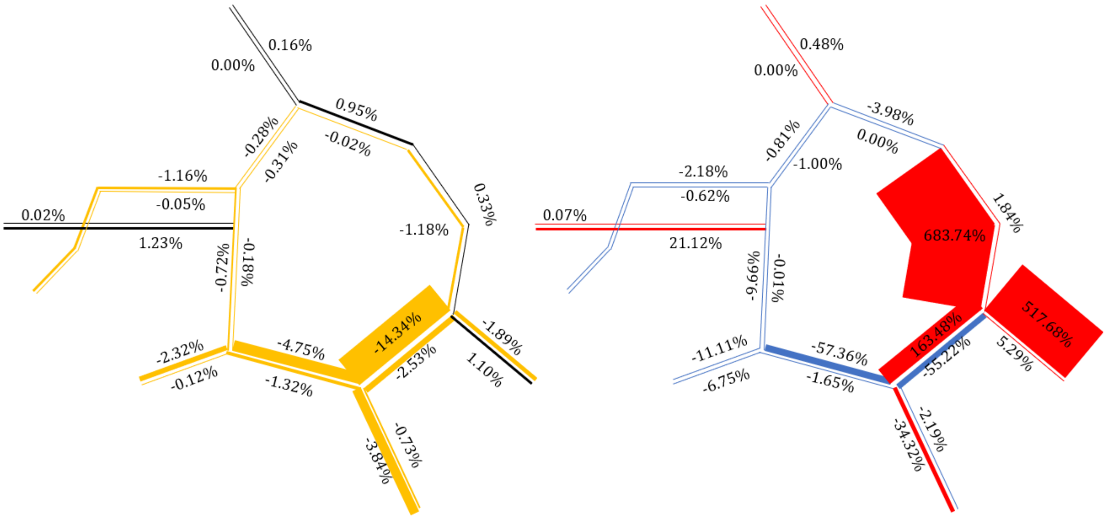


Figure 5-31. Effect map (Intensity & VVU change) with accident A10SER (no DRIP)

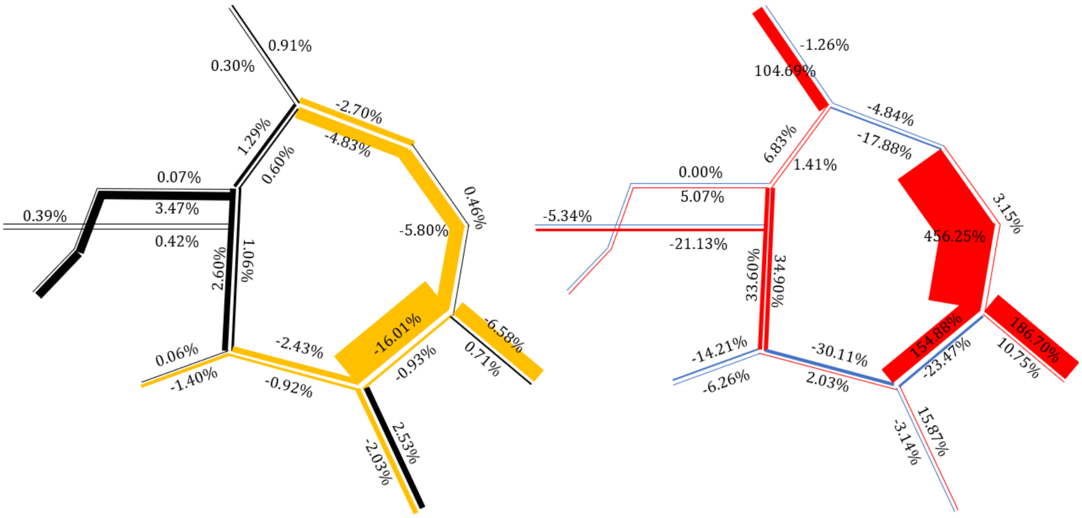


Figure 5-32. Effect map (Intensity & VVU change) with accident A10SER (A1L DRIPs)

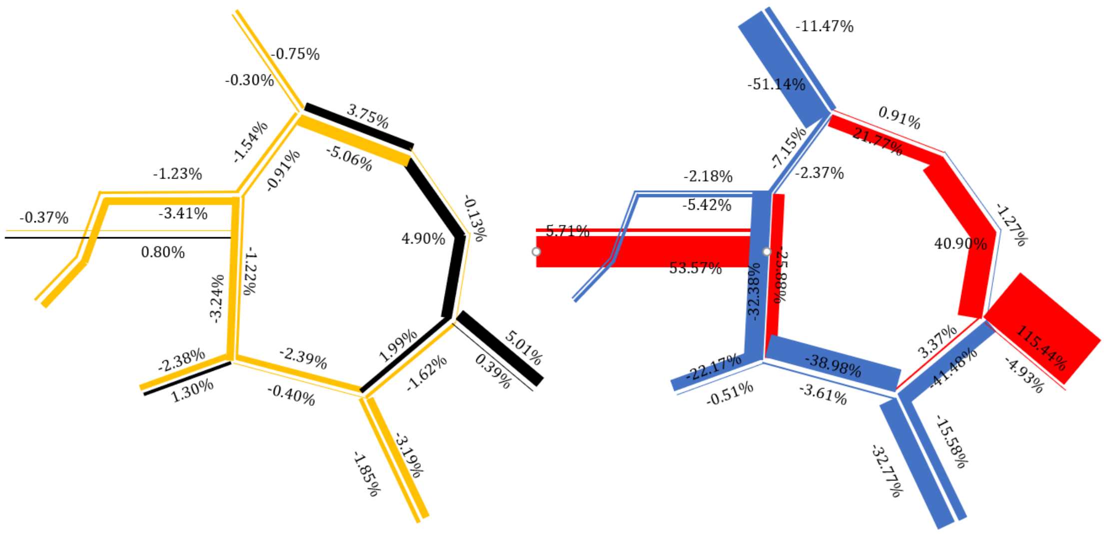


Figure 5-33. Comparison of effects with and without the A1L DRIPs in case of accident A10SER

Shown in Figures 5-28~5-30 and 5-31~5-33 are the impacts of an accident on A10NEL and an accident on A10SER, as well as the effect maps with & without the A1L DRIPs. In these figures, the left map shows the intensity (in terms of total travel distance) change and the right map shows the VVU change with the accident. Those corridors marked in yellow and blue refers to locations with changes in positive values, corridors marked in black and red refers to locations with changes in negative values, and the bandwidth indicates the severity level with percentage numbers . Figure 57 and 60 are the compared effects after the removal of A1L DRIPs.

In both accidents, Figure 5-28 and 5-31 indicate a higher proportion of route change with the accident happened at corridor A10NEL. The delay on A1L increased significantly, with 656.1% and 517.7% respectively, another upstream corridor (A10SEL and A10NER respectively) of the accidents were also greatly affected. Figure 5-29 and 5-32 show that the A1L DRIPs helped to redistribute and to weaken the negative impacts of the downstream accident. Shown in Figure 5-30 and 5-33 are the comparison of the traffic after removal of the A1L DRIPs, which indicate the malfunctions effects in situations of an accident downstream.

The malfunction effects of the A1L DRIPs with accident A10NEL and accident A10SER are summarized in Table 5-2. Similarly, malfunction effects of the A2L DRIPs are summarized in Table 5-3.

Table 5-2. Malfunction effects of DRIP rerouting on A1L

Accident Location	Performance Indicator	Accident Corridor	Upstream A1L	Upstream A10SEL	Upstream A10NER	Ring	AMS Network	Regional Network
A10NEL	Travel Distance	-2,534.2	1,552.8	4,435.0	-	-12,963.7	-32,540.6	-69,695.1
	veh.km & (%)	-2.11%	2.77%	4.39%	-	-1.08%	-1.44%	-0.58%
	VVU veh.hrs	-39.5	406.7	-387.4	-	-462.3	-361.5	1,832.4
	(%)	-4.42%	22.28%	-12.89%	-	-3.98%	-1.71%	1.69%
A10SER	Travel Distance	1,407.3	2,838.6	-	6,144.9	3,076.9	-5,218.7	-61,174.0
	veh.km & (%)	1.99%	5.01%	-	4.90%	0.25%	-0.23%	-0.51%
	VVU veh.hrs	20.0	977.4	-	491.1	-1,086.9	-294.0	541.6
	(%)	3.37%	115.44%	-	40.90%	-8.59%	-1.34%	0.49

Table 5-3. Malfunction effects of DRIP rerouting on A2L

Accident Location	Performance Indicator	Accident Corridor	Upstream A2L	Upstream A10SBL	Upstream A10SER	Ring	AMS Network	Regional Network
A10SEL	Travel Distance	-8089.1	2501.2	5348.0	-	-12635.7	-15331.1	-59096.3
	veh.km & (%)	-5.38%	3.35%	3.91%	-	-1.04%	-0.67%	-0.49%
	VVU veh.hrs	-119.7	622.1	723.3	-	1337.1	2433.1	2478.9
	(%)	-24.18%	1241.39%	18.75%	-	10.02%	11.23%	2.25%
A10SBR	Travel Distance	3212.4	271.9	-	-1403.1	-4325.5	-16980.3	-59958.3
	veh.km & (%)	3.18%	0.36%	-	-1.76%	-0.35%	-0.73%	-0.50%
	VVU veh.hrs	-110.4	-15.3	-	1330.3	-591.8	-971.5	-297.8
	(%)	-4.14%	-67.73%	-	192.56%	-4.59%	-4.58%	-0.27%

With regarding to combination of different DTM malfunctions, a sample event is given when the rush hour lane on the A10 south does not open due to malfunctions. The incident is defined as the rush hour lane stretch A4L-A10L (A4 Li 2.60 km to A10 Li 17.28 km) is closed from 15:00 to 17:00, while it is normally open from 6:00 to 20:00. In case of DRIP malfunctions, road users would have no information about the closure of the rush hour lane, and the service performance is compared in situations with and without rerouting information. After removing the DRIP information about the rush hour lane closure, the total vehicle delays increased 364 VVUs at the inner ring and 2,053 VVUs at the outer ring. The effect map is shown in Figure 5-34.

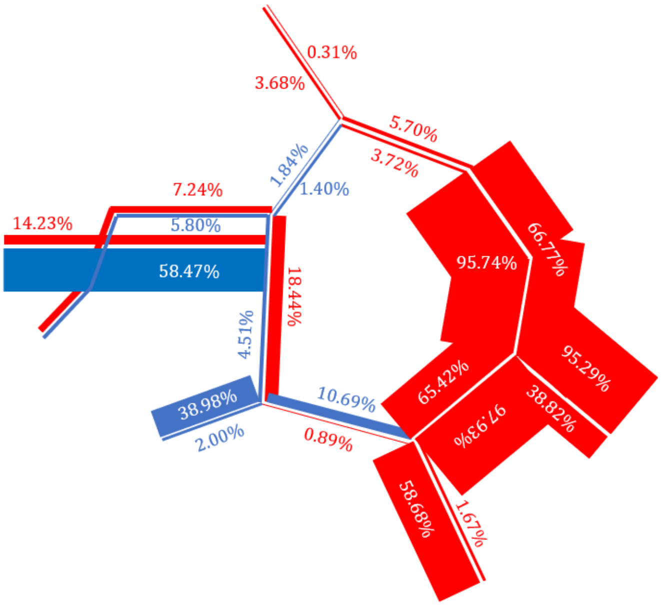


Figure 5-34. Effect map of rerouting & RHL malfunction

The effect map shows that the east part of the network is most affected, where the total vehicle delays almost doubled at the corridor A10SEL, A10NER and A1L, compared with the situation when DRIPs are available for the event.

The rerouting event can also be road works, with different impacts to the traffic (e.g. from one lane blocked to all lanes blocked) and different durations before the recovery, the benefits or the effects introduced by the DRIP availability can vary substantially from case to case.

5.4 Malfunctioning of the Ramp Metering Systems

The RM malfunction is modified by removing the signal control on the ramp link and changing the metering node to regular connecting node. Those metering links and nodes can be found in Appendix E. In the base situation, all 35 RM systems (32 on the ring, 2 on A8 and 1 on A5) were modified to be normally functioning during the whole simulation period. A total of 37 location scenarios (with all A10 RM and with all AMS RM) were conducted with the removal of corresponding RM system(s). The comparison of the traffic state in situations with and without the RM system summarized in Table 5-4.

Table 5-4. Overview effects of the ramp metering availability

Location	RM Code	Aggregation level of performance							
		Corridor		Ring		AMS		Regional Network	
		VVU	%	VVU	%	VVU	%	VVU	%
A5R	334	1.9	0.2%	51.3	0.4%	105.8	0.5%	-47.2	-0.0%
A8L	305	-0.0	-0.4%	230.9	1.9%	534.2	2.7%	-1380.1	-1.3%
A8R	306	3.6	0.2%	207.2	1.7%	503.1	2.5%	-1155.4	-1.1%
A10NWR	201	-375.5	-25.9%	-398.9	-3.4%	-66.4	-0.3%	-2135.1	-2.0%
	202	+22.7	1.6%	55.5	0.5%	276.7	1.4%	-1499.9	-1.4%
A10NWL	333	0.5	1.1%	43.5	0.4%	118.5	0.6%	120.0	0.1%
	335	0.7	1.6%	31.3	0.3%	77.0	0.4%	-183.7	-0.2%
A10SBR	323	-95.7	-3.8%	-281.7	-2.4%	-247.1	-1.2%	318.5	0.3%
	325	179.8	7.1%	10.7	0.1%	-554.3	-2.8%	-1455.2	-1.4%
A10SBL	324	-18.8	-1.1%	701.6	5.9%	978.7	4.9%	-503.4	-0.5%
	326	-492.1	-29.9%	-498.8	-4.2%	-264.9	-1.3%	-435.5	-0.4%
A10NBL	307	-51.5	-1.9%	256.5	2.2%	576.1	2.9%	-1131.5	-1.1%
	309	-43.0	-1.6%	234.2	2.0%	561.3	2.8%	-1131.6	-1.1%
A10NBR	308	-0.4	-3.9%	91.7	0.8%	400.7	2.0%	-1705.3	-1.6%
	310	-1.1	-10.8%	336.4	2.8%	782.5	3.9%	-879.0	-0.8%
A10NEL	311	66.1	8.1%	618.9	5.2%	810.6	4.1%	-329.2	-0.3%
	314	44.2	5.4%	-1037.7	-8.8%	-1016.5	-5.1%	-4252.8	-4.0%
	316	58.1	7.1%	149.4	1.3%	553.2	2.8%	-1339.4	-1.3%
A10NER	312	230.2	62.6%	267.6	2.3%	631.2	3.2%	-1231.6	-1.2%
	313	223.6	60.8%	204.7	1.7%	481.6	2.4%	-1112.8	-1.0%
	315	222.6	60.5%	189.6	1.6%	458.1	2.3%	-1416.5	-1.3%
A10SER	317	14.0	5.6%	207.6	1.8%	501.4	2.5%	-1309.7	-1.2%
	319	9.0	3.6%	-1142.1	-9.6%	-1237.6	-6.2%	-3774.2	-3.5%
	321	13.7	5.5%	250.8	2.1%	521.2	2.6%	-1075.1	-1.0%
A10SEL	318	313.3	24.7%	-60.9	-0.5%	249.0	1.2%	-2119.1	-2.0%
	320	413.6	32.6%	166.3	1.4%	531.4	2.7%	-1274.7	-1.2%
	322	416.6	32.9%	665.2	5.6%	956.3	4.8%	-428.2	-0.4%
A10SWR	203	91.2	29.9%	67.7	0.6%	336.9	1.7%	-1528.6	-1.4%
	204	85.4	28.0%	28.8	0.2%	274.9	1.4%	-1424.7	-1.3%
	328	-10.7	-3.5%	-435.7	-3.7%	-978.9	-4.9%	-3166.8	-3.0%
	330	31.9	10.5%	91.7	0.8%	21.6	0.1%	-437.4	-0.4%
A10SWL	327	-2.9	-0.6%	-42.4	-0.4%	-58.1	-0.3%	-450.7	-0.4%
	329	8.5	1.6%	69.6	0.6%	146.9	0.7%	301.8	0.3%
	331	-20.9	-4.0%	142.6	1.2%	109.8	0.5%	-301.5	-0.3%
	332	-14.5	-2.8%	85.5	0.7%	105.0	0.5%	-187.2	-0.2%
A10 32 RMs	-	-	-	23.6	0.2%	580.6	2.9%	-613.7	-0.6%
AMS 35 RMs	-	-	-	69.4	0.6%	825.6	4.1%	525.6	0.5%

The simulation results indicate the removal of the individual ramp metering system generally (32 out of 35 location scenarios) leads to less vehicle lost hours at the regional network level (expect for on-ramps of 333, 323 and 329). At the ring road level and the AMS network level, the VVUs increased in 28 out of 35 location scenarios except for the on-ramps of 201, 323, 326, 314, 319, 328 and 327. While at the corridor level, almost one third of the location scenarios showed negative VVU changes after removing the corresponding RM out of the network.

5.5 Discussion of the Results

As resources are limited for the evaluations of all DTM units in AMS network, the simulation results can only be partially compared with the measured effects of these DTM systems. Based on the comparison with existing evaluations, whether the MARPLE simulation revealed logical traffic behaviors and comparable effects is interpreted. Overall, the MARPLE simulations met the expectation for the response of DTM malfunctions and achieved a satisfactory agreement with the measured effects.

Since the measured effects were mainly evaluated at route levels, which makes the comparison can only compared at the corridor level. Though some simulation results are not as expected to have direct impact on the failure corridor, the predicted behaviors are still logical with plausible explanations. One possible reason is that the integrated effects of each corridor are affected by the corridor separation, which was defined by rules of thumb in this research.

In general, the average speed meets the expectation to show a downward tendency with DTM malfunctions, and more vehicle lost hours are produced as the consequence of capacity loss in the network. Since the value of VVUs is also affected by the number of vehicles passing through, the VVUs can also be less when with significant reductions in intensity. This phenomenon often occurs, resulting from the responses of a proportion of drivers change their original routes to avoid the perceived unacceptable traffic conditions, according to their prevailing experiences **(Goodwin, Hass-Klau & Cairns, 1998)**.

The overview simulation results for each DTM system are firstly summarized and discussed in section 5.5.1, according to which the severity and range of the malfunction effects can be easily presented. In section 5.5.2, the simulation results are compared with the measured effects from previous evaluations, which could provide additional justifications to the reality. As there is no evaluation prepared for the VVU effects of the MTM-AID and the DRIP rerouting, these two functions are not discussed in this section.

5.5.1 Overview of Malfunction Effects from MARPLE Simulation

Three RHL stretches in Amsterdam region were evaluated in this research, and it is found the delays resulting from the RHL malfunctions at stretch A10R-A4R and A8R-A7R are generally enforced, with the increase of malfunction durations at all three defined network levels (corridor level, AMS network level and regional network level). In comparison, the malfunction at stretch A4L-A10L leads to most VVU increase when with a 1.5-hour malfunction from 15:00 to 16:30, and the VVU increase becomes smaller at a stable value when with longer DTM downtimes. This phenomenon is logical considering that this stretch is already quite congested and blocked during the peak hours, the contribution to the VVU increase in blocked traffic is limited while the expected reduction in traffic demand keeps growing.

Summarized in Table 5-5 and 5-6, the direct effects (performance indicators including TTD, VVU and average speed) at the failure corridor(s) and spread effects at adjacent corridors due to capacity constricts show how the RHL and MTM malfunctions is spread over the network. The orders of the listed affected corridors are based on the severity levels (VVU percentage changes in a 5-hour malfunction). The upstream and downstream corridors are marked in red and blue respectively, the non-adjacent corridors are marked in black.

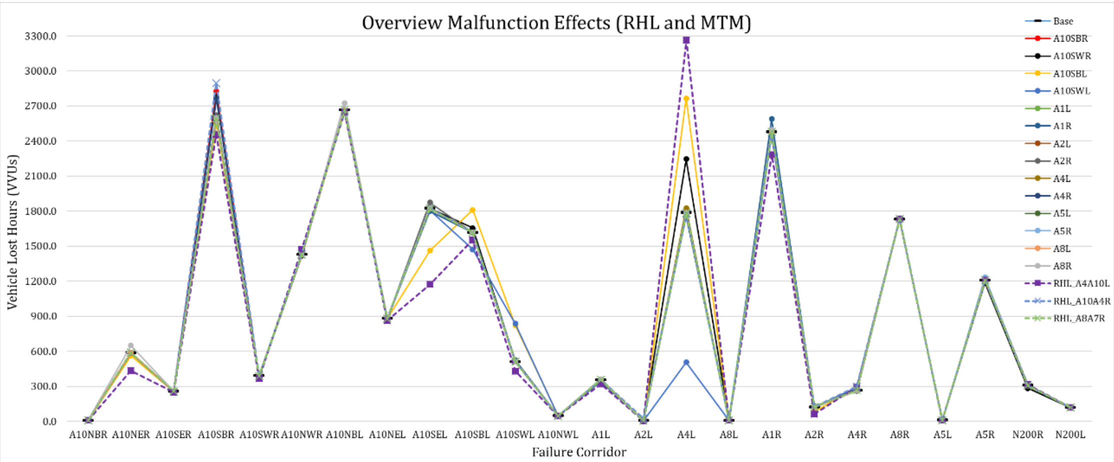
Table 5-5. Overview of RHL malfunction effects

Location scenarios	Failure corridor(s)			Affected Corridors	Most-affected Traffic		
	TTD veh.km	VVU hrs	Speed km/h	Ranked by percentages of the VVU change	TTD veh.km	VVU hrs	Speed km/h
A4-A10L	-18,758.0	+1,411.1	-4.8	A2R, A10SEL, A10NER	-5,524.6	-59.9	+2.8
A10-A4R	-264.6	+334.6	-2.7	A2L	-0.2	+20.1	-2.2
A8-A7R	-0.1	+62.7	-0.9	-	-	-	-

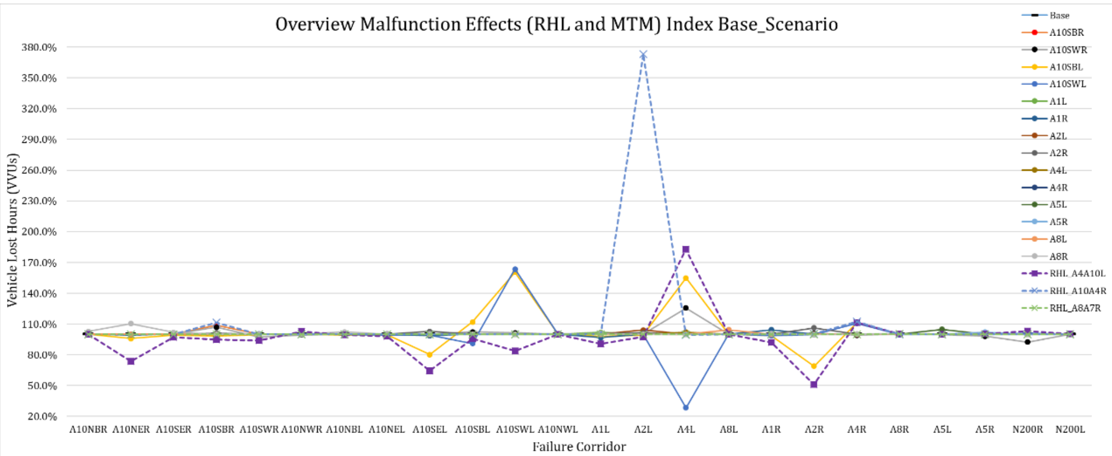
Table 5-6. Overview of MTM malfunction effects

Location scenario s	Failure corridor			Affected Corridors	Most-affected Traffic		
	TTD veh.km	VVU hrs	Speed km/h	Ranked by percentages of the VVU change	TTD veh.km	VVU hrs	Speed km/h
A1L	-	+6.6	-0.4	-	-	-	-
A1R	-224	+111.5	-0.9	A1L, A10SEL	-23.8	-11.7	+0.7
A2L	-	+0.3	-0.0	-	-	-	-
A2R	-114.7	+7.7	-0.4	A10SEL,A2L	+195.7	49.3	-0.6
A4L	-0.2	+38.4	-0.5	-	-	-	-
A4R	-878.1	+10.2	-0.7	A10SBR,A10SWL,A4L	-505.9	162.9	-1.4
A5L	-	+0.5	-0.1	-	-	-	-
A5R	-	+24.6	-0.5	-	-	-	-
A8L	+0.4	+0.4	-0.0	-	-	-	-
A8R	-1,742.7	+10.9	-0.5	A10NER, A10NBL	+1144.8	+60.9	-1.9
A10SBL	-3,555.5	+194.1	-3.4	A4L, A10SWL, A2R	-873.4	+980.7	-9.2
A10SBR	-12.5	+230.5	-1.8	-	-	-	-
A10SWL	-1.7	+29.6	-0.9	-	-	-	-
A10SWR	-2,234.5	-10.9	-0.1	A4L, N200R, A10SBR	250.3	459.3	-4.9

The applied capacity constrict leads to the VVU increase in almost all location scenarios with a speed decrease up to 4.8 km/h at the failure corridor. Since the malfunction difference between the RHL and MTM lies in the percentage of remaining capacities and changes in the number of lanes. With same reaming capacity, the lane availability contributed extra intensity reduction at the failure corridor(s), and it is confirmed by additional simulations.



(a)VVU changes (Absolute variance with base-scenario)



(b)VVU changes (Index base-scenario percentage)

Figure 5-35. Overview Malfunction Effects (MTM and RHL)

Figure 5-35 shows the visualized malfunction effects with the RHL and MTM malfunction. The capacity constrictions at those corridors without bottlenecks modified in the model, could hardly cause much negative impacts to the traffic. Malfunctions of the RHL stretch A8R-A7R, as well as MTM on A1L, A2L, A5L, A5R, A8L and A10SWL only contributed 0.4 to 62.7 more VVUs at the failure corridor, other network parts were not affected. For those locations where the capacity loss could not get buffered within the failure corridors, especially for locations where the bottlenecks already exist, the upstream traffic would receive most impacts resulting from spillback effects, as the corridors marked in red in Table 5-5 & 5-6. For the malfunction of the RHL stretch A4L-A10L, most spread impacts were received by downstream corridors A2R and A10SEL. The most obvious impact at these corridors is the intensity reduction, which is caused by the blocked traffic upstream.

Overall speaking, A4L is the most sensitive stretch in response to capacity constrictions, where the VVU varies dramatically among malfunction scenarios (RHL_A4LA10L, MTM_A10SBL, MTM_A10SWR, MTM_A10SWL). Corridor A10SBL is also greatly affected by the capacity constrict, where the MTM malfunction produces more VVUs than the RHL malfunction at the stretch A4L-A10L, it is because that there is less intensity reduction without the change in lane number.

Two functions of DRIPs were evaluated in this study, the travel time indication and rerouting. As the basic and permanent function of DRIPs, the indication of route travel time could save a total of 2,305 VVUs in the AMS network and 3,978 VVUs in the regional network, which is significant for the improvement of traffic conditions. However, the location scenarios of DRIP malfunctions did not show much variance with the regular condition. The simulation results are presented in this way, because road users are modelled in MARPLE to have better knowledge about the travel times than in reality. It is reasonable from realistic perspective, as the increasing use of in-car navigation and live maps via smart phones.

With regarding to the DRIP rerouting in case of a typical accident with 2 lanes closed for two hours, there can be up to 2,479 VVUs of more delay produced for the accident on A10SEL. In an occasional event (RHL A4L-A10L closed from 15:00 to 17:00), the lack of DIRP rerouting greatly increased the VVUs at eastern part of the AMS network, the total delay increased 3,395 vehicle hours at AMS network, 2,053 VVUs at the outer ring and 364 VVUs at the inner ring.

The simulation results for the ramp metering systems are summarized in Table 5-4. Changes in RM availability at a specific on-ramp produce impacts to almost all network parts. At some locations, the removal of the RM reduced the VVUs at all four aggregation levels, these are not as the desired effects of the RM malfunction.

There are two possible reasons behind. First comes with the way how the RM malfunction is modified. Since the unavailability of the RM is mimicked by removing the signaling at the on-ramp links, the traffic is distributed based on the revised initial network conditions instead of by additional assignment simulation with the RM suddenly out-of-work. The results obtained by comparing the traffic with and without the RM summarized in Table 5-4, are the estimated effects with a new user equilibrium assignment (SUE) for a long-term average traffic behavior, not the reaction of the RM malfunction. It is one important reason that almost all network parts are affected by the change of a single RM, due to stochastic features of the assignment. Secondly, only the threshold of the access inflow was adjusted for these RM systems, however, there are much more parameters for a RM to be tuned with local properties. Since the RWS algorithm (feed forward strategy) is applied for all RM systems in the Netherlands**,** when there is a bottleneck downstream the controlled on-ramp, the feed forward strategy would over-allow the inflow to the mainline traffic, due to the capacity drop at the bottleneck.

5.5.2 Comparison with Measured Effects

For the rush hour lane stretch A4L-A10L in the direction from Badhoevedorp to Amstel with a 5-hour malfunction, the VVUs increased 41.5% (1,411VVUs) at the corridor level, which are comparable with previous evaluation study from **Poorterman et al (2011)**. In their study, the total delays reduced 53.5% (1,715VVUs) after opening the RHL to the traffic. In comparison, the increased vehicle delay (11.7% growth with 335 VVUs more) on the RHL stretch in reverse direction is not comparable with the measured delays (74.2% reduction with 1,783 VVUs less). The less estimated effects than the actual measurement can be explained by the fact that the corridor A10SBL is fully blocked in the simulation, which makes the RHL closure do not add much to the congestion severity. Furthermore, the route length at the corridor level is longer than the measured route, since corridor A4L-A10SBL also contains the non-RHL sections.

The RHL malfunction at stretch A8R-A7R from 15:00 to 19:00 contributed 52.8 more VVUs from the MARPLE simulation. As no previous evidence can be used for the result justification, from the theoretical point of view, the outcome meets the expectation. As no bottlenecks are modified at this RHL stretch, and the observed congestion on corridor A8 ends before the RHL becomes available, road sections with the hard shoulder closed can still accommodate the traffic with limited impacts.

The route travel time information of DRIPs can lead to an overall 11.0 % reduction of VVUs, and a 5.3% of speed increase. The improvement with the implementation of DRIPs was proved to be significant (2,305 out of 20,879 VVUs). The model result is comparable with the RIA-4 evaluation in which 14% less VVUs were realized after the implementation of 11 DRIPs at the ring Amsterdam. The difference between the model simulation and practical evaluations can be raised by other DRIPs at connecting corridors, as well as their coordination effects.

The simulation of the ramp metering system is less comparable with the measured effects. It is estimated that the malfunction of all RM on A10 produced 0.2% more VVUs while they were measured with 1.8% reduction in the total vehicle delays.

6. Cost Calculation

The scenario costs are calculated based on the values of time (VOT) and changes in vehicle lost hours (VVU) contributed by DTM malfunctions. The VOT is determined based on the extent to which travelers are willing to pay for an hour's gain in travel time, these time value numbers are varied among different users with different motives. In the Netherlands, the costs per hour are estimated around 52.49 euros for freight vehicles and 10.75 euros for passenger vehicles at the price level of 2019 (with RWS price corrections), these are the costs of direct travel time losses and unreliability of travel times, which are generated when people change their behaviors in response to congestions **(KiM, 2013; Significance, VUA & John Bates, 2013; KiM, 2019)**.

As introduced in previous chapter, the effects in terms of VVUs have already been estimated per malfunction scenario. With the evaluated changes in VVUs, and the composition of lorries & passenger vehicles at each motorway corridor, as well as the latest VOT for both vehicle classes, the social costs per scenario can be calculated. The strategy shown in Figure 3-1 for the cost calculation is revised and shown in Figure 6-1, with the identified cost values and sources for the calculation of safety costs.

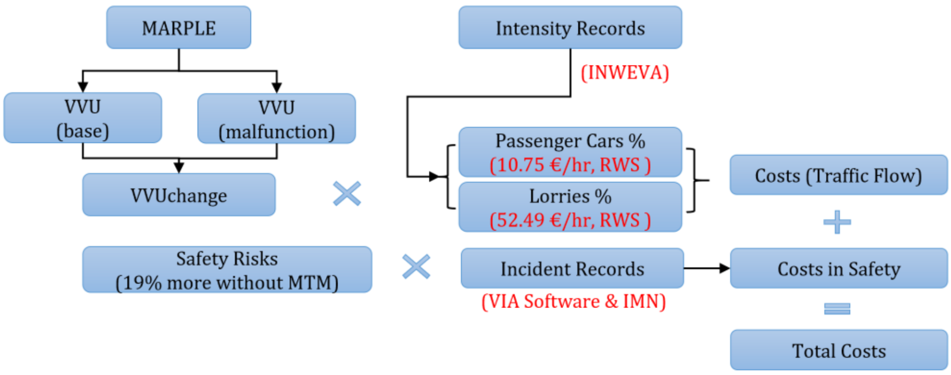


Figure 6-1. Framework for cost calculation of DTM malfunctions

The corridor intensities and vehicle compositions are firstly introduced in section 6.1, which are calculated based on the database from INWEVA. Afterwards, the scopes of VVU costs at different aggregation levels are discussed in section 6.2, then a revised network level with only victim corridors (where the VVUs increased), is taken as the baseline for the calculation of the social costs. In section 6.3 to 6.5, the social costs per malfunction scenario are calculated at the revised network level.

6.1 Intensity and Vehicle Compositions

The traffic intensity is obtained via INWEVA (INtensiteiten op WEgVAkken), from which the intensity is measured on all lanes of Dutch national roads including entrances, exits, parallel lanes and connecting roads. As shown the intensity map in Figure 6-2, the southern part of the ring road is with the highest level of traffic demand. As for connecting corridors, corridor A4 is with the highest demand. In INWEVA database, the weekday average intensity is divided into three vehicle classes (passenger vehicles, medium-heavy freight vehicles and heavy freight vehicles) in different time periods (morning, evening and night).

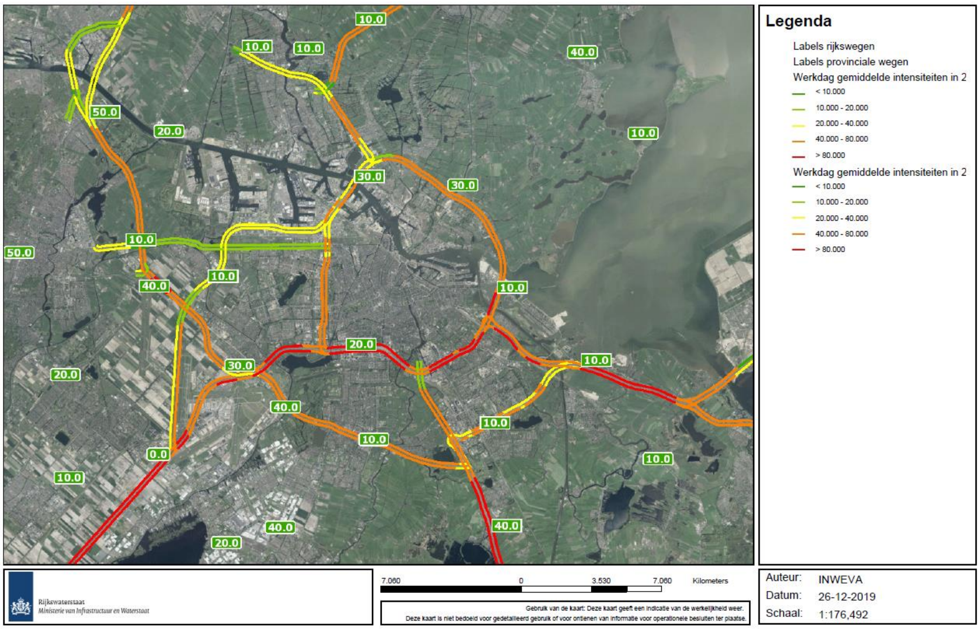


Figure 6-2. Intensity map Amsterdam region (INWEVA, 2019)

As the intensity is registered per road segment, the length of which is much shorter than the defined motorway corridors, therefore, a weighted average intensity per corridor is determined following the equation (1). The sum of total travel distance is calculated per corridor a based on segment intensities $I_{a,i}$ and segment lengths $l_{a,i}$, and the average corridor intensity is obtained by dividing the sum segment lengths. Following such a calculation methodology, the processed corridor intensities and the vehicle class compositions are listed in Table 6-1 (the type of freight vehicles was not distinguished).

$$I_a = \frac{\sum_i^n I_{a,i} \cdot l_{a,i}}{\sum_i^n l_{a,i}} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (1)$$

Table 6-1. Average corridor intensities (volume of flows, INWEVA)

Corridor	Average Intensity (7:00-19:00)	Assumed Intensity (14:30-20:00)	Nr of Passenger Vehicles	Passenger Vehicle (%)	Nr of Trucks	Truck (%)
A10 NBL	38078	19039	33883	88.98%	4195	11.02%
A10 NBR	41648	20824	37323	89.62%	4325	10.38%
A10 SWL	42805	21403	38948	90.99%	3857	9.01%
A10 SWR	43740	21870	40487	92.56%	3253	7.44%
A10 NWL	23152	11576	20657	89.22%	2495	10.78%
A10 NWR	40759	20380	37269	91.44%	3490	8.56%
A10 SBL	75247	37624	68478	91.00%	6769	9.00%
A10 SBR	73180	36590	67216	91.85%	5964	8.15%
A10 SEL	61885	30943	55881	90.30%	6004	9.70%
A10 SER	59048	29524	53535	90.66%	5513	9.34%
A10 NEL	50784	25392	45727	90.04%	5057	9.96%
A10 NER	52242	26121	46485	88.98%	5757	11.02%
A1 L	48744	24372	44204	90.69%	4540	9.31%
A1 R	55898	27949	49644	88.81%	6254	11.19%
A2 L	35225	17613	33377	94.75%	1848	5.25%
A2 R	41083	20542	38530	93.78%	2553	6.22%
A4 L	67240	33620	62055	92.29%	5185	7.71%
A4 R	62412	31206	57899	92.77%	4513	7.23%
A5 L	22490	11245	19915	88.55%	2575	11.45%
A5 R	23642	11821	21006	88.85%	2636	11.15%
A8 L	39720	19860	36205	91.15%	3515	8.85%
A8 R	42703	21352	38187	89.43%	4516	10.57%
N200 L	11313	5657	10031	88.67%	1282	11.33%
N200 R	10936	5468	9457	86.48%	1479	13.52%

The weekday intensity data from 7:00-19:00 are used for the calculation, and it is assumed that the intensity within the simulation period (14:30 to 20:00) is half of the total intensity. The number of trucks is the summation of medium-heavy freight vehicles and heavy freight vehicles. The resulting truck percentage ranges from 5.25% at corridor A2L to 13.52% at corridor N200R.

6.2 Social Costs at Different Aggregation Levels

When calculating the costs of the theoretical negative effects resulting from DTM malfunctions, the level of the scope should be determined and be consistent for all malfunction scenarios. Options including scopes at the regional network level, the AMS network level and the corridor level. The absolute values of the VVU change in malfunction scenarios at different aggregation levels are summarized in Table 6-2 and 6-3 (the delay figures of the RHL and MTM are based on the malfunction of 5 hours). Strengths and drawbacks of scopes at above aggregation levels for the cost calculation are discussed in Table 6-4.

Table 6-2. Overview of RHL malfunction effects

		A4-A10	A10-A4	A8-A7
Corridor Level	TTD (veh.km)	-18,757.6	-264.6	-0.1
	VVU (veh.hrs)	+1,411.1	+334.6	+62.7
	Speed (km/hr)	-9.9	-2.7	-0.9
AMS Network Level	TTD (veh.km)	-24,960.2	-10.7	+0.1
	VVU (veh.hrs)	+123.8	+349.1	+2.8
	Speed (km/hr)	-0.4	-0.4	-
Regional Network Level	TTD (veh.km)	+5,515.3	-560.6	+0.4
	VVU (veh.hrs)	+3,329.9	+249.8	+62.6
	Speed (km/hr)	-0.7	-0.1	-
AMS Negative*	Intensity (veh.km)	-7,270.4	-30.2	-
	VVU (veh.hrs)	+1,542.6	+360.4	+2.8 (+60.0)
	Speed (km/hr)	-4.8	-0.51	-

Table 6-3. Overview of MTM malfunction effects

		A1L	A1R	A2L	A2R	A4L	A4R
Corridor Level	TTD (veh.km)	-	-224.0	-	-114.7	-0.2	-878.1
	VVU (veh.hrs)	+6.6	+111.5	+0.3	+7.7	+38.4	+10.2
	Speed (km/hr)	-0.4	-0.9	-	-0.4	-0.5	-0.7
AMS Network Level	TTD (veh.km)	-0.2	-171.3	-1.1	+1,625.6	-2.6	-1,255.6
	VVU (veh.hrs)	+6.5	+69.7	+0.3	+101.5	+37.6	+158.9
	Speed (km/hr)	-	-0.1	-	-0.10	-	-0.2
Regional Network Level	TTD (veh.km)	-0.6	-749.8	-1.5	+5,142.4	-5.1	-3,556.9
	VVU (veh.hrs)	+6.6	-49.4	+0.3	+486.0	+38.0	+71.8
	Speed (km/hr)	-	-	-	-0.09	-	-
AMS Negative*	TTD (veh.km)	-	-224.0	-0.2	+1,651.0	-0.2	-1,134.6
	VVU (veh.hrs)	+6.6	+111.5	+0.4	+101.9	+38.4	+190.1
	Speed (km/hr)	-0.4	-0.9	-	-0.1	-0.5	-0.4
		A8L	**A8R**	**A10SBL**	**A10SBR**	**A10SWL**	**A10SWR**
Corridor Level	TTD (veh.km)	-	-1,742.7	-3,555.5	-12.5	-1.7	-2,234.5
	VVU (veh.hrs)	+0.4	+10.9	+194.1	+230.5	+29.6	-10.9
	Speed (km/hr)	-	-0.5	-3.4	-1.8	-0.9	-0.05
AMS Network Level	TTD (veh.km)	+0.4	+841.8	-5,734.0	+295.8	-12.3	+42.5
	VVU (veh.hrs)	+0.3	+169.3	+991.6	+224.1	+28.0	+637.6
	Speed (km/hr)	-	-0.2	-1.2	-0.3	-	-0.7
Regional Network Level	TTD (veh.km)	+0.5	-1907.7	+1,919.4	+627.6	-11.3	+2,516.5
	VVU (veh.hrs)	+0.2	+225.3	+1,100.1	+182.8	+29.6	+690.1
	Speed (km/hr)	-	-0.1	-0.2	-	-	-0.1
AMS Negative*	TTD (veh.km)	-	+813.7	-3,183.4	+160.5	-1.7	+2,100.2
	VVU (veh.hrs)	+0.4	+169.7	+1,517.6	+232.4	+29.6	+723.9
	Speed (km/hr)	-	-0.2	-6.7	-0.6	-0.9	-1.1

Table 6-4. Scopes of aggregation levels for the cost calculation

	Strengths	Drawbacks
Corridor level	▪ Direct effects at the malfunction location ▪ Existing measured effects can be used for the simulation justification	▪ The impacts to the rest of the larger network are neglected
AMS network level	▪ Consistent with the research scope ▪ Propagation effects are considered	▪ The net VVU effects can be negative as compensated by other network parts; ▪ Malfunctions at the ring can be spread out to connecting corridors, while malfunctions at connecting corridors may be spread outside the AMS network
Regional network level	▪ Impacts to the other motorway parts are considered	▪ Compensation effects can be considerable when a larger network is involved; ▪ Urban roads are included as well, which is not interest of RWS; ▪ Road parts outside the AMS network was not calibrated
AMS Negative*	▪ The DTM malfunction always produce positive values of the VVU change ▪ Policy objectives to avoid worsening traffic	▪ Overestimation of the negative effects of the DTM malfunction

As discussions summarized in Table 6-4, though cost calculation at any aggregation level would have its unique strengths and drawbacks, the baseline still exists for calculating the costs at the same aggregate level for all malfunction scenarios. Since it is not desired to have the costs on urban roads included, and also since the urban road network was less calibrated (both at the physical and the performance perspectives), it is suggested that we still focus on the corridor level and the AMS network level.

Besides, though a network perspective is preferred as it is desired to look at the effects not only locally, drawbacks of defined AMS network could not be ignored. Take the RHL stretch A4L-A10L as an example, the total delay increased 1,411 VVUs at the corridor level while it only increased 124 VVUs at the AMS network level. It is not suggested to conclude that costs are underestimated at the AMS network level and overestimated at the corridor level, since network performance could not be independently described by the vehicle lost hours, the vehicle travel distance, average travel speed, and the total travel time are also network performance indicators to represent the DTM malfunction effects, also, none of them could be independently used.

Previous practice for the calculation of malfunction costs did not take considerations of traffic re-allocation due to changes in network conditions, the VVU was determined with unchanged intensity, and therefore the increase of VVUs are always accumulated **(Muhurdarevic, 2016 & 2018).** This method caused the overestimations for the increased delay hours.

It is argued whether the net negative effects or the gross negative effects could be a better option for the cost calculation. When looking at a large network, changes in network conditions can always cause “effects” to the traffic, while only the direct and visible effects could be expected and calculated. It is not possible accuse the DTM malfunctions of unexplainable “ghost traffic jams **(Transpute, 2011)**” or “butterfly effects” at locations too far from the failure location.

Based on all arguments mentioned above, a revised network level named as AMS-N* (of which “N” donates “negative”) could be taken as the first attempt for the cost calculation. The ring road together with 6 connecting corridors are included in the revised network level, but only victim corridors (corridors with increased VVUs) are considered. This strategy comes from the policy perspective that disruptions to the traffic should be limited as much as possible and the worsened parts of the network ought to be more focused. In this sense, VVU changes at the level of AMS-N are counted, and already summarized in the last row in Table 6-2 and 6-3. It can be observed that the intensity reduction got compensated more or less at the AMS-N level, which offsets the drawbacks of taking all corridors in AMS network into consideration. Based on this assumption, the costs can be calculated according to the increased VVUs, the VOTs and the vehicle compositions at each corridor, as formulated below:

$$C = \sum_i VVU_i \cdot (VOT_{truck} \cdot P_{ti} + VOT_{passenger} \cdot P_{pi}), if\ VVU_i > 0 \dots \dots \dots (2)$$

6.3 Social Costs with Malfunctions of Rush Hour Lane

Based on the formulated strategy in previous section, the relation between the social costs and the malfunction durations D for each RHL stretch S can be obtained, which can be presented as

$$C_{RHL} = f(S, D) \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (3)$$

Shown in Figure 6-3 to 6-5 are the cost curves for the RHL stretch A4L-A10L, A10R-A4R and A8R-A7R respectively. The formulated (3) can be simply approximated by modifying the trendline of the cost curves at the AMS-N level across malfunction durations, shown (4) as the example for the RHL stretch A4L-A10L.

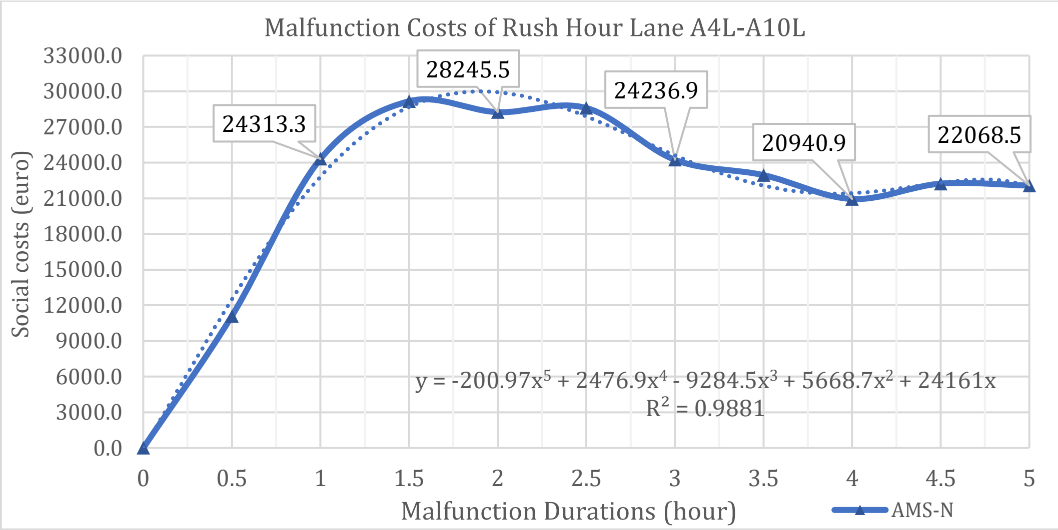


Figure 6-3. Cost curves for the RHL malfunction (A4L-A10L)

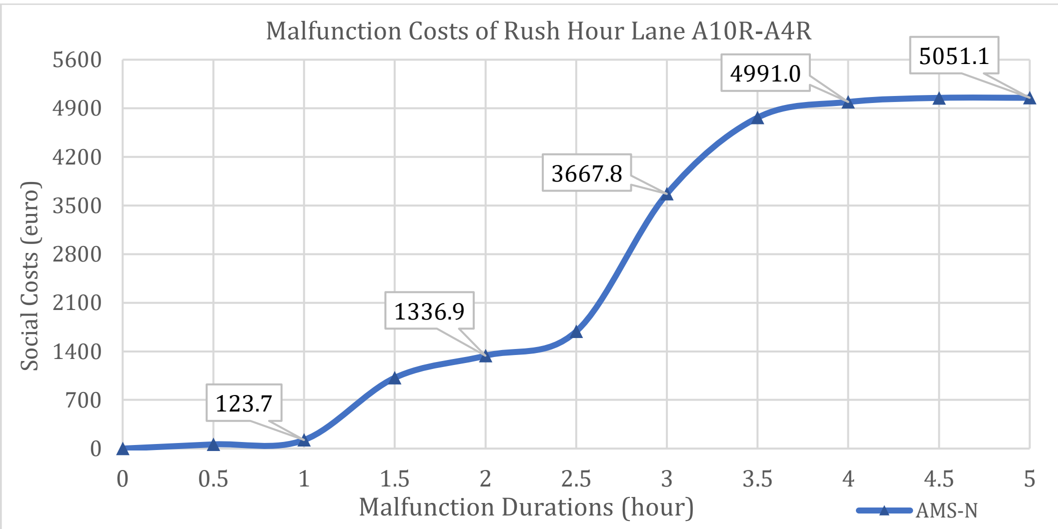


Figure 6-4. Cost curves for the RHL malfunction (A10R-A4R)

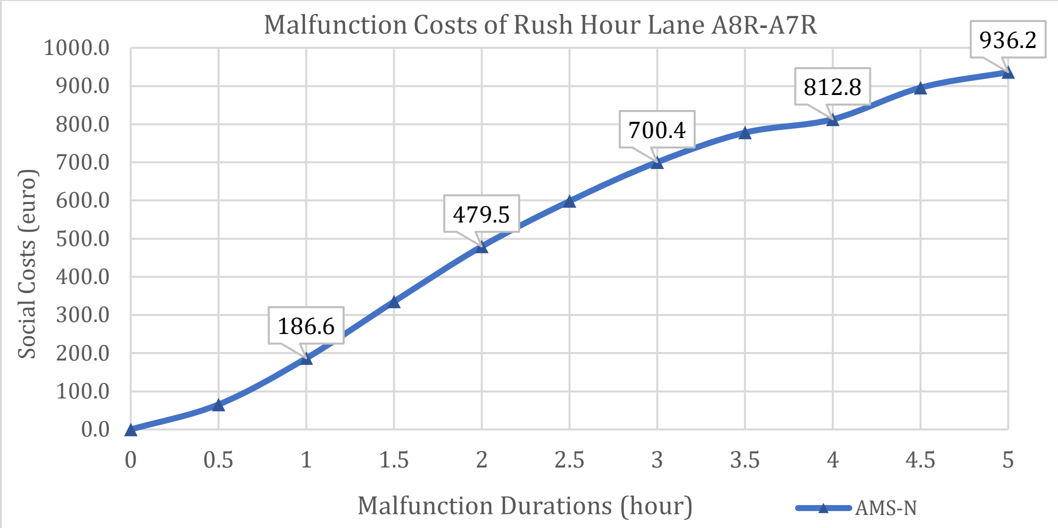


Figure 6-5. Cost curves for the RHL malfunction (A8R-A7R)

$$C_{RHL,SA4A10L} = -200.97h^5 + 2476.9h^4 - 9284.5h^3 + 5668.7h^2 + 24161h \ldots\ldots\ldots (4)$$

Where *h* donates the malfunction hours, *C* refers to the social costs due to the increased VVUs. The formulas are expected to be only valid with maximum of 5 hours, it is expected that the cost values would remain relatively stable around 22,000 euros when the RHL malfunction at stretch A4L-A10L is longer than 5 hours.

The shape of the cost curves for the RHL malfunction shows huge variance among three studied stretches, which indicates that the local circumstance plays an important role in influencing the consequence of the RHL malfunctions. Since the location defined in this study is not a discrete variable, which contains the properties of intensity/capacity, OD relation, vehicle compositions and et cetera, further research is necessary to sort out the location properties in generalizing the cost relations with the malfunction durations.

6.4 Social Costs with Malfunctions of MTM

As summarized in Table 5-6, the MTM malfunction in terms of 2% capacity reduction at the failure corridors including A1L, A2L, A5R, A5L and A8L can hardly have significant effects (taking 30VVUs as the minimum threshold) to the traffic, and thus social costs raised by flow impacts are only calculated for corridors A1R, A2R, A4L, A4R, A8R, A10SBL, A10SBR, A10SWL and A10SWR. However, as one of the most widely implemented DTM measures in the Netherlands, costs with only capacity reduction of 2-5% would underestimate the impacts of the MTM malfunctions, since the safety benefits with on average 19% accidents reduced are more significant than its flow benefits. Therefore, it is necessary to make concise assumptions to add bias to weight up the importance of the MTM system, by taking costs in safety aspects into consideration.

Hereafter, an important issue comes for how to calculate the social costs of the increased safety risks. Though the overall safety impact of the MTM system can be identified by comparing the number of accidents before and after the use of MTM signaling system in yearly basis, it is still impossible to predict the occurrence of the accident during its malfunction period especially with the accuracy of few hours. Moreover, even indeed an accident occurs at the location where the MTM fails, it would be too abrupt to conclude that the MTM malfunction is the cause of the accident, since an accident always occurs with sum of various coincidences.

Firstly, the accident rates of each motorway part in the AMS network is checked, which can be obtained from the IMN (Incident Management Nederland) foundation, who is responsible for the handling of passenger vehicle incidents on all motorways and 2,500 kilometers of other important roads in the Netherlands. These roads also known as IM (Incident Management) roads, all incident reports (excluding truck only incidents) from Police, Rijkswaterstaat and ANWB are recorded **(IMN, 2019)**. The annual incident records are available for every five kilometers at these IM roads, detailed information about the annual accident records at the prespecified motorway network of Amsterdam region is summarized in Appendix H. It can be assumed 19% more accidents would occur without the MTM system, by applying the number of registered accidents, the expected number of increased accidents can be determined.

However, after vast of literature investigations for an "average cost per accident", it is found that the average costs are generally calculated per victim instead. As the costs vary dramatically at different injury severity levels, and several victims could fall with several injury severities with huge difference in costs in an accident. Moreover, the social costs of road accidents are often grossly calculated, separated by six categories: *medical costs* (medical expenses relating to transport and nursing of casualties); *production costs* (lost future production due to illness, permanent disability or death); *intangible costs* (costs of human life quality lost based on the value-of-a-statistical-life "VOSL"); *material costs* (property damage to vehicle, infrastructures and so on); *settlement costs* (deployment of police, justice and fire department, management of insurance companies) and *congestion costs* (creation of jams due to the occurrence of a traffic accident). The material costs, settlement costs and congestion costs are the costs related to the accident, while the other three are related to the victim.

According to the severity of the accident (road death, severely injured, slightly injured and other injured victims), the victim costs were calculated with proportional allocations of the accident-related costs. On average it costs 2.6115 million euro per accident fatality, 280,600 euros per severely injury, 8,600 euros per slight injury, and 4,900 euros per other injuries at the price level of 2009. The average cost per material-only (UMS) crash was also estimated with 3,520 euros at the price level of 2009 **(De Wit & Methorst, 2012)**.

SWOV categorized the accidents into fatalities and serious injuries, the cost per fatality is 2.6 million euros in 2009, which is the same amount with **De Wit & Methorst (2012)**, and the cost per serious injury is taken as 0.53 million euros in 2009, of which all other injuries and UMS accidents are included **(Van der Linde et al., 2012)**.

Since no such an average cost value per accident regardless the severity level was determined, based on the cost values found for accident casualties, assumptions are made for calculating the costs according to registered type and number of accident victims per motorway trajectory, and these assumptions were discussed with experts in road safety field.

The VIA service and the BRON (databank of accident figures in the Netherlands, in Dutch: Bestand geRegistreerde Ongevallen in Nederland) provide the information about the number of road fatalities and serious injuries at each motorway trajectory. By sorting out the accidents into each defined corridor in AMS network, the safety costs can be calculated with the estimated cost value per victim identified by SWOV (2.6115 million and 0.53 million). The number of road fatalities and serious injuries per corridor are also calculated with a weighted average method according to trajectory lengths, and accidents records from 2015 to 2017.

Comparing with the sorted figures from the BRON (Table H-2) and the IMN figures (Table H-1), it is found that there are more accidents recorded by the IMN. Assuming those extra figures recorded by IMN are for the UMS accidents, the costs are then calculated with the combination of BRON and IMN data, by applying 3,520 euros per UMS accident to the total costs.

Since the number of accidents was recorded for three years, and by assuming the accident costs uniformly distributed each day, the average daily costs resulting from accidents can be obtained. Furthermore, the costs during the simulation period are also proportionally allocated, based on the registered serious casualty crashes on motorways over one day from 2012 to 2014 **(WVL & Grontmij, 2016)**. Afterwards, the safety costs raised by MTM malfunctions are determined by multiplying 19% to the regular costs, it is formulated as

$$C_{safety} = 0.19 \cdot \frac{N_d V_d P_d + N_i V_i P_i + N_u V_u P_u}{365} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where N_d, N_i, and N_u are the number of accident death, injury, and UMS accident. P_d, P_i, and P_u are corresponding share of distribution across the day, the values used in this research are 30.87%, 37.88%, and 34.17% respectively.

Following the same strategy for the cost calculation of the rush hour lane malfunction, and with supplementations of the safety costs without the signaling system, relations between the social costs of MTM malfunctions and the durations can be determined. The cost curves of each MTM location scenario are shown in Figure 6-6 to Figure 6-19.

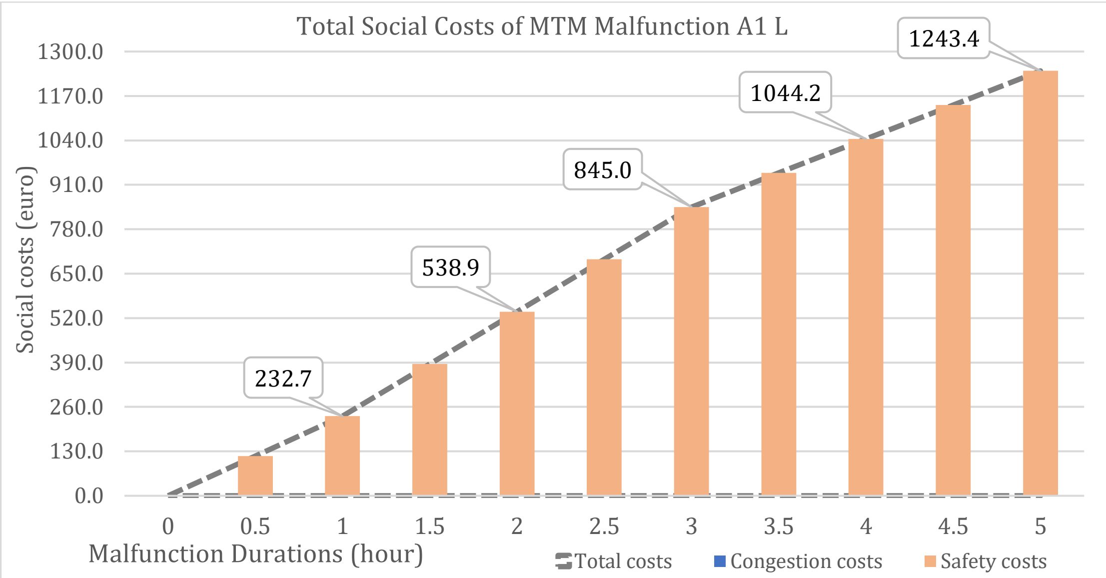


Figure 6-6. Total social costs of MTM malfunction A1L

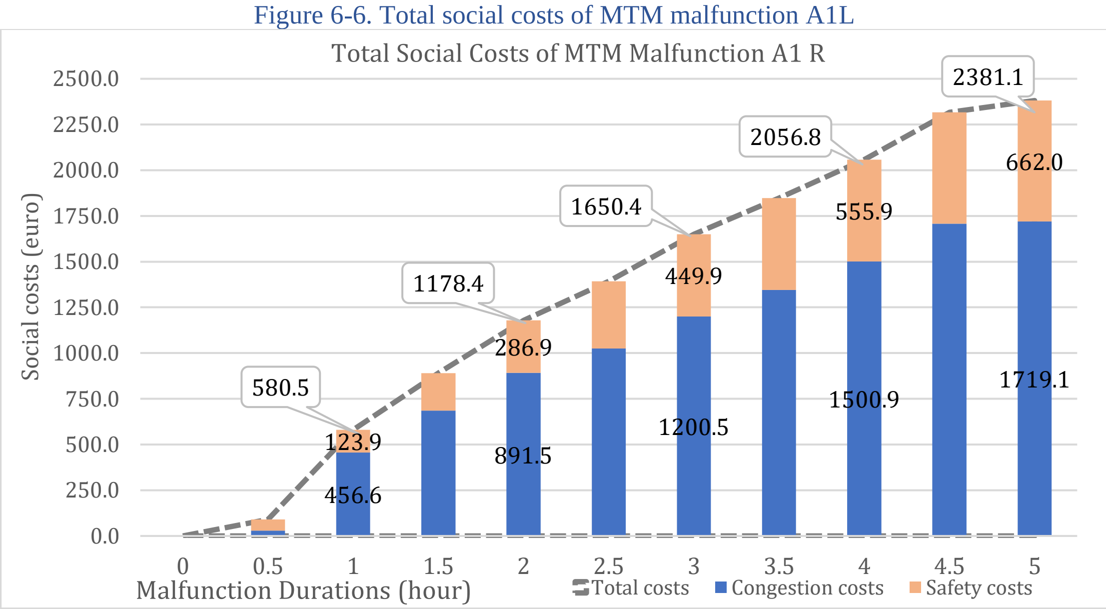


Figure 6-7. Total social costs of MTM malfunction A1R

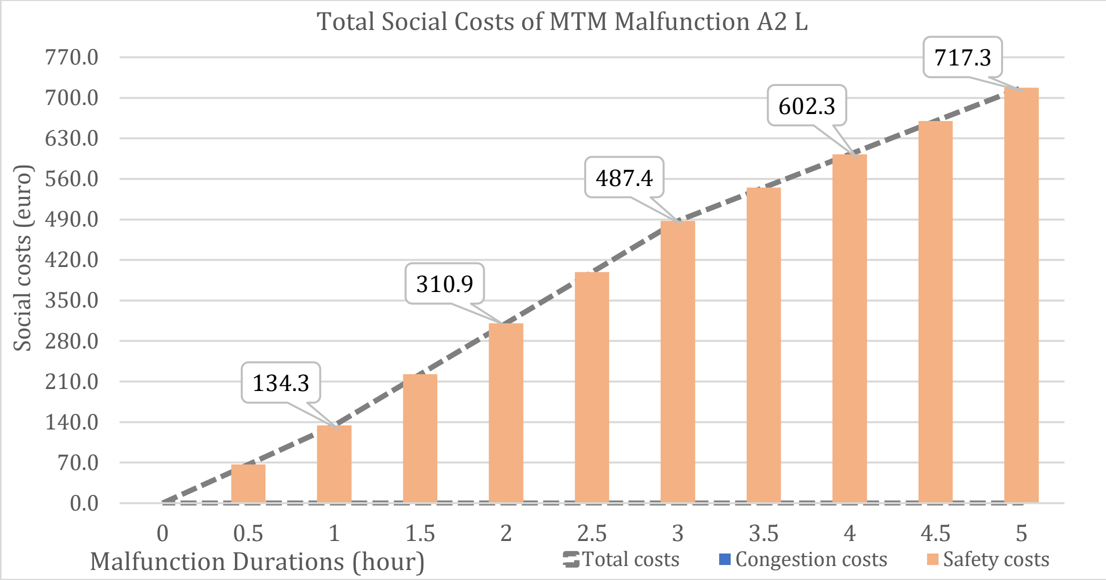


Figure 6-8. Total social costs of MTM malfunction A2L

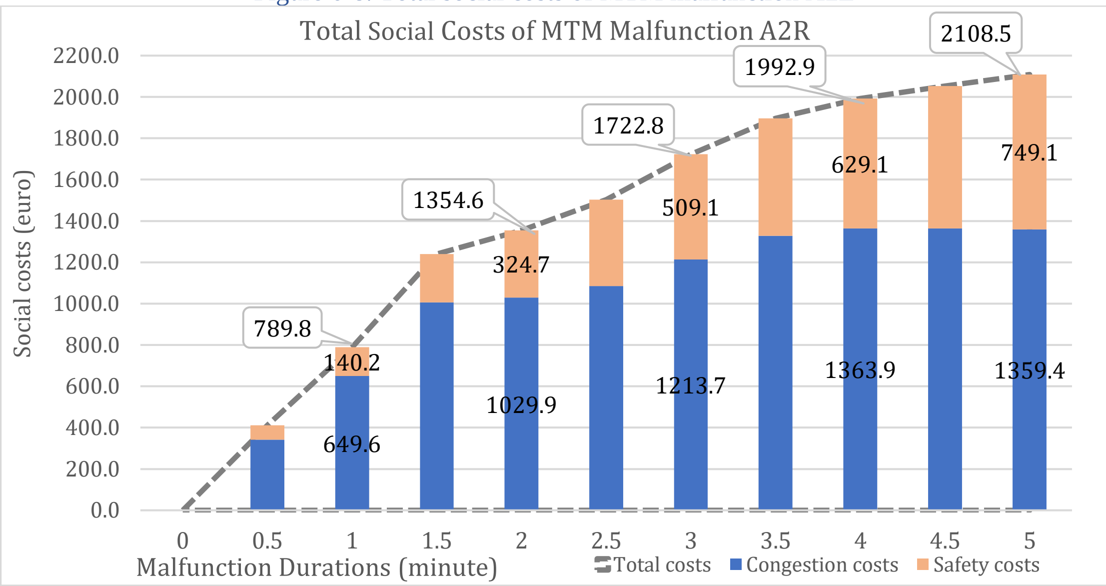


Figure 6-9. Total social costs of MTM malfunction A2R

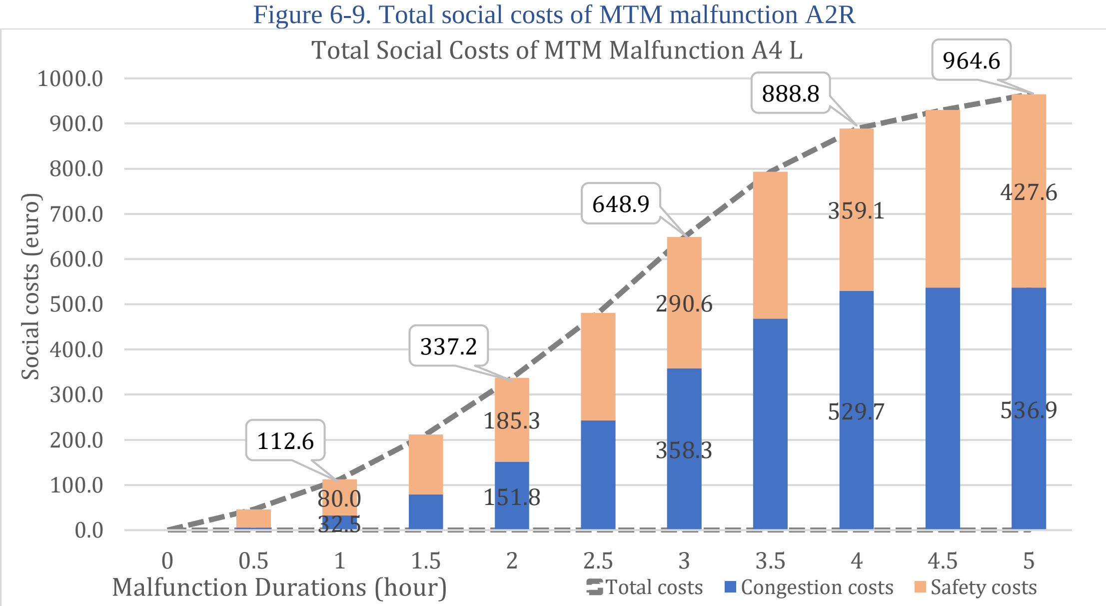


Figure 6-10. Total social costs of MTM malfunction A4L

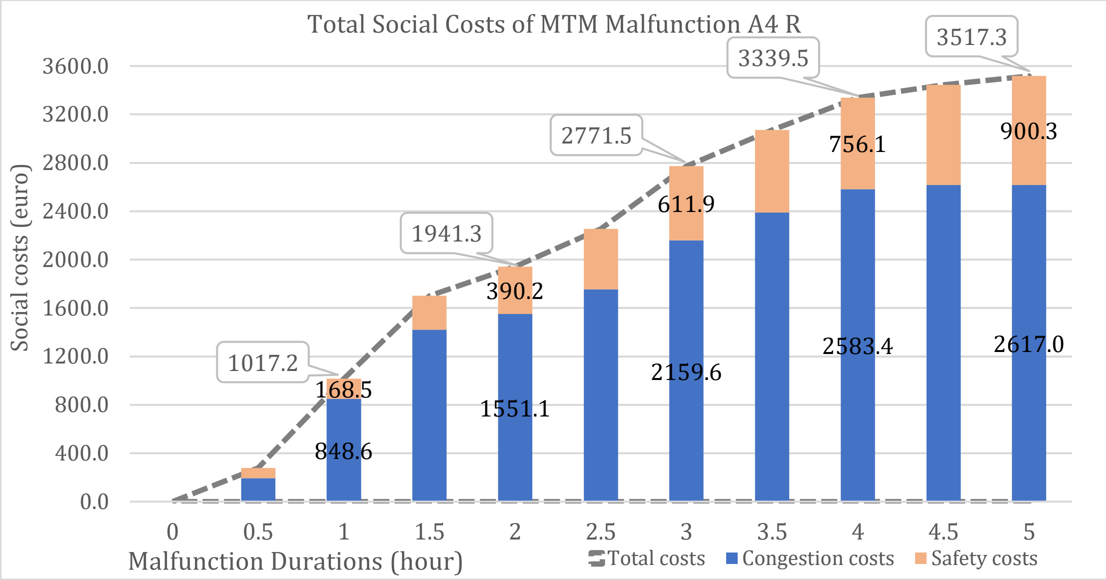


Figure 6-11. Total social costs of MTM malfunction A4R

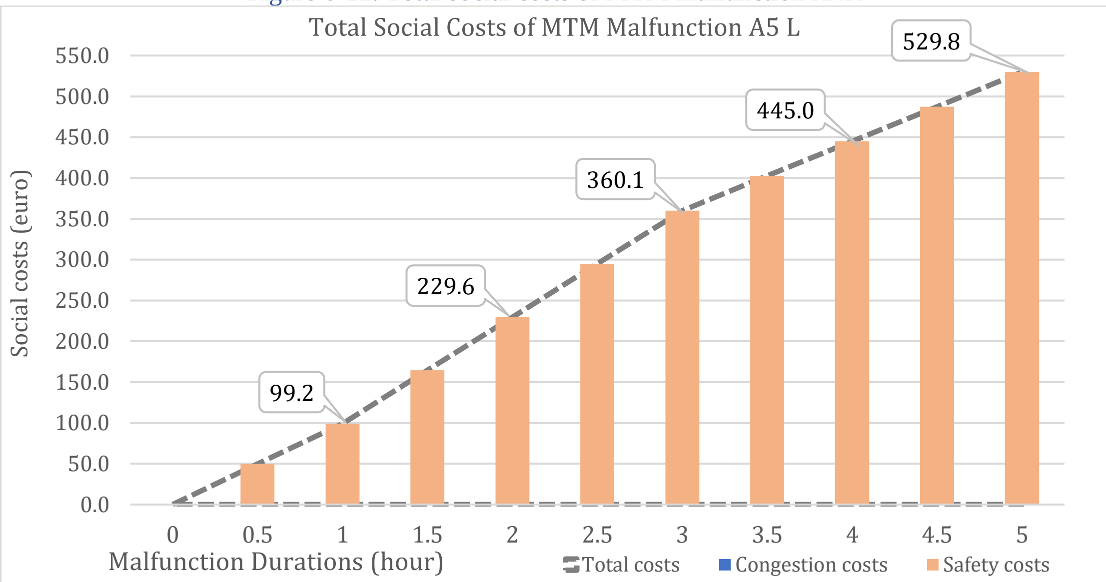


Figure 6-12. Total social costs of MTM malfunction A5L

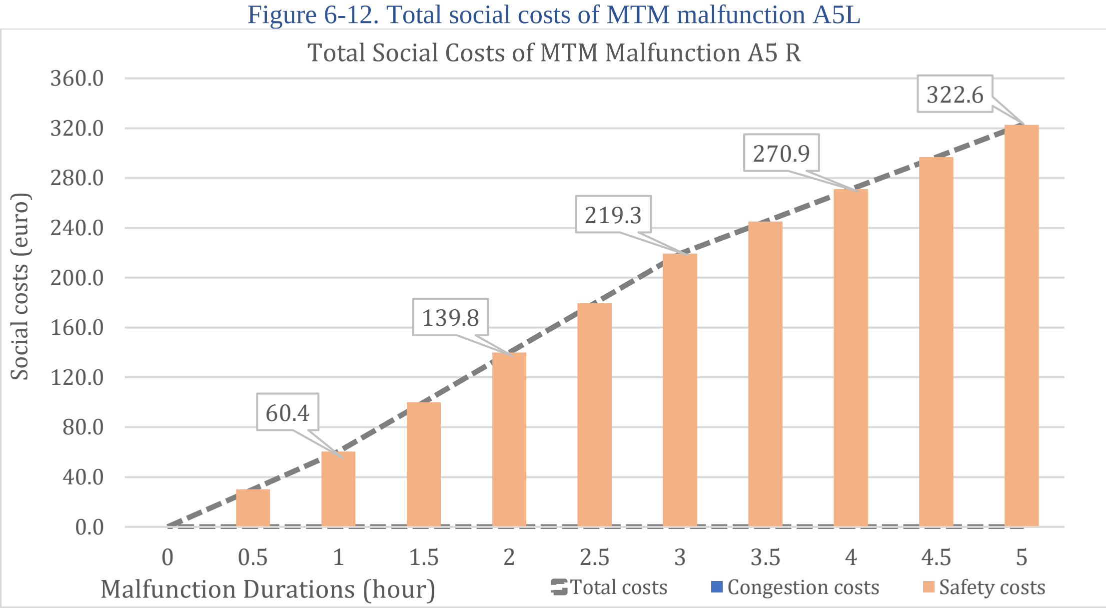


Figure 6-13. Total social costs of MTM malfunction A5R

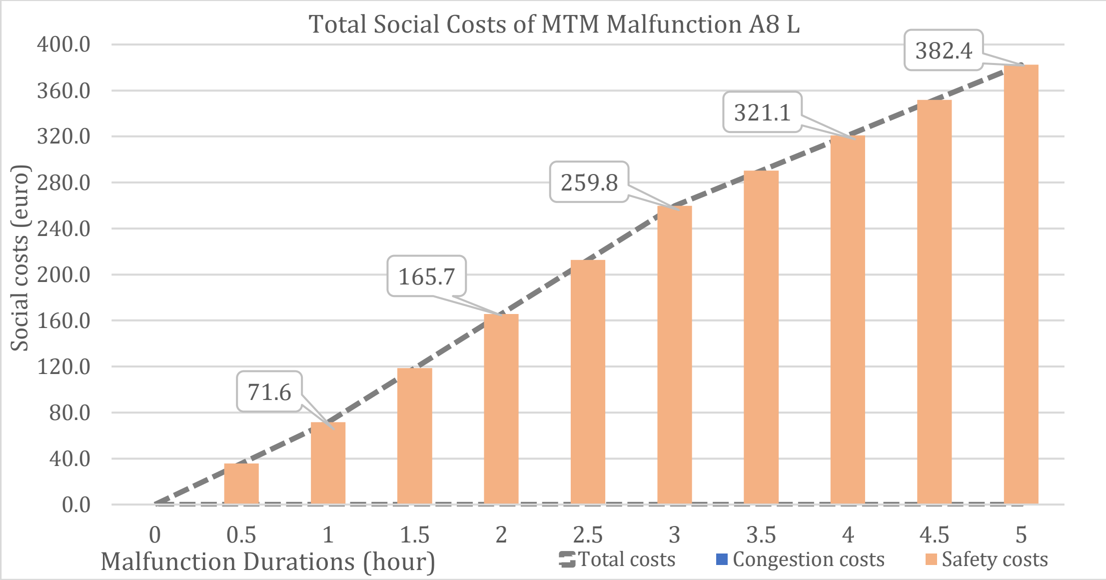


Figure 6-14. Total social costs of MTM malfunction A8L

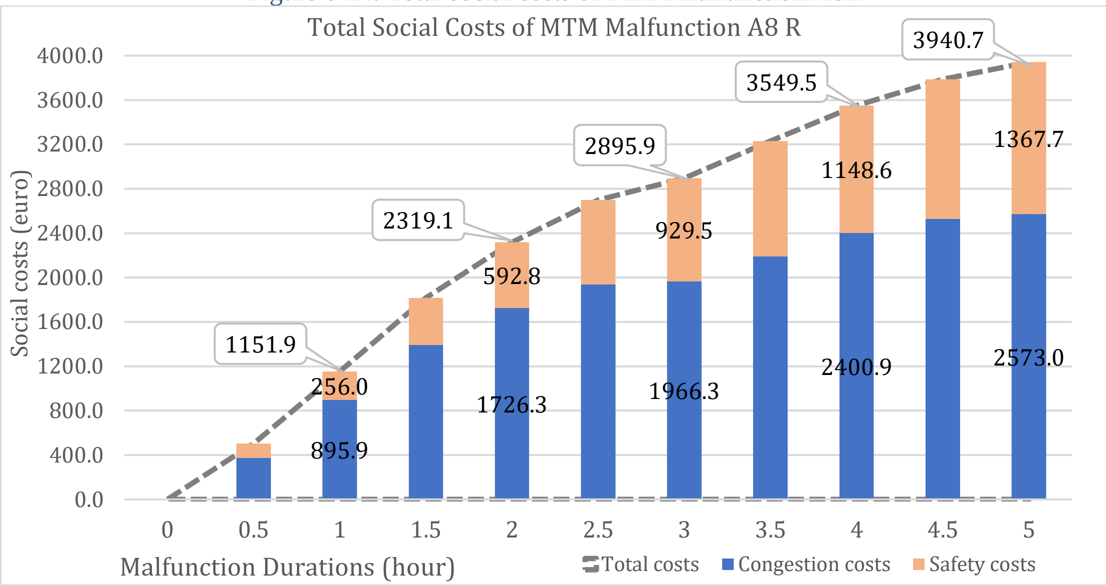


Figure 6-15. Total social costs of MTM malfunction A8R

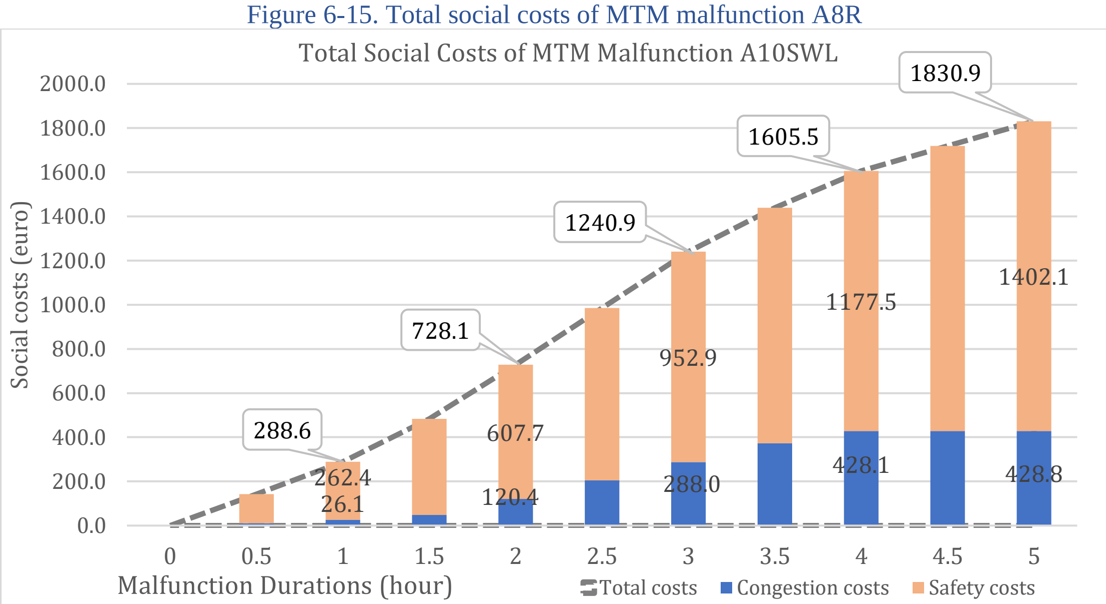


Figure 6-16. Total social costs of MTM malfunction A10SWL

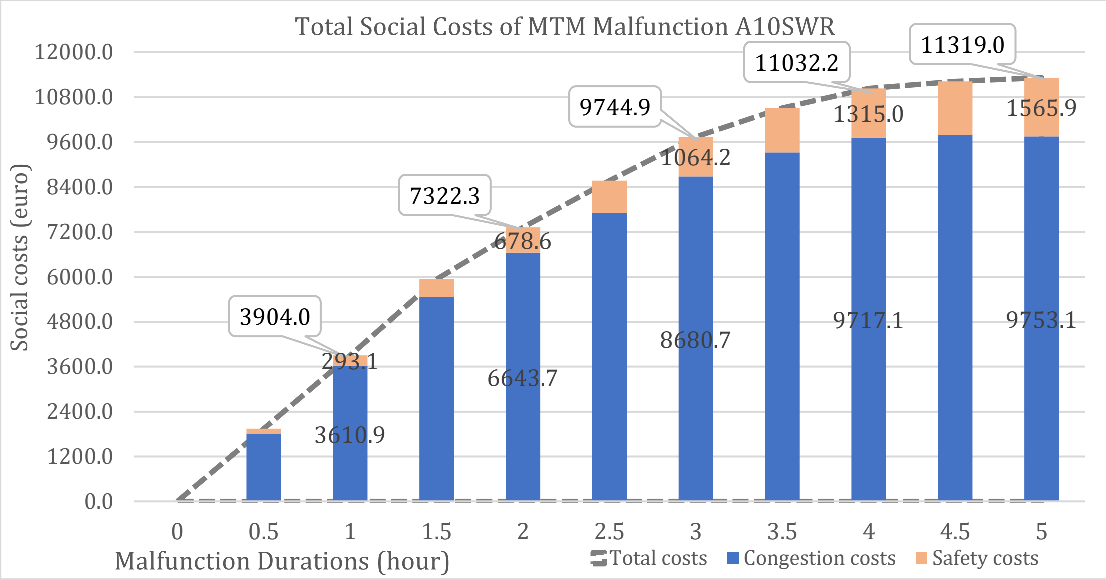


Figure 6-17. Total social costs of MTM malfunction A10SWR

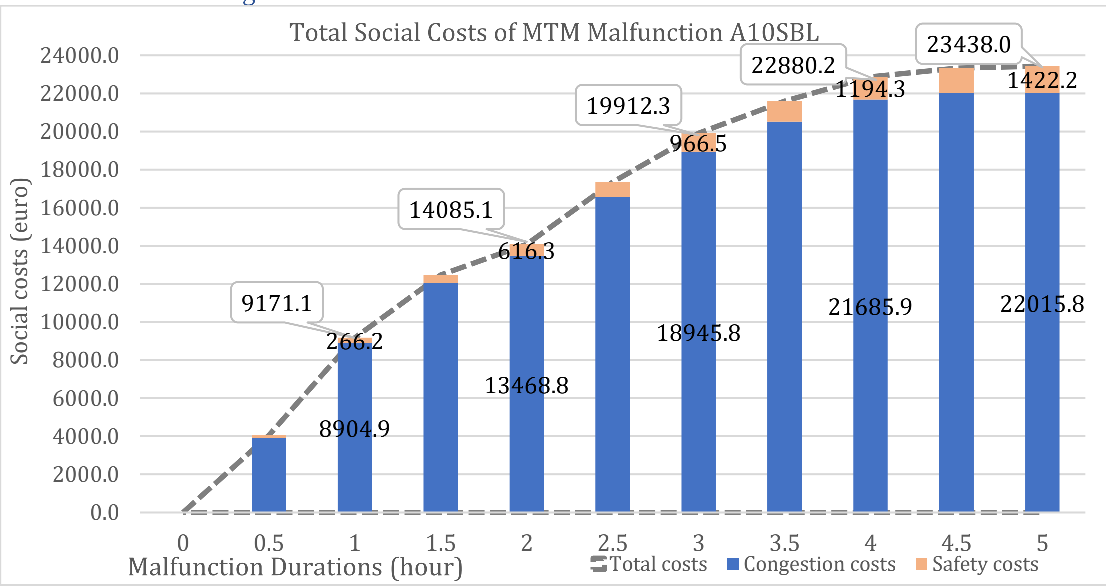


Figure 6-18. Total social costs of MTM malfunction A10SBL

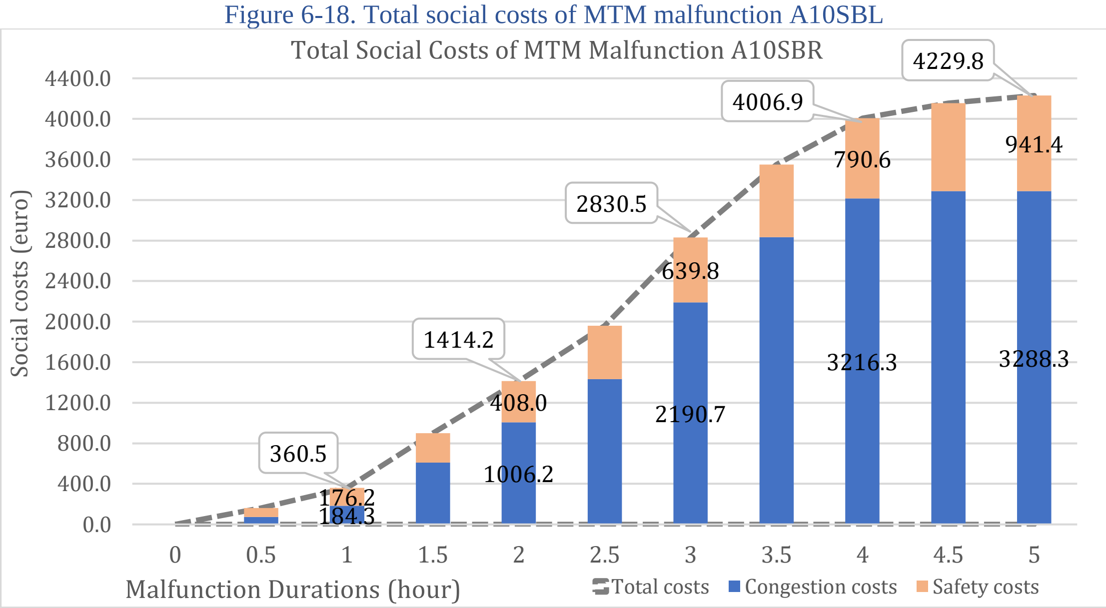


Figure 6-19. Total social costs of MTM malfunction A10SBR

For corridors with both cost categories involved, the increased VVUs are still the dominating cost source at those corridors where substantial delay changes were observed due to the MTM malfunctions, while safety costs take the lead (ranges from 73.4% to 92.3% of the total costs) at corridor A10SWL. Since the safety risks are assumed to be accumulated with the increase of malfunction durations, the cost curves of those corridors where safety costs are dominated (or only safety costs are involved) tend to present linear relationships with the failure durations. By contrast, cost curves of those corridors where congestion costs are dominated are more likely to show parabolic growing relationships with the malfunction durations, since the vehicle lost hours are also affected by the intensity changes.

Corridor A10SBL proves to be the critical location for the MTM malfunction, at which a total amount of 23,438 euros cost be produced with a 5-hour malfunctioning of the MTM signaling. The congestion costs contributed 93.9% to 97.1% of the total costs, which is resulting from a 5% capacity constriction at this corridor.

6.5 Social Costs with Malfunctions of DRIPs

The network was compared after the implementation of all 37 DRIPs at the AMS network, and it is found that the total delay decreased 235 VVUs at the inner ring, 861 VVUs at the outer ring and 1,210 VVUs at the six connecting corridors. Results of location scenarios indicated that the unavailability of a single DRIP or a stretch of DRIPs can hardly have impact to the traffic, therefore, it is expected there would be no added social cost when several DRIPs do not function in regular conditions (DRIPs are only used for providing information on route travel time). The costs are only calculated under the condition of all DRIPs at the AMS network are out of work for 5.5 hours, which leads to a total of 2,803 more VVUs when only victim corridors are considered, those increased VVUs contribute 40,488 euros in total by applying the vehicle compositions and the VOTs for each mode of transport.

Since the rerouting information can be displayed by all upstream DRIPs, and one DRIP can be used for the rerouting event occurred at any downstream corridor, it is assumed that the effects of the rerouting event without DRIPs are equally distributed by the upstream DRIPs.

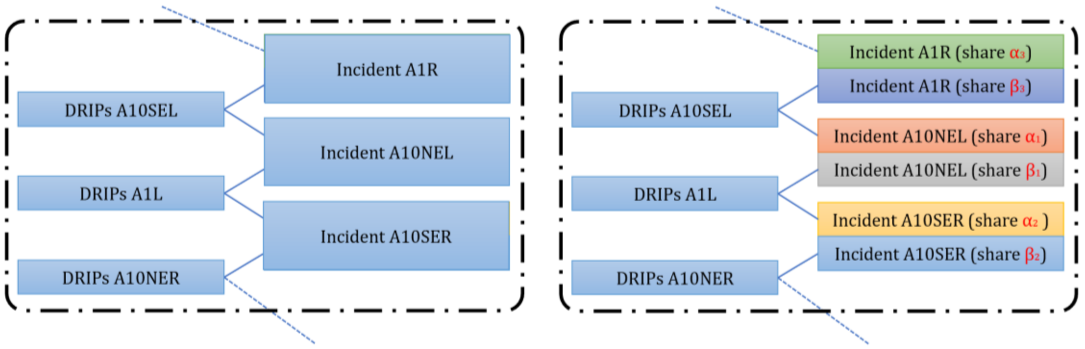


Figure 6-20. Chain relation of DRIPs and control corridors

Shown in Figure 6-20 as the chain relation between DRIPs and incident locations. The A1L DRIPs are assumed to be only responsible for the incident on corridor A10NEL and A10SER, and reversely, these two incidents are also controlled by A10SEL DRIPs and A10NER DRIPs. By assuming $\alpha_1 = \beta_1 = 50\%$, the proposed costs for the malfunction of A1L DRIPs rerouting can be calculated. Following the strategy to only look at the victim corridors in AMS-N level, a typical 2-hour accident without the rerouting of A1L DRIPs can lead to 2,995 more VVUs, resulting in 43,951 euros of social costs.

However, the costs can only be produced when an accident happens at the same time with the malfunction of upstream rerouting DRIPs, the probability of this situation can be extremely low.

Hereafter, the accident risks each motorway section are used again to distribute the malfunction costs in situations of accidents. The average number of vehicle accidents per year based on the records from 2014 to 2018 is used to represent the chance of accident occurrence. Multiplying the costs per accident without rerouting C_i with the yearly number of accidents N_a, the total costs of the DRIP malfunction in a whole year can be obtained. Distributing the yearly costs per day or per time periods, the average costs per malfunction can be obtained, which can be formulated as below:

$$C_{rerouting,\alpha} = \frac{\frac{1}{m} \cdot \sum_i^m \frac{1}{n_i} \cdot C_i \cdot N_{a,i}}{365} \cdot P_t \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (6)$$

Where

- m denotes the number of controlled downstream corridors of DRIP α
- n_i denotes the number of upstream DRIP corridors of accident at corridor i
- C_i denotes the cost of VVUs raised by the accident at corridor i, based on equation (2)
- $N_{a,i}$ denotes the average number of accidents per year at corridor i
- P_t denotes the percentage of accident occurrence across the day

Following the formulated strategy, the average cost of the DRIP rerouting malfunction per hour at six connecting corridors in the direction to ring A10 are summarized in Table 6-5.

Table 6-5. Hourly costs of rerouting malfunction

	Costs per malfunction hour (euro)					
	A1L	**A2L**	**A4L**	**A5L**	**A8L**	**N200L**
14:00 to 20:00	259	453	393	93	91	102
Day Average	191	333	289	68	67	75

The rerouting function was also evaluated under the situation of the RHL malfunction at A4L-A10L from 15:00 to 17:00 in the direction from west to east. With the rerouting information, 364 VVUs at the inner ring, 2,053 VVUs at the outer ring and 978 VVUs at connecting corridors can be saved. It is assumed that the saved VVUs would in turn become the increased VVUs once the rerouting function is not available, therefore it is expected that the total delays would increase 4,011 VVUs when only victim corridors in AMS network are taken into account, this results in a total social cost of 60,142 euros.

6.6 Social Costs with Malfunctions of Ramp Metering

Shown in Table 6-6 are the malfunction costs of the RM system at the AMS-N level (5.5 hours), though these values can represent the relative importance level among the studied RM systems, they are too high to be used for the consequence of RM malfunction, especially when compared with the calculated costs for the RHL and MTM. The AMS-N is not applicable in this case, considering its overestimation effects and improper modifications for the RM malfunction via MARPLE.

Table 6-6. Summary costs of the RM malfunction

RM	**201**	**202**	**203**	**204**	**305**	**306**	**307**	**308**	**309**	**310**	**311**	**312**
Cost (euro)	14,990	14,430	14,281	13,609	17,522	16,695	18,704	18,418	18,745	28,710	19,981	19,161
RM	**313**	**314**	**315**	**316**	**317**	**318**	**319**	**320**	**321**	**322**	**323**	**324**
Cost (euro)	17,456	4,015	17,585	17,146	16,803	17,259	1,599	20,240	16,870	18,857	2,173	15,397
RM	**325**	**326**	**327**	**328**	**329**	**330**	**331**	**332**	**333**	**334**	**335**	
Cost (euro)	3,572	5,510	1,011	1,189	2,999	2,906	3,596	2,320	2,722	1,945	1,913	

7. Conclusions

In this chapter, the scientific contributions are firstly summarized in section 7.1, and the answers for the research questions are illustrated in section 7.2.

7.1 Scientific Contributions

Since no previous study was found on the evaluation of the DTM malfunctions, and thus no connection to the social costs. This project initiates the first attempt to link the maintenance planning of the DTM systems and the social costs resulting from the system malfunctions.

This research develops a framework to modify the malfunctions of four DTM systems (RHL, MTM, DRIPs and the RM) implemented in the Netherlands, through a macroscopic dynamic traffic assignment model MARPLE. The MARPLE was used in a backward process to evaluate the effects at a network level after "removing" those DTM systems. Not only flow effects were evaluated, but also a methodology to distribute the accident costs across a day was firstly used to calculate the safety-related costs in an hourly basis, with combined data sources.

With the proposed social costs determined for the four DTM systems, the maintenance strategy could be improved to better deploy the budget plans by taking the social costs into consideration. The outcome of this research proved the feasibility of building up a performance model of the DTM malfunctions through a macroscopic assignment model.

The simulation results of each malfunction scenario indicate that, the motorway categorizations used for the risk analysis of DTM components could not be taken as the criterion to interpret the severity of the consequence of DTM malfunctions. Other than the length of failure durations, the existence and size of the bottleneck plays an important role in determining the malfunction impacts.

Overall, with the development of the framework in modifying the DTM malfunctions, and the converting effects identified through literatures, a first attempt in the evaluation of malfunction effects via a dynamic macroscopic traffic assignment model is utilized. For the first time what-if questions with regarding to DTM malfunctions were answered in this research. Accompanied by step-by-step instructions, the methodology developed in this research laid the foundation for further explorations of the DTM malfunction both in the vertical and horizontal dimensions, to provide more reliable predications in a broader range of applications.

7.2 Answers for the Research Questions

- **Sub Research Questions**

1) *What are the recognized benefits of the selected dynamic traffic management systems?*

   The benefits of the selected DTM systems were identified via the intra resources including evaluation reports, design manuals and safety directives. As a capacity measure, the extra capacity provided by the rush hour lane at the right hard shoulder (spitsstrook) is around 900 veh/h according to the capacity manual (WVL & Grontmij, 2015), and the capacity value is higher (1400 to 1700 veh/h) for the rush hour lane on the left (plusstrook).

   The motorway traffic management (MTM) system nowadays has been developed as an integrated and basic system in supporting of other DTM systems and functions, while in this study the independent functions of the MTM system are studied. Two typical functions including the automatic incident detection and warning (AID) and flow homogenization are utilized by indicating a maximum speed value (50 km/h, 70km/h, 90 km/h) on the signal matrixes, since the function of flow homogenization is less effective in the improvement of traffic flow and therefore less used in current practice, the AID function was extensively evaluated. Various studies (de Kroes, Donk & de Klein, 1983; McKinsey & MinVenW,

1994; EAVES, 1994; AVV & BGC, 1994**)** indicated that the road capacity could be better utilized (1% to 5%) after its implementation. While there are still evaluations to show the negative impacts to the road capacity, e.g. a 4% capacity less on *Lokale filebeveiling A27*.

Compared with the improvements on the traffic flow, the MTM system brings more safety benefits to the road traffic. Around 24% of the accidents were reduced, and the secondary accidents got further decreased with 46% after the implementation of the MTM systems (de Kroes et al., 1983). Taale (2018) summarized the overview utilization effects of DTM systems according to 210 practical evaluations, in his report, the signaling system realized a 2% higher capacity and 19% less accidents on average.

In current practice on Dutch motorways, two types of DRIPs (Standard DRIPs and Berm DRIPs) are used, to provide information on downstream traffic situations to road users. According to the type of information displayed by the DRIPs, the DRIPs can be further divided into textual DRIPs and graphical DRIPs. The basic functions of the textual DRIPs are to provide route information (in terms of travel time) and reroute the traffic, most of the studies for the DRIPs are the comprehensibility investigations to the road users (Grontmij, 2007; Ergo, 2010). According to evaluation reports [RIA-3&-4], the implementation of DRIPs helps to reduce 13%~25% of the vehicle lost hours, the congestion size is also reduced by 20%~25%.

As one of the most studied DTM measures, it is still difficult to judge the effects of the ramp metering system. The most common effect is the speed increase on the motorway ranges from 4 km/h to 30km/h (Taale, 2009). Based on the measured effects of the ramp metering systems in project VDA10, a 10% reduction in vehicle lost hours was utilized for the flow on ring road A10, safety effects were also evaluated with 25%-50% less accidents.

2) *What method is applicable to determine the effects of system or function failure? Which method or tool is used in this research, and why?*

Few studies on the DTM malfunction was found to provide insights for its modification, and thus this research proposed a new methodology to convert the malfunctions of different DTM systems to changes in network conditions (in terms of model input). The strategy for the conversion of DTM malfunctions was developed based on the benefits brought by the system(s), and the benefits have already been identified in the answers of the sub research question 1. The malfunction of the rush hour lane was modified with a 900 veh/h of capacity constriction, and the MTM malfunction was modified with 2% or 5% of less capacity.

The malfunction of the DRIPs and the RM systems were achieved, by directly removing or the corresponding system unit from the network. The responses to the DTM malfunctions were predicted and estimated by dynamic macroscopic assignment models. MARPLE is chosen in this study with its capability in representing the traffic conditions with a good agreement of the reality. Furthermore, since MARPLE was also used for the evaluation of DTM systems and measures at the road network around Amsterdam in previous projects (*FileProof, Praktijkproef Amsterdam*), most of works for the network setup have already been done, by choosing which much labors and times in network preparations can be saved.

3) *What would be the impact if one function breaks down at one or more locations at the local level? And at the network level(s)?*

The malfunction scenarios for each system were conducted at the corridors defined in AMS network (the ring road the six connection corridors), depending on the availabilities of the DTM systems at each corridor. The local level is defined as the corridor level, at which only road sections with the occurrence of system malfunction are considered. Existing field evaluations for the DTM systems are generally conducted at the local level, these studies could provide additional justifications for the simulation outcomes. Several network levels are defined in research, including the AMS network level, the ring road level (both inner ring and outer ring), and the regional network level. With different policy perspectives, the aggregated malfunction impacts show great variance among different network levels. The variance between progressive network levels also indicates the propagation size of a "local" system failure.

The summary for the malfunction effects of the RHL and the MTM systems at different aggregation levels can be found at Table 6-2 and 6-3. The VVU changes without the route travel time information are less significant in each location scenario. The malfunctions of DRIP rerouting reveal the negative impacts to traffic with more vehicles entering the jam and thus more delays and longer jams formulated upstream the incident location. Detailed results can be found in Appendix F-3.

The simulation results of the RM indicate that its malfunction was not well modified, since the obtained effects without the corresponding RM are the prediction of long-term behavior adaptations, which raised the traffic state changes almost everywhere in the network. It is suggested to conduct further research for the RM before interpreting its malfunction effects according to MARPLE simulations.

The MTM malfunctions at both the outer ring and the inner ring were also evaluated in this research to show the effects of multi-location malfunctions. VVU increase and intensity reduction are the two main effects introduced by the MTM malfunction. It is found that the MTM malfunction at the outer ring is severer than the malfunction at the inner ring, both in VVU developments and intensity reductions.

4) *How could those impacts resulting from the malfunctions of DTM systems and functions be converted into monetary costs?*
Rijkswaterstaat developed an impact indicator to quantify the negative effect of time losses, the vehicle lost hours (Abbreviated to VVU in Dutch: *Voertuigverliesuren*), which stands for the total number of hours of travel losses due to limitations in road capacity. The VVUs are often used in situations of accidents and maintenance works. A VVU is equivalent to one vehicle delayed by one hour. The social costs are calculated based on the increased vehicle lost hours and the safety risks, donating the flow-related costs and the safety-related costs. Studies about the economic costs of the VVUs and accident victims are available to convert those negative effects of DTM malfunctions to social costs in euros. The cost values used in this research including 52.49 euros per VVU of trucks, 10.75 euros per VVU of passenger vehicles (KiM, 2013; RWS, 2019); 2.6 million euros per accident fatality, 0.53 million euros per serious injury (Van der Linde et al., 2012) and 3,520 euros per material-only accident (De Wit & Methorst, 2012).

- **Main Research Question**

What are the costs when functions of the dynamic traffic management systems fail at different locations at the motorway network?

The costs of system malfunctions are determined in the perspective of looking at the victim corridors only within the AMS network (AMS-N). The costs of RHL and MTM malfunctions are represented by cost curves with the variance in failure hours, shown in Figure 6-3 to 6-19. Safety-related costs are also counted for the MTM malfunction, which are proportionally added and accumulated by the increasing exposure times without the MTM signaling. The cost values vary among locations according to registered number of fatalities, serious injuries and material -only accidents from BRON and IMN. The cost of RM malfunctions according to variance in failure hours was not investigated due to the capability of MARPLE, it is only calculated for a downtime of 5.5 hours. Shown in Table 7-1 and Figure 7-1 are the proposed malfunction costs (euros) of four DTM systems evaluated in this study.

Table 7-1. Overview of malfunction costs (MTM, RHL, DRIPs)

Location	MTM (5 hours)					RHL (5 hours)					DRIPs
	1h	2h	3h	4h	5h	1h	2h	3h	4h	5h	1h
A1L	233	539	845	1,044	1,243	-					259
A1R	581	1,178	1,650	2,057	2,381						-
A2L	134	311	487	602	717						453
A2R	790	1,355	1,723	1,993	2,109						-
A4L	113	337	649	889	965	24,313	28,246	24,237	20,941	22,069	393
A10SBL	9,171	14,085	19,912	22,880	23,438						-
A4R	1,017	1,941	2,772	3,340	3,517	124	1,337	3,668	4,991	5,051	-
A10SBR	361	1,414	2,831	4,007	4,230						-
A5L	99	230	360	445	530	-					93
A5R	60	140	219	271	323						-
A8L	72	166	260	321	382						91
A8R	1,152	2,319	2,896	3,550	3,941	187	480	700	813	936	-
A10SWL	289	728	1,241	1,606	1,831	-					-
A10SWR	3,904	7,322	9,745	11,032	11,319						-
N200	-										102

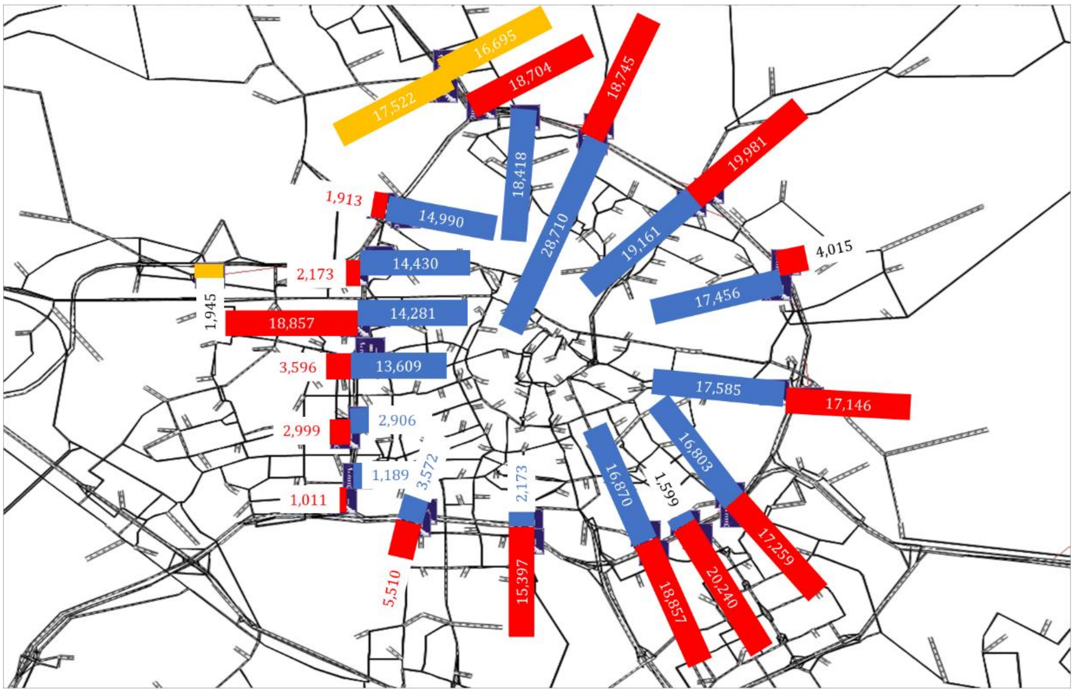


Figure 7-1. Costs of the RM malfunctions (euros)

The inner-ring RMs are marked in blue, the outer ring RMs are marked in red, and other RMs in AMS network are marked in yellow. Those numbers are the calculated costs across a 5.5-hour period from 14:30 to 20:00.

8. Limitations & Recommendations

In this chapter, limitations of this research and possible improvements are illustrated in section 8.1, based on which recommendations are given in section 8.2 for further researches.

8.1 Limitations and Improving Strategies

In this section, decisions made on the methodology and assumptions during the whole research process are discussed, and the corresponding alternatives are provided, by applying which the accuracy and reliability of research outcomes can be improved. In addition, recommendations are given based on the limitations of this research, which might be helpful for further researches to complete the objectives of the "P-IHP-DVM II" project.

8.1.1 Network & Model Setup

A global scaling factor of 1.14 was used in this research to represent the average intensity growth. Calibration of O-D relationships was neglected considering the time constraints and the mainline of this research, since the calibration process for the O-D matrix with goodness-of-fit measures in such a large regional network is too laborious, which assumed that all O-D relations remain unchanged. It is a fast and simple way to map the demand change from the year of 2007 to 2018, however, the value of 14% is derived from the average intensity change on all Dutch motorways, while motorway intensity at Amsterdam region may show different patterns from the general trend. Since good O-D matrix is necessary for obtaining good results **(Taale & Van Zuylen, 2006)**, improvements can be made by having at least important O-D relations calibrated before starting the simulations.

The performance calibration of the network was based on visual judgements, by matching the speed/free speed plot from MARPLE with the typical traffic condition from Google maps. The criterion of the performance consistency is crude without any statistical comparison, especially when the legend of Google maps is different with the model plot. To represent the bottlenecks not modified in the model and to eliminate the bottlenecks not exist in reality, the capacity and saturation flow rates were adjusted iteratively until the model simulation could produce good consistency with the Google maps, however, to what extent should the saturation flow rates be adjusted was done by rules of thumb, which exacerbated the inaccuracies. A better option is to adjust the saturation flow rates according to measured floating car data, for instance through VIVA viewer, MoniGraph, NDW and ADY data.

Additionally, the traffic on urban roads and other motorway parts outside the AMS network was not calibrated in model setup, of which the link characteristics, intersection types and signal control plans could also create substantial impacts to the traffic in the AMS network.

8.1.2 Effects of the DTM Systems

One of the fundamental assumptions made in this research, is to take the benefits brought by these DTM systems equal to the negative effects when they are not available. It looks rational with the first glance, however, especially for the MTM system, the malfunction of which was assumed to reduce 2% or 5% of the motorway capacity and could cause considerable variance with the reality. Since the two main identified effects introduced by the capacity constriction is the delay growth and the intensity drop, which takes the route choice change into consideration. It is argued how much the MTM malfunction could contribute to the route change. In reality, the route choice change with the MTM malfunction could be much less than the simulated figures, when road users do not have direct feeling of the capacity impacts introduced by the signaling system. In other word, road users may not expect that the congestion would become much more severe without the signaling system. It is argued if modifying the MTM malfunction via static queuing model with unchanged demand input could make the simulation results closer to reality or not.

With regarding to the rush hour lane malfunctions, road users can have direct feeling about the “upcoming more congested” traffic when one lane is closed. However, occasional closures of the rush hour lane could lead to greater problems than the benefits it brought, since the regular traffic demand during peak hours has been increased with its regular opening **(Transpute,2011).**

In this research, the effects of the RM malfunction were obtained by comparing the traffic with and without the corresponding RM in the initial network. While the simulations results indicate that this assumption is not applicable for the RM malfunction, since the traffic across the whole network was re-distributed, the response behaviors to the RM malfunction was not modified. It is expected the malfunction effects of a single RM is limited to a certain range of area, and it is to be discussed whether a microscopic assignment model is a better option for the modification of RM malfunctions.

8.1.3 Base Scenario and Malfunction Scenarios

Considering the time constricts, time series with different malfunction starting times were only conducted for the RHL stretch A4L-A10L, and a critical time series with most delay increased due to malfunctions was identified at the 15:00, which was then applied for all RHL and MTM malfunction scenarios. While to be more accurate, this assumption on the critical time series should be verified per scenario. Besides, as identified already, the worst half-hour malfunction was found in 15:30 series, and it could be used to replace the half-hour malfunction in 15:00 series, through which the worst-case delay curve that is independent with the starting time can be formed.

With regarding to the comparison between the base scenario and malfunction scenarios. The base condition in DRIP malfunction scenarios is different with the RHL and MTM malfunction scenarios. A different event simulation type was applied for the DRIP malfunctions, which makes it impossible to allocate the regular function of travel time indication together with the regular closure of the RHL stretch A8R-A7R in the last hour of simulation period (19:00-20:00). In contrast, the regular closure was modified in the RHL and MTM malfunction scenarios.

Due to the inconsistency in base conditions among different DTM malfunction scenarios, the malfunction effects among DTM systems could not be transversally compared. Though an ex-ante & ex-post strategy was used to derive the net malfunction effects and can compensate the deviation from network base conditions to some degree, it neglects the associated effects introduced by the coordination among DTM systems. In other word, the effects by removing the only one DTM system from the network can be different with the effects by removing the same DTM system from the network equipped with other DTM systems.

Additionally, the DRIPs were evaluated in a corridor basis instead of per DRIP, which made a rough approximation for the equal effects contributed by the DRIPs at the same stretch. Though the positioning of the DRIPs depends on the intended aim of the control measures **(AVV & Witteveen+Bos, 2007)**, the function or the target users of a DRIP is also affected by its location. Only the DRIPs placed immediately prior to a trajectory or in front of the decision point for an alternative route can have direct impact to drivers’ route choice. Since there are decision points within the same corridor stretch (e.g. the off-ramps), it is better to conduct the evaluation per DRIP.

8.1.4 Network Boundaries

The selection of network level for the cost calculation is based on rules of thumb. As discussed earlier, the vehicle lost hours show huge variance among different network levels, and therefore the network level choice is crucial to the cost calculation.

In capacity-constricted malfunction scenarios (RHL and MTM), two features of the predicted response behaviors are identified, the speed drop which contributes to delay growth and the intensity reduction which compensates the increase of vehicle lost hours. When the intensity reduction plays the dominating role in response to the constricted capacity on the main road, the changes in integrated vehicle lost hours can be negative (for instance, RHL malfunction on A4L-A10L stretch at AMS network level; MTM malfunction on stretch A1R at regional network level; MTM malfunction on stretch A8R at corridor level), and the negative VVUs were often observed at less congested corridors, where the average travel speed is less affected whilst the intensity reduction is relatively more significant.

As the negative values were observed at all three network levels, the integrated VVU changes cannot be directly used at existing network levels, otherwise there would be no social costs or even social "benefits" with the DTM malfunction. Therefore, a network level named "AMS-N" is came up to look at the victim corridors only, by this way the VVU changes are always positive with DTM malfunctions.

Though the drawback of negative values of the VVUs can be eliminated, by choosing the AMS-N network level as the reference for the social cost calculation, an attentional issue still exists with regarding to the "boundary problem". The "boundary problem" was firstly noticed in the scenario of RHL malfunction at A8R-A7R stretch, where the main effects were observed outside the AMS network, and actually the "boundary problem" exists in all malfunction scenarios especially at the connecting corridors. For the malfunction scenarios at the ring road, the simulation results indicate how much propagated effects were received by the connecting corridors, and the division of the AMS network reveals whether the propagation of malfunction effects could terminate or not before the first motorway interchange. For the corridor traffic in the direction to the ring road, it is possible that the malfunction effects would be extended upstream beyond the first interchange; and for corridor traffic in reverse direction, when the malfunction enforced the congestion severity at the failure corridor and blocked the traffic leaving AMS network, corridors downstream would also be affected. Therefore, how much malfunction effects would be received by other motorway parts is unknown when only the motorway sections in AMS network are focused.

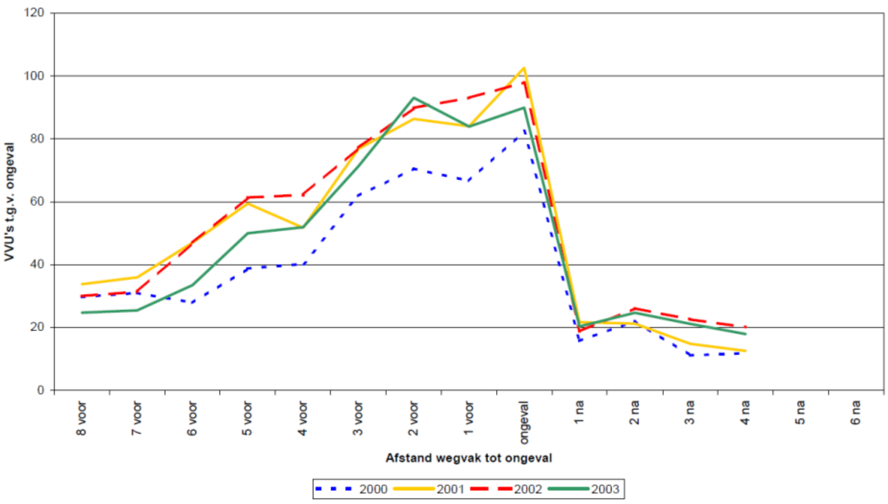


Figure 8-1. VVU effects of an accident at a day (regression) (AVV, 2004)

The impact of an accident (similar to the RHL and MTM malfunctions) in terms of VVUs was evaluated **(AVV, 2004)**, which is relatively largest at the accident section itself up to about three adjacent road sections, and the upstream traffic is highly affected, as shown in Figure 8-1. To improve the reliability of network level choice, it can be better to always define a larger network for the malfunction studies in a smaller network. To fit for this case study of motorway network around Amsterdam, motorway A9, which is like the second ring of Amsterdam, can be included to define a larger network, in order to identify the malfunction effects received from the connecting corridors in AMS network.

8.1.5 Cost Calculations

Two values-of-time (VOT) are used in this research, 52.49 euros for freight vehicles and 10.75 euros for passenger vehicles, which is referred in the corrected 2019 price level. In cost studies of Significance et al. (2007) and KiM (2013), costs were also separated according to truck types (light, medium, heavy) and passenger vehicle trip purposes (business, housing work), which can be used to improve the calculation when the trip distribution could be identified per location.

Furthermore, in economic and social cost-benefit analysis (SCBA) studies, the time values are always applied with growth factors, according to which the price in future years is predicted. It comes to a question how long the model developed in this research could be valid, and whether such a growth factors can be applied in DTM malfunction studies. Though there are many firm studies about the growth factors for the value-of-time, the validity of the VVU model developed in this study is still to be discussed, since even the seasonal effects were not taken into account, applying a growth factor for the time value units becomes less unnecessary at this moment.

With regarding to the safety costs of the MTM malfunction, and the proposed costs of the DRIP rerouting, the chance of accident occurrence is assumed to be equal every day across the year. In reality, it is expected that the accident numbers during working days and non-working days can differ a lot, while it requires extra work on sorting out the accident records. Also, the IMN records were combined with BRON in this research, whether they can be well matched requires further efforts into the improvement of the cost calculation, with multiple sources combined, to refine the cost in different accident categories.

8.1.6 Network Performance

Since the network delay in terms of vehicle lost hours is accumulated with the lost travel time and the number of vehicles, and it is expected a longer road section can accommodate more vehicles when the number of lanes and the average flow density are same, which makes the corridor length can also have impact on the intensities and thus on the accumulation of the vehicle lost hours. In this research, corridors are separated according to location of motorway interchanges, the corridor length varies per trajectory, which could lead to some unfairness in the comparison of corridor sensitivities to the DTM malfunctions.

8.2 Recommendations for Further Studies

In this research, the DTM malfunctions were evaluated at 12 corridors in 24 location scenarios, combinations of DTM malfunction at different locations and malfunction combinations of different DTM systems are less investigated. In future studies, malfunction effects in scenarios with different location and DTM system combinations can be further determined, based on the DTM availabilities at each location.

Since it is hard to validate the malfunction effects identified by MARPLE, external and parallel studies can be conducted to amend the simulation results. For instance, stated preference (SP) experiments about response distributions of road users to DTM malfunctions, can be conducted via online questionnaires and postal surveys, through which proportions of people who would switch their mode choice (e.g. via public transport), departure time choice, route choice or even choice combinations could be identified. In this way, additional justifications for the intensity changes in model simulations can be provided.

As explained earlier, the model simulation for the ramp metering malfunction is less successful due to re-assignment for the whole network. A microscopic assignment model for the metering control with high flexibility of signaling timing and detailed horizontal and vertical queueing could be a better option to provide more reliable predictions. Moreover, it is possible to conduct purely statistical analysis for the ramp metering malfunction without MARPLE simulations, according to operation logs and measured floating car data (e.g. periodical monitoring reports from VWM).

In this research, the malfunction models were developed in a 5-hour duration scale, however, a question mark here is what will happen when the malfunction lasts longer than five hours, for instance, ten hours, one day or even few days? Though there are policy documents to regulate the maximum recovery time for the DTM systems, according to intervention priorities (H1 to H4[5]), the recovery time can vary from few hours to weeks. Therefore, it could be necessary to know the malfunction effects in a longer duration scale.

Insights from the VVU changes during the extended evening peak period (14:30 to 20:00) indicate that, the accumulated vehicle delays generally tend to become stable after four hours' malfunction. It is strongly believed that this phenomenon would occur again in an extended morning peak period, since the intensity level at the morning peak hours and the evening peak hours follows a similar pattern (as shown in Figure 4-6). However, it is hard to know beforehand the effects when two intensity peaks are included in the malfunction period (e.g. malfunction from 5:00 to 20:00). Therefore, even the DTM malfunctions during the morning peak can be expected with comparable consequence of the evening peak, sum of the malfunction effects in two peak periods still could not represent a whole-day malfunction, since the "sub" malfunction events split from a successive malfunction event are not independent. Therefore, building up a long-lasting malfunction model (e.g. a piecewise-defined model) valid in a longer duration scale can be an intersecting topic for future studies.

In this research, safety costs were only considered for the MTM system, actually it can also be taken into account for other DTM systems, e.g. the ramp metering system (*VDA10 project, 25% less accidents in the evening peak, Van der Veen & Taale, 2011*). Furthermore, costs in the emission, fuel consumption, driving comfort can also be considered, e.g. the emission models are already embedded in MARPLE. Besides, extra focus can be put on special locations like tunnels and bridges.

[5] HI-immediate maintenance; H2- maintenance within 24 hours; H3-maintenance within 7 days; H4-maintenance with first scheduled plan. (National Tunnel Standard)

Still, when comes to the question how long the malfunction models developed in this research, can be used to support the maintenance planning and therefore how often should the models be updated to fit for latest maintenance plan, it is necessary to collect the average traffic conditions in different periods over a year and take seasonal effects into account, in this way, the results from the model can be more reliable.

When talking about the futures, the intervention of automated vehicles (AVs) and advanced driving assistance systems (ADAS) should never be neglected. How they interact with the DTM systems? Would the effects introduced by these DTM systems be affected? For instance, will the MTM still be significant in the road safety? And how DTM systems and measures could be improved or maybe removed with the increasing penetration of AVs and ADAS? All of these could be interesting topics in further studies and be considered for the risk-based maintenance planning.

At last, comparison among related models according to capability, time-efficiency and accuracy for specific policy objectives can also be investigated, to normalize their implementations. For instance, *wegwerkplanner* which is used to calculate the vehicle lost hours introduced by road works during the planned time windows (based a static queuing model); *Delta Pi method* according to failure scenarios (optimization between severity categories and recovery priority); *Mobiliteitsscan*; *COBRA+*; *FIONA and so on.*

REFERENCE

AVV. (2004). Explanatory analyzes traffic performance road network 2000-2003 (*In Dutch: Verklarende analyse verkeersprestatie hoofdwegennet 2000-2003*). Retrieved from: http://publicaties.minienm.nl/-documenten/verklarende-analyse-verkeersprestatie-hoofdwegennet-2000-2003

AVV. (2003). Handbook Sustainable Traffic Management: A Guide for Users. Retrieved from: http://publicaties.minienm.nl/documenten/handbook-sustainable-traffic-management-a-guide-for-users

AVV. (2004). The Application of Sustainable Traffic Management in the Netherlands – An Overview

AVV. (2005). Alternative Routes During Incidents - Working on Regional Accessibility (*Alternatieve routes bij verstoringen- werken aan regionale bereikbaarheid: introductie en beknopte handleiding).* http://publicaties.minienm.nl/documenten/alternatieve-routes-bij-verstoringen-werken-aan-regionale-bereik

Berghout, L., Van Koningsbruggen, P.H. and Westerman, M. (2002). Making Traffic Management Operational, Proceedings of 9th World Congress on ITS, Chicago, U.S.A.

Bliemer, M.C.J. (2001). Analytical dynamic traffic assignment with interacting user-classes. PhD Thesis, TU Delft. Retrieved from: http://resolver.tudelft.nl/uuid:e15f721f-ad60-426b-88c8-b262364189dd

Bliemer, M & Taale, H. (2006). Route Generation and Dynamic Traffic Assignment for Large Networks. In Proceedings of the 1st International Symposium on Dynamic Traffic Assignment, Leeds, U.K., 2006. https://www.researchgate.net/publication/272497797_Route_Generation_and_Dynamic_Traffic_Assignment_for_Large_Networks

Cairns, S., Hass-Klau, C. and Goodwin, P. (1998) Traffic Impact of Highway Capacity Reductions: Assessment of the Evidence, Landor Publishing, London, United Kingdom. Retrieved from: https://trid.trb.org/view/484127

Cascetta, E., Nuzzolo, A., Russo, F. and Vitetta, A. (1996). A modified logit route choice model overcoming path overlapping problems: specification and some calibration results for interurban networks. Proceedings of the 13th International Symposium on Transportation and Traffic Theory, Lyon, France.

Calvert, S. (2016). Stochastic macroscopic analysis and modelling for traffic management. PhD thesis. Delft: TRAIL Research School. https://doi.org/10.4233/uuid:aef70813-0edd-4ff6-9e7d-4656c1d86646.

Calvert, S., Minderhoud, M., Taale, H., Wilmink, I. & Knoop, V. (2016). Traffic Assignment and Simulation Models. *TrafficQuest Report*. https://doi.org/10.13140/RG.2.1.3784.4560.

Dikmen. M. & Burns, C.M. (2016). Autonomous Driving in the Real World: Experiences with Tesla Autopilot and Summon. In Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '16), October 24–26, 2016, Ann Arbor, MI, USA. P225-228. Retrieved from: https://dl.acm.org/doi/10.1145/3003715.3005465

DHV. (2005). Quick Scan Traffic Management Measures Heerenveen- Skasterlân. Report for the Directorate North-Holland.

GPO. (2019). Prestatie gestuurd Instandhoudingsplan Plusstrook A28R Zwolle-Ommen, 2018.

Goodwin, P., Hass-Klau, C. and Cairns, S. (1998) Evidence on the Effects of Road Capacity Reduction on Traffic Levels, Traffic Engineering + Control, Vol. 39, No. 6, pp. 348-354. Retrieved from: https://nacto.org/docs/usdg/traffic_impact_highway_capacity_cairns.pdf

Goudappel coffeng. Traffic control major maintenance A10-west (In Dutch Verkeersbeheersing groot onderhoud A10-west). Retrieved from: http://publicaties.minienm.nl/documenten/verkeersbeheersing-groot-onderhoud-a10-west

Gunn, H. F. (1981). Travel budgets-A review of evidence and modelling implications. Transportation

Research Part A: General. https://doi.org/10.1016/0191-2607(83)90012-2

KiM. (2019). Mobility Image 2019 (*In Dutch: Mobiliteitsbeeld 2019*). Knowledge Institute of Mobility Policy. Retrieved from: https://www.kimnet.nl/mobiliteitsbeeld/mobiliteitsbeeld-2019#/rapport/4.5.1

Hoogendoorn, S., Landman, R., van Kooten, J., & Schreuder, M. (2013). Integrated Network Management Amsterdam: Control approach and test results. 16th International IEEE Conference on Intelligent Transportation Systems (ITSC 2013), 474–479. https://doi.org/10.1109/ITSC.2013.6728276

Mercier, S., Villeneuve, S., Mondor, M., & Uysal, I. (2017). Time-Temperature Management Along the Food Cold Chain: A Review of Recent Developments. Comprehensive Reviews in Food Science and Food Safety, 16(4), 647–667. https://doi.org/10.1111/1541-4337.12269

Middelham, F. (2003). State of Practice in Dynamic Traffic Management in the Netherlands. IFAC Proceedings Volumes, 36(14), 293–298. https://doi.org/10.1016/S1474-6670(17)32435-7

Mudd S.C. (1972). Technology for Motor Mechanics, Second Edition, Gibrine Publishing Company, Maryland, Pg. 213 – 241.

Muhurdarevic, Z. (2016). Probabilistic maintenance model for dynamic traffic management systems on motorways in the Netherlands. https://doi.org/10.1201/9781315375175-202. Retrieved from "*Life-cycle of engineering systems: Emphasis on sustainable civil infrastructure" (pp.*1420–1422). Leiden: CRC PRESS, 2017. ISBN 978-1-138-02847-0.

MinVenW. (2004). Mobility Policy Document: Towards Reliable and Predictable Accessibility, VROM, http://publicaties.minienm.nl/documenten/nota-mobiliteit-towards-reliable-and-predictable-accessibility

MinVenW. (2008). Policy framework for utilization-A pillar of better accessibility. Ministry of Transport, Public Works and Water Management. http://publicaties.minienm.nl/documenten/policy-framework-for-utilisation-a-pillar-of-better-accessibilit

Muhurdarevic, Z. (2016). Presentation "Probabilistic maintenance model for dynamic traffic management systems: A business case for motorways in the Netherlands". IALCCE 2016.

Muhurdarevic, Z. (2019). Presentation "Risk-based Maintenance for Dynamic Traffic Management systems" (*In Dutch: Risico gestuurd Onderhoud DVM*). BOO-DVM-WVL, Rijkswaterstaat. July 2019.

Middelham, F. (2002). The Dutch Motorway Control System - 21 Years of Evolution. *A revision of Remeijn. H' report in 1995*. AVV-transport research center, Ministry of transport, Public works and water management, 2002.

NIS. (2019). Official RWS Area Figures Main Road Network: HWN Collective Table for Area Data" (In Dutch: Officiële RWS Areaalcijfers Hoofdwegennet - De "HWN Verzameltabel Areaalgegevens"). Issued at 25th, March 2019. Network Management Information System [NIS]. Retrieved from: http://corporate.intranet.rws.nl/Kennis_en_Expertise/Netwerkmanagement_Informatie_Systeem/Areaalgegevens_in_NIS/

Nijenhuis, T.A., Elbers J.A.C.M. & Kijk in de Vegte N. (2006-2010). Large roadworks 2007/…/-2011 ('Groot onderhoud 2007/../2011', in Dutch). Transpute/Rijkswaterstaat-VCNL. Amersfoort.

Johnston, P. & Harris, R. (2019). The Boeing 737 MAX Saga: Lessons for Software Organizations https://embeddedartistryconsulting.com/the-boeing-737-max-saga-lessons-for-software-organizations/

Pasztor , A., Tangel, A., Wall, R. & Sider, A. (2019). How Boeing's 737 MAX Failed. The Wall Street Journal. Retrieved from https://www.wsj.com/articles/how-boeings-737-max-failed-11553699239

Oduro, S.D. (2012). Brake Failure and its Effect on Road Traffic Accident in Kumasi Metropolis, Ghana. International Journal of Science and Technology Volume 1 No. 9. Sep 2012.

Otten, J. (2019). Network Management Information System - Network Formats. RWS Water- Verkeer en Leefomgeving, Intranet Rijkswaterstaat. Modified at 12:34, 22/07/2019. Retrieved from:

http://corporate.intranet.rws.nl/Kennis_en_Expertise/Netwerkmanagement_Informatie_Systeem/Netwerkindelingen/

RWS. (2019). National Road Network Report (*Rapportage Rijkswegennet*) 3rd Period 2018, 1st Sep - 31rd Dec. Retrieved from: https://www.rijksoverheid.nl/documenten/rapporten/2019/02/25/rapportage-rijkswegennet

Taale, H., Middelham, F. (2000). Ten years of ramp-metering in the Netherlands. 10th International Conference on Road Transport Information and Control, 2000. (Conf. Publ. No. 472), London, UK, 2000, pp. 106-110. https://doi.org/10.1049/cp:20000114

Taale, H. (2014). Integrated and Real-Time Anticipatory Control of Road Networks PAO. Dynamische verkeersmodellen: de nieuwe norm: PAO-cursus 29-30 Jan. 2014 Amersfoort, Netherlands. Retrieved from: http://pure.tudelft.nl/ws/files/28022420/2014_0.pdf

Taale, H., Westerman, M., Stoelhorst, H. and Van Amelsfort, D. (2004). Regional and Sustainable Traffic Management in the Netherlands: Methodology and Applications. In: *Proceedings of the European Transport Conference 2004*, October 4-6, 2004, Strasbourg, France, Association for European Transport. Retrieved from: https://www.researchgate.net/publication/237806330_Regional_and_Sustainable_Traffic_Management_in_The_Netherlands_Methodology_and_Applications

Taale, H. and Westerman, M. (2005) The Application of Sustainable Traffic Management in The Netherlands, In: *Proceedings of the European Transport Conference 2005*, October 3-5, 2005, Strasbourg, France, Association for European Transport.

Taale, H & Van Zuylen, H. (2006). Validation of A Dynamic Traffic Assignment Model. 1st International Symposium on Dynamic Traffic Assignment, Leeds, United Kingdom. Retrieved from: https://www.researchgate.net/publication/272503683_Validation_of_a_Dynamic_Traffic_Assignment_Model

Taale, H, Witteveen + Bos. (2017). MARPLE Manual version 3.4.5. Issued at 16, August 2017.

Taale, H. (2009). The Application of the Regional Utilization Explorer for the Practical Trial Traffic Management Amsterdam. The 8th symposium Dynamic Traffic Management, 14 May 2009, De Doelen, Rotterdam. (In Dutch: De toepassing van de Regionale BenuttingsVerkenner voor de Praktijkproef Verkeersmanagement Amsterdam. In: *Proceedings van het 8e Symposium Dynamisch Verkeersmanagement* ANWB, Verkeerskunde. 14 mei 2009, De Doelen, Rotterdam.) Retrieved from: http://resolver.tudelft.nl/uuid:3a998b9a-56d7-47bf-a389-fdec31a29575

Taale, H., & Hoogendoorn, S. (2012). Network-wide traffic management with integrated anticipatory control: The Results of Trials and Simulations. 91st Meeting of the Transportation Research Board, (January 2012), 22–26.

Taale, H., & Pel, A. (2019). Route Set Generation for Quick Scan Applications of Dynamic Traffic Assignment. In MT-ITS 2019 - 6th International Conference on Models and Technologies for Intelligent Transportation Systems [8883324] IEEE. https://doi.org/10.1109/MTITS.2019.8883324

Taale, H. (2009). The Simulation of the Effects of the Traffic Management Trial Amsterdam. In Proceedings of the European Transport Conference 2009 Association for European Transport (AET). Retrieved from: http://resolver.tudelft.nl/uuid:20d63d97-7b4e-4cbf-b995-7b392cd9fccd

Taale, H/ Rijkswaterstaat. (2018). Effects of Utilization in the Netherlands: An overview of 210 practical evaluations. *Version 4.0*, issued in 21 December, 2018. (In Dutch: Effecten van benutting in Nederland: Een overzicht van 210 praktijk evaluaties)

Taale, H. (2017). Overzicht tools voor berekening VVU's. Presentation for Project "P-IHP DVM".

Transpute. (2008). Congestion Thermometer 2007 – The congestion situation on the main roads of North-Holland, Report for Rijkswaterstaat North-Holland (in Dutch).

Transpute. (2011). A poorly functioning road network? What is there to go?

Van Toorenburg J.A.C. (2003). FlowSimulator, description of the model (In Dutch: “Flowsimulator; beschrijving van het model deelrapport project 'Basisbestand indicatoren en methodiek trajectsnelheid'). Transpute & Rijkswaterstaat-AVV, Gouda. http://publicaties.minienm.nl/documenten/flowsimulator-beschrijving-van-het-model-deelrapport-project-bas

Van Toorenburg, J.A.C, Kijk in de Vegte, N. & Bédorf, J. (2011). On-line and Off-line Simulation of Large Motorway Networks. Transpute, Leiden Observatory, The Netherlands. Retrieved from: http://www.transpute.nl/content/downloads/Online_and_offline_simulation_of_large_motorway_networks.pdf

Visser, J. (2018). Dynamic Traffic Management Systems - Motorway Traffic Management (Version 2). RWS Verkeer- en Watermanagement, Intranet Rijkswaterstaat. Modified at 12:17, 29/06/2018. Retrieved from: http://corporate-cms.intranet.rws.nl/CategoryPreview.aspx?CategoryId=4619

WVL & Grontmij. (2016). Safety on National Roads 2014 Part A: Traffic safety national picture (In Dutch: Veilig over Rijkswegen 2014 *Deel A: Verkeersveiligheid landelijk beeld*). Carried out by Robin Abma (Grontmij), Wouter Mieras (Grontmij), Niels Heeres (Grontmij) & Hans Drolenga (Grontmij). Retrieved from: http://publicaties.minienm.nl/documenten/veilig-over-rijkswegen-2016

▪ Rush hour lanes

Antea Group. (2016) Evaluation of road safety on rush hour lanes with extended opening hours (In Dutch: Evaluatie verkeersveiligheid verruimde openingstijden spitsstroken).

Arcadis. (2007) Integral Final Report: Evaluation of traffic safety on rush hour lanes *(In Dutch: Evaluatie verkeersveiligheid spitsstroken, Integraal eindrapport*)

Poorterman, R., Brandt, R., Kijk in de Vegte, N., Nijenhuis, A. (2011) Second evaluation of the Emergency Strips approach (*In Dutch: Tweede evaluatie Spoedaanpak Stroken*). Dienst Verkeer en Scheepvaart [DVS], Rijkswaterstaat.

GPO. (2017). Design and layout rush-hour lanes *(In Dutch: Ontwerp en Inrichting Spitsstroken*). Grote Projecten en Onderhoud, Rijkswaterstaat. From: http://publicaties.minienm.nl/documenten/ontwerp-en-inrichting-spitsstroken-versie-2017

GPO. (2017). Rush hour lane safety (*In Dutch:Veiligheid Spitsstroken*). Grote Projecten en Onderhoud, Rijkswaterstaat. Retrieved from: http://www.rws.nl/zakelijk

Grontmij. (2010). Investigation on the incident scales on opening rush hour lanes (*In Dutch: Onderzoek naar omvang incidenten op geopende spitsstroken*). Grontmij Netherlands B.V.

Grontmij. (2015). Main Report: Differentiation in road safety of rush-hour lanes (*In Dutch: Differentiatie Verkeersveiligheid Spitsstroken, Hoofdrapport*). Grontmij Netherlands B.V.

House of Representatives of the States General, 28679 Rules for speeding up and simplifying procedures with a view to increasing the capacity of a number of main roads as soon as possible through better use and widening of those roads (Road Widening Emergency Act), No. 3 Explanatory memorandum, Meeting year 2002-2003 (*In Dutch: Tweede Kamer de Staten-Generaal, 28679 Regels ter bespoediging en vereenvoudiging van procedures met het oog op het zo spoedig mogelijk vergroten van de capaciteit van een aantal hoofdwegen door middel van een betere benutting en verbreding van die wegen (Spoedwet wegverbreding), nr. 3 Memorie van toelichting, Vergaderjaar 2002-2003).*

VIA. (2011). Safety on rush-hour lanes: Exploratory investigation into the road safety of rush-hour lanes (*In Dutch: Veilig over spitsstroken, Verkennend onderzoek naar de verkeersveiligheid van spitsstroken*). VIA verkeersadvies B.V.

WVL & Grontmij. (2015) Capacity Values Infrastructure Motorways Manual version 4 (CIA) (*In Dutch:*

Capaciteitswaarden Infrastructuur Autosnelwegen Handboek). Water, Verkeer en Leefomgeving. RWS.

▪ DRIPs

AVV & Witteveen+Bos. (2007). Directive for Locating DRIPs. (*In Dutch: Richtlijn plaatsbepaling DRIPs*). version 1.0. Adviesdienst Verkeer en Vervoer [AVV], Rijkswaterstaat.

DVS. (2012). Information provision on (berm) DRIPs *(In Dutch: Richtlijn Informatievoorziening op (berm) DRIPs, Version 1.1)*. Dienst Verkeer en Scheepvaart [DVS], Rijkswaterstaat.

Ergo. (2010). Evaluation Travel times on DRIPs - Interim report (*In Dutch:Evaluatie Reistijden op DRIPs, tussenrapport*).

Grontmij. (2007). Usage investigation of bermDRIPs - survey results, final report *(In Dutch: Gebruiksonderzoek bermDRIPs - resultaten enquête, eindrapport*), Grontmij Netherlands B.V.

Grontmij. (2007). Usage investigation of bermDRIPs - research results, final report *(In Dutch: Gebruiksonderzoek bermDRIPs - resultaten onderzoek, eindrapport),* Grontmij Netherlands B.V.

Goudappel Coffeng. (1998). Evaluation RIA phase 4: Sub-report cost-benefit analysis. (*In Dutch: Evaluatie RIA fase 4: Deelrapport kosten-batenanalyse*). Rijkswaterstaaî directie Noord-Holland.

Van der Mede, P.H.J. and Van Berkum, E.C. (1993). The Impact of Traffic Information: Dynamics in Route and Departure Time Choice, PhD Thesis, Delft University of Technology. Retrieved from: http://resolver.tudelft.nl/uuid:9c679fb1-1d04-4666-a7d7-30d84a7cc07a

VMW. (2017). Directive Design bermDRIP Layout (*In Dutch: Richtlijn ontwerp bermDRIP lay-out*), Directie Verkeer- en Watermanagement, Rijkswaterstaat.

WVL. (2019). Monitoring road traffic related information services and driving task support systems 2018 (*In Dutch: Monitoring wegverkeergerelateerde informatiediensten en rijtaakondersteunende systemen 2018*). Retrieved from: http://publicaties.minienm.nl/documenten/monitoring-wegverkeergerelateerde-informatiediensten-en-rijtaakondersteunende-systemen-2018

▪ MTM

AVV, BGC. (1994) Effects of traffic signaling on capacities (*In Dutch: Effecten van verkeerssignalering op capaciteiten*). Bureau Goudappel Coffeng [BGC], Adviesdienst Verkeer en Vervoer [AVV]. http://publicaties.minienm.nl/documenten/effecten-van-verkeerssignalering-op-capaciteiten

AVV & BGC. (1994) ***EAVES*** Variable Message Signs for Road Works and Queue Warning Systems, Bureau Goudappel Coffeng [BGC], Adviesdienst Verkeer en Vervoer [AVV], Rijkswaterstaat.

AVV. (1994). Traffic signaling evaluation: a knowledge overview (*In Dutch: Evaluatie verkeerssignalering:een kennisoverzicht).* http://publicaties.minienm.nl/documenten/evaluatie-verkeers-signalering-een-kennisoverzicht

De Kroes, J. L., Donk, P. & De Klein, S. J. (1983). An Evaluation of the external effects of the traffic signaling system on motorways (*In Dutch: Evaluatie van de externe effecten van het verkeerssignaleringssysteem voor autosnelwegen*). http://publicaties.minienm.nl/documenten/an-evaluation-of-the-external-effects-of-the-motorway-traffic-co

DVK. (1985). Traffic jam warning and traffic flow (*In Dutch: Filewaarschuwing en verkeersafwikkeling*). http://publicaties.minienm.nl/documenten/filewaarschuwing-en-verkeersafwikkeling-effekt-van-het-tonen-van

DVK. (1985). Evaluation of traffic signaling systems - Projects *National Motorway 13* and *National Road 2/12 (In Dutch: Evaluatie Verkeerssignaleringssystemen Projecten Rijksweg 13 en Rijkswegen 2/12)*. Dienst Verkeerskunde [DVK], Rijkswaterstaat.

Elvik, R. (2009). The Power Model of the Relationship between speed and road safety. Retrieved from: https://www.toi.no/getfile.php?mmfileid=13206

McKinsey Company & MinVenW. (1994). Utilization of constructions (*In Dutch: Benutten naast bouwen*). Retrieved from: http://publicaties.minienm.nl/documenten/benutten-naast-bouwen-samenvatting-conclusies-en-aanbevelingen

Transpute. (1993). Capacity at convergence points, measurement of road capacity at thirteen convergence points *(In Dutch :Capaciteit op convergentiepunten, meting van de wegcapaciteit op een dertiental convergentiepunten).* http://publicaties.minienm.nl/documenten/capaciteit-op-convergentiepunten-meting-van-de-wegcapaciteit-ter

- **Ramp Metering**

AVV. (2000). Technical specification of a metering algorithm for ramp metering installations (*In Dutch: Verkeerstechnische specificatie van een applicatieprogramma voor toeritdoseerinstallatie*). Retrieved from: http://publicaties.minienm.nl/documenten/verkeerstechnische-specificatie-van-een-doseeralgaritme-voor-toe

BGC. (1990). Test Ramp-Metering Coentunnel (*In Dutch: Proef toeritdosering Coentunnel*). Retrieved from http://publicaties.minienm.nl/documenten/proef-toeritdosering-coentunnel

Grontmij. (1995). An assessment of multiple ramp metering on the Amsterdam ring road. Report for the Transport Research Centre, DRIVE project 'EUROCOR'. http://publicaties.minienm.nl/documenten/an-assessment-of-multiple-ramp-metering-on-the-amsterdam-ring-road

Grontmij. (1991). Second Assessment of Ramp-Metering Delft-Zuid A13 (*In Dutch: Vooronderzoek evaluatie proef toeritdosering A13 toerit Delft-Zuid*). Report for the Transport Research Centre. From http://publicaties.minienm.nl/documenten/vooronderzoek-evaluatie-proef-toeritdosering-a13-toerit-delft-zu

Grontmij. (1994). Assessment Ramp-Metering Zoetermeer (*Evaluatie toeritdosering Zoetermeer-Oost*). Retrieved from: http://publicaties.minienm.nl/documenten/evaluatie-toeritdosering-zoetermeer-oost

Grontmij. (1998). Assessment Ramp-Metering and Moveable Physical Closures. Report for Directorate South-Holland (in Dutch).

Goudappel Coffeng. (1998). Assessment Ramp-Metering A8/Kolkweg. Report for Directorate North-Holland. Retrieved from http://publicaties.minienm.nl/documenten/evaluatie-toeritdosering-a8-kolkweg

Heidemij. (1996). Assessment Ramp-Metering Schiedam-Noord and Barendrecht. Report for the Directorate South-Holland (in Dutch).

Knoop, V., Taale, H., Meulenberg, M., van Erp, P., & Hoogendoorn, S. (2019). Ramp Metering with Real-Time Estimation of Parameters. In 21st IEEE International Conference on Intelligent Transportation Systems: November 4-7, 2018, Maui, Hawaii, USA (pp. 3619-3626). [8569808] IEEE. https://doi.org/10.1109/ITSC.2018.8569808

Middelham, F., & Taale, H. (2006). RAMP METERING IN THE NETHERLANDS: AN OVERVIEW. IFAC Proceedings Volumes, 39(12), 267–272. https://doi.org/10.3182/20060829-3-nl-2908.00047

Taale, H., Middelham, F. (2000). Ten years of ramp-metering in the Netherlands. 10th International Conference on Road Transport Information and Control, 2000. (Conf. Publ. No. 472), London, UK, 2000, pp. 106-110. https://doi.org/10.1049/cp:20000114

Van der Ross, S./ WVL. (2018). Manual for preparation and implementation of the equipment for Ramp Metering systems. (In Dutch: Handleiding Voorbereiding en Uitvoering Toeritdoseerinstallaties v1.40). Retrieved from: http://corporate-cms.intranet.rws.nl/CategoryPreview.aspx?CategoryId=4641

Van der Veen, F. & Taale, H. (2011). Evaluation of Ramp Metering on the A10 Amsterdam Ring Road. Evaluation Expert Group (EasyWay EEG) Document-EEG/11/7. Retrieved from: www.easyway-its.eu

Witteveen+Bos. (1999).“Assessment Ramp-Metering A1, On-Ramps Muiden and Muiderslot (*In Dutch: Evaluatie toeritdosering A1 toeritten Muiden en Muiderslot)*”, report for the Directorate North-Holland. http://publicaties.minienm.nl/documenten/evaluatie-toeritdosering-a1-toeritten-muiden-en-muiderslot

- ## Cost Calculation

De Wit, M & Methorst, R. (2012). Cost of Traffic Accidents in the Netherlands: Developments 2003-2009 (*In Dutch: Kosten verkeersongevallen in Nederland Ontwikkelingen 2003 – 2009*). DVS0812RE213. Dienst Verkeer en Scheepvaart [DVS], Rijkswaterstaat. Retrieved from: http://publicaties.minienm.nl/documenten/kosten-verkeersongevallen-in-nederland-ontwikkelingen-2003-2009

IMN. (2019). Accidents on Motorways 2010-2018 (Ongevallen op snelwegen 2010 – 2018). Stichting Incident Management Nederland. Retrieved from: https://www.stichtingimn.nl/

Linde, G. van der, Donkelaar, J., van, Witmond, B., Devillers, E. & Spit, W. (2012). Safety in social cost-benefit analysis: working document (*In Dutch: Veiligheid in maatschappelijke kosten-baten analyse; Werkdocument*). Directoraat-Generaal Rijkswaterstaat, Dienst Verkeer en Scheepvaart, Rotterdam. Retrieved from: https://library.swov.nl/action/front/cardweb?id=334282

KiM. (2013). The social value of shorter and more reliable travel times (In Dutch: De maatschappelijke waarde van kortere en betrouwbaardere reistijden). Knowledge Institute of Mobility Policy (KiM), 2013. Retrieved from: https://www.rwseconomie.nl/kengetallen/kengetallen-bereikbaarheid-map

KiM (2019). Mobility Image and Key Figures-2019. Knowledge Institute of Mobility Policy. Retrieved from: https://www.kimnet.nl/mobiliteitsbeeld/mobiliteitsbeeld-2019#/rapport/8.3.2

Significance, VU Amsterdam, & John Bates. (2007). The value of travel time and travel time reliability, survey design. Final Report prepared for The Netherlands Ministry of Transport, Public Works and Water Management, Significance. Leiden. Retrieved from: http://publicaties.minienm.nl/documenten/the-value-of-travel-time-and-travel-time-reliability-survey-desi

SWOV. (2014). Factsheet: Cost of traffic accidents (*In Dutch: Kosten van verkeersongevallen*). Retrieved from: https://www.swov.nl/feiten-cijfers/factsheet/kosten-van-verkeersongevallen

Wijnen, W. (2012). The Building Blocks for Calculating the Cost of Road Traffic Accidents 2003- 2009: Material, Intangible Costs and Handling Costs (*In Dutch: Bouwstenen voor berekening van de kosten van verkeersongevallen 2003-2009; Materiële en immateriële kosten en kosten van afhandeling*). D-2012-4. SWOV, Retrieved from: https://www.swov.nl/publicatie/bouwstenen-voor-berekening-van-de-kosten-van-verkeersongevallen-2003-2009

WVL & Sweco Nederland. (2016). Safe on National Roads 2016- Part B: Road safety national picture (In Dutch: *Veilig over Rijkswegen Deel B 2016 - Toelichting Risicocijfers*). Retrieved from: http://publicaties.minienm.nl/documenten/veilig-over-rijkswegen-2016

APPENDIX INDEX

Appendix A. Modification of the Road Network

- **Motorway A5**

Table A- 1. A5 Modification (direction north to south)

A5 Li 19.3 km tot A5 Li 8.5 km							
Link Number	Start node	End node	Link type	Length (km)	Lanes	Speed (km/h)	Capacity (veh/h)
10650	3179	7999	Motor 18	2.9	2	100	4000
10667	7999	8005	Motor 18	0.4	2	100	4000
10657	7999	5161	off-ramp 14	0.4	1	40	2000
10673	5161	8005	on-ramp 14	0.4	1	40	2000
10668	8005	8007	Motor 18	0.8	2	100	4000
10669	8007	8000	Motor 18	0.4	2	100	4000
10675	8007	2074	off-ramp 14	0.6	1	40	2000
10659	2074	8000	on-ramp 14	0.4	1	40	2000
10662	8000	8004	Motor 18	4.9	2	100	4000
10663	8004	5176	Motor 18	0.5	1	100	2000
10664	8004	7605	Motor 18	1	2	100	4000
SUM				12.7			

Table A- 2. A5 Modification (direction south to north)

A5 Re 8.4 km tot A5 Re 18.9 km							
Link Number	Start node	End node	Link type	Length (km)	Lanes	Speed (km/h)	Capacity (veh/h)
10665	7604	8003	Motor 18	1	2	100	4000
10666	5221	8003	Motor 18	0.5	1	100	2000
10661	8003	8002	Motor 18	4.9	2	100	2000
10672	8002	8008	Motor 18	0.4	2	100	4000
10660	8002	2000	off ramp 14	0.4	1	40	2000
10676	2000	8008	on ramp 14	0.6	1	40	2000
10671	8008	8006	Motor 18	0.8	2	100	4000
10670	8006	8001	Motor 18	0.4	2	100	4000
10674	8006	2309	off ramp 14	0.6	1	40	2000
10658	2309	8001	on ramp 14	0.4	1	40	2000
10652	8001	7780	Motor 18	3.2	2	100	4000
SUM				13.2			

- **Urban Connection S103** (Seineweg)**, Roundabout** (Sierenborch-Luvernes)

Table A- 3. Urban road connection (direction South to North)

Link Number	Start node	End node	Link type	Length (km)	Lanes	Speed (km/h)	Capacity (veh/h)
10680	2192	2433	Access 12	1.75	1	50	2000
10680	2433	2192	Access 12	1.75	1	50	2000

Note: The nodes marked in red are existing nodes

Appendix B. Rush Hour Lane Capacity Adjustments

Table B- 1. Spitsstrook rechts A4/A10 (Direction: Badhoevedorp to Amstel)

Spitsstrook rechts A4/A10 HRL							
Link number	Marple Link	Length (km)	Number of lanes	Saturation flow rate	Spitsstroo k rechts (+1)	Adjusted saturation rate (per lane)	Percentage of saturation flow rate
1866	361	0.63	3	2150	4	1850	88%
9476	2317	0.37	4	1800	5	1800	90%
9478	2319	0.48	2	1900	3	1750	83%
8945	2030	0.91	2	1800	3	1750	83%
9472	2314	0.54	2	1800	3	1750	83%
10172	2593	0.28	4	900	5	1900	91%
10171	2592	0.38	4	2000	5	1900	91%
10375	2720	0.39	3	2000	4	1850	88%
10376	2721	0.49	3	2000	4	1850	88%
10380	2725	0.44	3	2000	4	1850	88%
10379	2724	0.78	3	2000	4	1850	88%
2915	568	0.17	3	2000	4	1850	88%
10371	2716	0.37	4	2000	5	1800	90%
SUM		6.23					

Table B- 2. Spitsstrook rechts A4/A10 (Direction: Amstel to Badhoevedorp)

Spitsstrook rechts A4/A10 HRR (a)							
Link number	Marple Link	Length (km)	Number of lanes	Saturation flow rate	Spitsstroo k rechts (+1)	Adjusted saturation rate (per lane)	Percentage of saturation flow rate
10369	2714	0.33	3	1710	4	1850	88%
10149	2578	0.56	3	2150	4	1850	88%
10377	2722	0.46	3	1400	4	1900	88%
10378	2723	0.42	3	1563	4	1900	88%
10374	2719	0.49	3	1563	4	1900	88%
10373	2718	0.39	3	1563	4	1900	88%
10156	2580	0.32	3	1900	4	1900	88%
SUM		2.97					
Spitsstrook rechts A4/A10 HRR (b) A4 Re 1.8 km to A4 Re 2.7 km							
2000	384	0.91	3	2150	4	1850	88%

Table B- 3. Spitsstrook rechts A8/A7 (Direction: Purmerend to Oostzaan)

Spitsstrook rechts A7/A8 HRL							
Link number	Marple Link	Length (km)	Number of lanes	Saturation flow rate	Spitsstroo k rechts (+1)	Adjusted saturation rate (per lane)	Percentage of saturation flow rate
8811	1965	0.66	2	2150	3	1733	82.7%
9350	2262	1.60	2	2150	3	1733	82.7%
6261	1081	0.26	2	2150	3	1733	82.7%
9348	2260	1.53	2	2150	3	1733	82.7%
9346	2258	1.61	2	2150	3	1733	82.7%
6217	1064	0.74	2	2150	3	1733	82.7%
8878	2003	0.87	2	2150	3	1733	82.7%
9008	2059	0.91	2	2150	3	1733	82.7%
9012	2062	0.37	2	2150	3	1733	82.7%
9014	2063	0.33	2	2150	3	1733	82.7%
9010	2061	0.16	2	2000	3	1633	81.6%
10221	2625	0.17	4	2150	5	1900	90.5%
SUM		9.21					
Spitsstrook rechts A7/A8 HRL *A8 Li 4.9 km to A7 Li 3.5 km*							
10481	2805	1.39	2	2150		1733	82.7%

Table B- 4. Spitsstrook rechts A8/A7 (Direction: Oostzaan to Purmerend)

Spitsstrook rechts A8/A7 HRR							
Link number	Marple Link	Length (km)	Number of lanes	Saturation flow rate	Spitsstrook rechts (+1)	Adjusted saturation rate (per lane)	Percentage of saturation flow rate
9183	2184	0.64	2	2000	3	1633	81.6%
9184	2185	0.47	2	2000	3	1633	81.6%
9001	2057	0.24	2	2000	3	1633	81.6%
SUM		1.35					
Spitsstrook rechts A8/A7 HRR ***A7 Re 5.1 km*** **to** ***A7 Re 12.9 km***							
8879	2004	0.96	2	2000	3	1633	81.6%
8880	2005	0.91	2	2150	3	1733	82.7%
8874	2000	0.69	2	2150	3	1733	82.7%
9347	2259	1.60	2	2150	3	1733	82.7%
9349	2261	1.66	2	2150	3	1733	82.7%
6256	1076	0.20	2	2150	3	1733	82.7%
9351	2263	1.53	2	2150	3	1733	82.7%
9201	2190	0.68	2	2150	3	1733	82.7%
SUM		8.23					

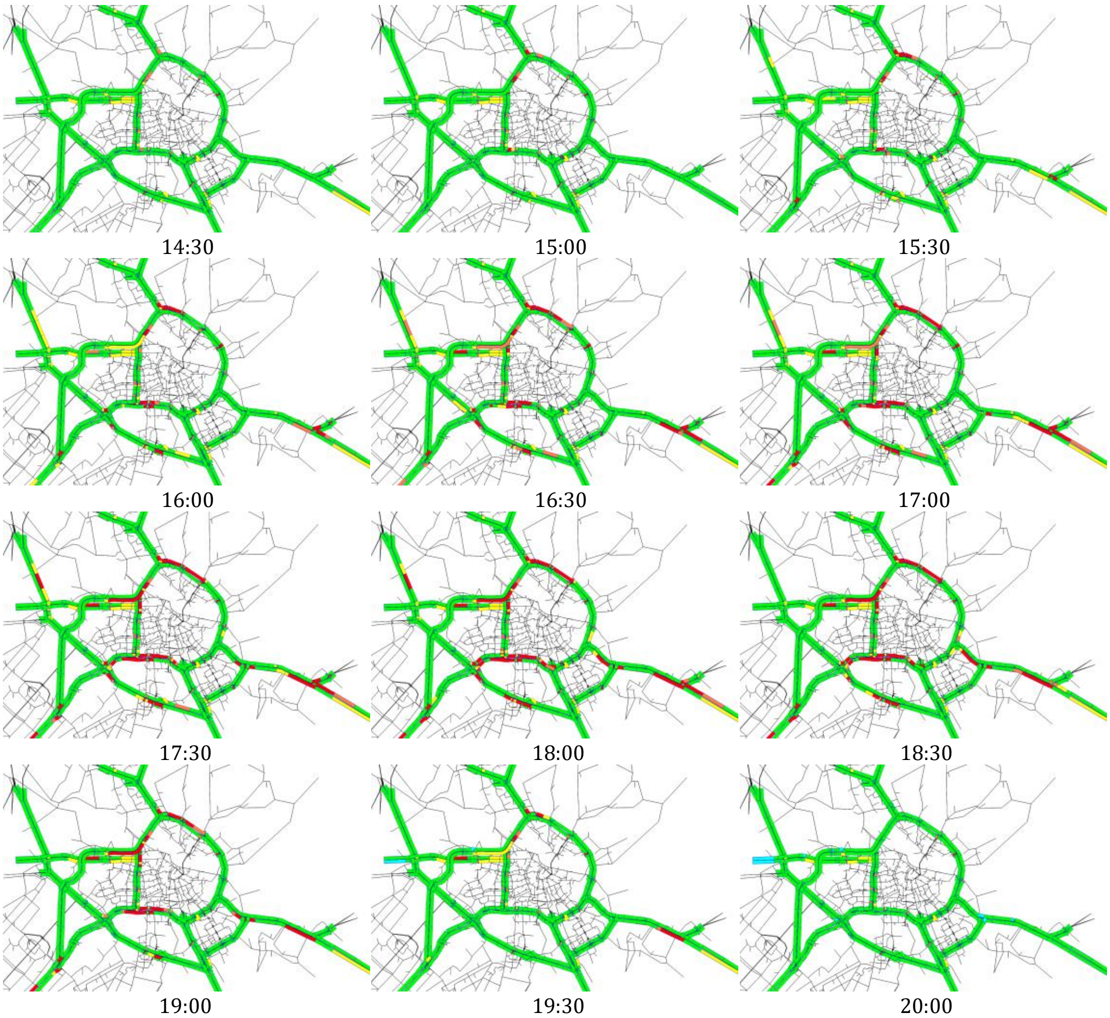


Figure B- 1. Speed/free speed plots (MARPLE simulation)

Appendix C. Malfunction Scripts in MARPLE Network Files

Appendix C-1. Rush Hour Lanes

A7/A8 HRR (Opening from 14:00 to 19:00)

```
//Events
;begintime endtime linknr nrlanes satflow   vfree  type
                              (%)    (%)
   16200  19800  2184   -1     82     100     1
   16200  19800  2185   -1     82     100     1
   16200  19800  2057   -1     82     100     1
   16200  19800  2004   -1     82     100     1
   16200  19800  2005   -1     83     100     1
   16200  19800  2000   -1     83     100     1
   16200  19800  2259   -1     83     100     1
   16200  19800  2261   -1     83     100     1
   16200  19800  1076   -1     83     100     1
   16200  19800  2263   -1     83     100     1
   16200  19800  2190   -1     83     100     1
```

A4/A10 HRR (Malfunctioning from 15:00 to 20:00)

```
//Events
;begintime endtime linknr nrlanes satflow   vfree  type
                              (%)    (%)
   16200  19800  2184   -1     82     100     1
   16200  19800  2185   -1     82     100     1
   16200  19800  2057   -1     82     100     1
   16200  19800  2004   -1     82     100     1
   16200  19800  2005   -1     83     100     1
   16200  19800  2000   -1     83     100     1
   16200  19800  2259   -1     83     100     1
   16200  19800  2261   -1     83     100     1
   16200  19800  1076   -1     83     100     1
   16200  19800  2263   -1     83     100     1
   16200  19800  2190   -1     83     100     1
    1800  19800  2714   -1     88     100     2
    1800  19800  2578   -1     88     100     2
    1800  19800  2722   -1     88     100     2
    1800  19800  2723   -1     88     100     2
    1800  19800  2719   -1     88     100     2
    1800  19800  2718   -1     88     100     2
    1800  19800  2580   -1     88     100     2
    1800  19800   384   -1     88     100     2
```

A4/A10 HRL (Malfunctioning from 15:00 to 20:00)

```
//Events
;begintime endtime linknr nrlanes satflow   vfree  type
                              (%)    (%)
   16200  19800  2184   -1     82     100     1
   16200  19800  2185   -1     82     100     1
   16200  19800  2057   -1     82     100     1
   16200  19800  2004   -1     82     100     1
   16200  19800  2005   -1     83     100     1
   16200  19800  2000   -1     83     100     1
   16200  19800  2259   -1     83     100     1
   16200  19800  2261   -1     83     100     1
   16200  19800  1076   -1     83     100     1
   16200  19800  2263   -1     83     100     1
   16200  19800  2190   -1     83     100     1
    1800  19800   361   -1     88     100     2
    1800  19800  2317   -1     90     100     2
    1800  19800  2319   -1     83     100     2
    1800  19800  2030   -1     83     100     2
    1800  19800  2314   -1     83     100     2
    1800  19800  2593   -1     91     100     2
    1800  19800  2592   -1     91     100     2
    1800  19800  2720   -1     88     100     2
    1800  19800  2721   -1     88     100     2
```

```
 1800  19800  2725   -1    88    100   2
 1800  19800  2724   -1    88    100   2
 1800  19800   568   -1    88    100   2
 1800  19800  2716   -1    90    100   2
----------------------------------------------------------------------------------------------------------------------------------
----------------------------------------------------------------------------------------------------------------------------------
```

A4/A10 HRR+HRL (Malfunctioning from 15:00 to 20:00)

```
//Events
;begintime endtime linknr nrlanes satflow   vfree  type
                          (%)     (%)
 16200  19800  2184   -1    82    100   1
 16200  19800  2185   -1    82    100   1
 16200  19800  2057   -1    82    100   1
 16200  19800  2004   -1    82    100   1
 16200  19800  2005   -1    83    100   1
 16200  19800  2000   -1    83    100   1
 16200  19800  2259   -1    83    100   1
 16200  19800  2261   -1    83    100   1
 16200  19800  1076   -1    83    100   1
 16200  19800  2263   -1    83    100   1
 16200  19800  2190   -1    83    100   1
  1800  19800  2714   -1    88    100   2
  1800  19800  2578   -1    88    100   2
  1800  19800  2722   -1    88    100   2
  1800  19800  2723   -1    88    100   2
  1800  19800  2719   -1    88    100   2
  1800  19800  2718   -1    88    100   2
  1800  19800  2580   -1    88    100   2
  1800  19800   384   -1    88    100   2
  1800  19800   361   -1    88    100   2
  1800  19800  2317   -1    90    100   2
  1800  19800  2319   -1    83    100   2
  1800  19800  2030   -1    83    100   2
  1800  19800  2314   -1    83    100   2
  1800  19800  2593   -1    91    100   2
  1800  19800  2592   -1    91    100   2
  1800  19800  2720   -1    88    100   2
  1800  19800  2721   -1    88    100   2
  1800  19800  2725   -1    88    100   2
  1800  19800  2724   -1    88    100   2
  1800  19800   568   -1    88    100   2
  1800  19800  2716   -1    90    100   2
----------------------------------------------------------------------------------------------------------------------------------
----------------------------------------------------------------------------------------------------------------------------------
```

A7/A8 HRR (Malfunctioning from 15:00 to 20:00)

```
//Events
;begintime endtime linknr nrlanes satflow   vfree  type
                          (%)     (%)
 16200  19800  2184  -1    82    100   1
 16200  19800  2185  -1    82    100   1
 16200  19800  2057  -1    82    100   1
 16200  19800  2004  -1    82    100   1
 16200  19800  2005  -1    83    100   1
 16200  19800  2000  -1    83    100   1
 16200  19800  2259  -1    83    100   1
 16200  19800  2261  -1    83    100   1
 16200  19800  1076  -1    83    100   1
 16200  19800  2263  -1    83    100   1
 16200  19800  2190  -1    83    100   1
  1800  19800  2184  -1    82    100   2
  1800  19800  2185  -1    82    100   2
  1800  19800  2057  -1    82    100   2
  1800  19800  2004  -1    82    100   2
  1800  19800  2005  -1    83    100   2
  1800  19800  2000  -1    83    100   2
  1800  19800  2259  -1    83    100   2
  1800  19800  2261  -1    83    100   2
  1800  19800  1076  -1    83    100   2
  1800  19800  2263  -1    83    100   2
  1800  19800  2190  -1    83    100   2
```

Appendix C-2. Motorway Traffic Management Systems

A1 Links (Malfunction from 15:00 to 20:00)

```
//Events
;begintime endtime linknr nrlanes satflow   vfree  type
                              (%)     (%)
    16200  19800  2184    -1    82    100    1
    16200  19800  2185    -1    82    100    1
    16200  19800  2057    -1    82    100    1
    16200  19800  2004    -1    82    100    1
    16200  19800  2005    -1    83    100    1
    16200  19800  2000    -1    83    100    1
    16200  19800  2259    -1    83    100    1
    16200  19800  2261    -1    83    100    1
    16200  19800  1076    -1    83    100    1
    16200  19800  2263    -1    83    100    1
    16200  19800  2190    -1    83    100    1
     1800  19800   880     0    98    100    2
     1800  19800   886     0    98    100    2
     1800  19800  2167     0    98    100    2
     1800  19800  2168     0    98    100    2
     1800  19800  2726     0    98    100    2
     1800  19800  2731     0    98    100    2
     1800  19800  2734     0    98    100    2
     1800  19800  2735     0    98    100    2
     1800  19800  2736     0    98    100    2
     1800  19800  2737     0    98    100    2
     1800  19800  2740     0    98    100    2
     1800  19800  2741     0    98    100    2
```

A1 Rechts (Malfunction from 15:00 to 20:00)

```
//Events
;begintime endtime linknr nrlanes satflow   vfree  type
                              (%)     (%)
    16200  19800  2184    -1    82    100    1
    16200  19800  2185    -1    82    100    1
    16200  19800  2057    -1    82    100    1
    16200  19800  2004    -1    82    100    1
    16200  19800  2005    -1    83    100    1
    16200  19800  2000    -1    83    100    1
    16200  19800  2259    -1    83    100    1
    16200  19800  2261    -1    83    100    1
    16200  19800  1076    -1    83    100    1
    16200  19800  2263    -1    83    100    1
    16200  19800  2190    -1    83    100    1
     1800  19800   877     0    98    100    2
     1800  19800   878     0    98    100    2
     1800  19800  2165     0    98    100    2
     1800  19800  2166     0    98    100    2
     1800  19800  2727     0    98    100    2
     1800  19800  2728     0    98    100    2
     1800  19800  2729     0    98    100    2
     1800  19800  2730     0    98    100    2
     1800  19800  2742     0    98    100    2
     1800  19800  2743     0    98    100    2
```

A2 Links (Malfunction from 15:00 to 20:00)

```
//Events
;begintime endtime linknr nrlanes satflow   vfree  type
                              (%)     (%)
    16200  19800  2184    -1    82    100    1
    16200  19800  2185    -1    82    100    1
    16200  19800  2057    -1    82    100    1
    16200  19800  2004    -1    82    100    1
    16200  19800  2005    -1    83    100    1
    16200  19800  2000    -1    83    100    1
    16200  19800  2259    -1    83    100    1
    16200  19800  2261    -1    83    100    1
    16200  19800  1076    -1    83    100    1
    16200  19800  2263    -1    83    100    1
    16200  19800  2190    -1    83    100    1
     1800  19800   532     0    98    100    2
     1800  19800  2080     0    98    100    2
     1800  19800  2081     0    98    100    2
     1800  19800  2082     0    98    100    2
     1800  19800  2083     0    98    100    2
     1800  19800  2084     0    98    100    2
     1800  19800  2085     0    98    100    2
     1800  19800  2086     0    98    100    2
     1800  19800  2087     0    98    100    2
     1800  19800  2782     0    98    100    2
```

A2 Rechts (Malfunction from 15:00 to 20:00)

```
//Events
;begintime endtime linknr nrlanes satflow   vfree  type
                              (%)     (%)
    16200  19800  2184    -1    82    100    1
    16200  19800  2185    -1    82    100    1
    16200  19800  2057    -1    82    100    1
    16200  19800  2004    -1    82    100    1
    16200  19800  2005    -1    83    100    1
    16200  19800  2000    -1    83    100    1
    16200  19800  2259    -1    83    100    1
    16200  19800  2261    -1    83    100    1
    16200  19800  1076    -1    83    100    1
    16200  19800  2263    -1    83    100    1
    16200  19800  2190    -1    83    100    1
     1800  19800   457     0    98    100    2
     1800  19800   462     0    98    100    2
     1800  19800   463     0    98    100    2
     1800  19800   484     0    98    100    2
     1800  19800   536     0    98    100    2
     1800  19800   570     0    98    100    2
     1800  19800   594     0    98    100    2
     1800  19800   626     0    98    100    2
     1800  19800  2088     0    98    100    2
     1800  19800  2089     0    98    100    2
     1800  19800  2090     0    98    100    2
     1800  19800  2091     0    98    100    2
     1800  19800  2154     0    98    100    2
     1800  19800  2155     0    98    100    2
     1800  19800  2397     0    98    100    2
     1800  19800  2398     0    98    100    2
     1800  19800  2399     0    98    100    2
     1800  19800  2400     0    98    100    2
     1800  19800  2401     0    98    100    2
     1800  19800  2712     0    98    100    2
     1800  19800  2713     0    98    100    2
```

A4 Links (Malfunction from 15:00 to 20:00)

//Events
;begintime endtime linknr nrlanes satflow vfree type

begintime	endtime	linknr	nrlanes	satflow (%)	vfree (%)	type
16200	19800	2184	-1	82	100	1
16200	19800	2185	-1	82	100	1
16200	19800	2057	-1	82	100	1
16200	19800	2004	-1	82	100	1
16200	19800	2005	-1	83	100	1
16200	19800	2000	-1	83	100	1
16200	19800	2259	-1	83	100	1
16200	19800	2261	-1	83	100	1
16200	19800	1076	-1	83	100	1
16200	19800	2263	-1	83	100	1
16200	19800	2190	-1	83	100	1
1800	19800	361	0	98	100	2
1800	19800	2028	0	98	100	2
1800	19800	2029	0	98	100	2
1800	19800	2030	0	98	100	2
1800	19800	2034	0	98	100	2
1800	19800	2314	0	98	100	2
1800	19800	2317	0	98	100	2
1800	19800	2318	0	98	100	2
1800	19800	2319	0	98	100	2

A4 Rechts (Malfunction from 15:00 to 20:00)

//Events
;begintime endtime linknr nrlanes satflow vfree type

begintime	endtime	linknr	nrlanes	satflow (%)	vfree (%)	type
16200	19800	2184	-1	82	100	1
16200	19800	2185	-1	82	100	1
16200	19800	2057	-1	82	100	1
16200	19800	2004	-1	82	100	1
16200	19800	2005	-1	83	100	1
16200	19800	2000	-1	83	100	1
16200	19800	2259	-1	83	100	1
16200	19800	2261	-1	83	100	1
16200	19800	1076	-1	83	100	1
16200	19800	2263	-1	83	100	1
16200	19800	2190	-1	83	100	1
1800	19800	384	0	98	100	2
1800	19800	392	0	98	100	2
1800	19800	407	0	98	100	2
1800	19800	2021	0	98	100	2
1800	19800	2031	0	98	100	2
1800	19800	2032	0	98	100	2
1800	19800	2037	0	98	100	2
1800	19800	2315	0	98	100	2

A5 Links (Malfunction from 15:00 to 20:00)

//Events
;begintime endtime linknr nrlanes satflow vfree type

begintime	endtime	linknr	nrlanes	satflow (%)	vfree (%)	type
16200	19800	2184	-1	82	100	1
16200	19800	2185	-1	82	100	1
16200	19800	2057	-1	82	100	1
16200	19800	2004	-1	82	100	1
16200	19800	2005	-1	83	100	1
16200	19800	2000	-1	83	100	1
16200	19800	2259	-1	83	100	1
16200	19800	2261	-1	83	100	1
16200	19800	1076	-1	83	100	1
16200	19800	2263	-1	83	100	1
16200	19800	2190	-1	83	100	1
1800	19800	2960	0	98	100	2
1800	19800	2966	0	98	100	2
1800	19800	2967	0	98	100	2
1800	19800	2968	0	98	100	2
1800	19800	2971	0	98	100	2
1800	19800	2972	0	98	100	2
1800	19800	2973	0	98	100	2

A5 Rechts (Malfunction from 15:00 to 20:00)

//Events
;begintime endtime linknr nrlanes satflow vfree type

begintime	endtime	linknr	nrlanes	satflow (%)	vfree (%)	type
16200	19800	2184	-1	82	100	1
16200	19800	2185	-1	82	100	1
16200	19800	2057	-1	82	100	1
16200	19800	2004	-1	82	100	1
16200	19800	2005	-1	83	100	1
16200	19800	2000	-1	83	100	1
16200	19800	2259	-1	83	100	1
16200	19800	2261	-1	83	100	1
16200	19800	1076	-1	83	100	1
16200	19800	2263	-1	83	100	1
16200	19800	2190	-1	83	100	1
1800	19800	2961	0	98	100	2
1800	19800	2965	0	98	100	2
1800	19800	2974	0	98	100	2
1800	19800	2975	0	98	100	2
1800	19800	2976	0	98	100	2

A8 Links (Malfunction from 15:00 to 20:00)

```
//Events
;begintime endtime linknr nrlanes satflow   vfree  type
                               (%)    (%)
    16200  19800  2184    -1    82    100    1
    16200  19800  2185    -1    82    100    1
    16200  19800  2057    -1    82    100    1
    16200  19800  2004    -1    82    100    1
    16200  19800  2005    -1    83    100    1
    16200  19800  2000    -1    83    100    1
    16200  19800  2259    -1    83    100    1
    16200  19800  2261    -1    83    100    1
    16200  19800  1076    -1    83    100    1
    16200  19800  2263    -1    83    100    1
    16200  19800  2190    -1    83    100    1
     1800  19800  1995     0    98    100    2
     1800  19800  2625     0    98    100    2
     1800  19800  2626     0    98    100    2
     1800  19800  2732     0    98    100    2
     1800  19800  2733     0    98    100    2
     1800  19800  2775     0    98    100    2
     1800  19800  2776     0    98    100    2
     1800  19800  2778     0    98    100    2
     1800  19800  2779     0    98    100    2
     1800  19800  2805     0    98    100    2
     1800  19800  2806     0    98    100    2
     1800  19800  2807     0    98    100    2
```

A8 Rechts (Malfunction from 15:00 to 20:00)

```
//Events
;begintime endtime linknr nrlanes satflow   vfree  type
                               (%)    (%)
    16200  19800  2184    -1    82    100    1
    16200  19800  2185    -1    82    100    1
    16200  19800  2057    -1    82    100    1
    16200  19800  2004    -1    82    100    1
    16200  19800  2005    -1    83    100    1
    16200  19800  2000    -1    83    100    1
    16200  19800  2259    -1    83    100    1
    16200  19800  2261    -1    83    100    1
    16200  19800  1076    -1    83    100    1
    16200  19800  2263    -1    83    100    1
    16200  19800  2190    -1    83    100    1
     1800  19800   942     0    98    100    2
     1800  19800   964     0    98    100    2
     1800  19800   971     0    98    100    2
     1800  19800   983     0    98    100    2
     1800  19800  2054     0    98    100    2
     1800  19800  2055     0    98    100    2
     1800  19800  2056     0    98    100    2
     1800  19800  2057     0    98    100    2
     1800  19800  2184     0    98    100    2
     1800  19800  2185     0    98    100    2
     1800  19800  2186     0    98    100    2
     1800  19800  2187     0    98    100    2
     1800  19800  2257     0    98    100    2
```

A10 SWL (Malfunction from 15:00 to 20:00)

```
//Events
;begintime endtime linknr nrlanes satflow   vfree  type
                               (%)    (%)
    16200  19800  2184    -1    82    100    1
    16200  19800  2185    -1    82    100    1
    16200  19800  2057    -1    82    100    1
    16200  19800  2004    -1    82    100    1
    16200  19800  2005    -1    83    100    1
    16200  19800  2000    -1    83    100    1
    16200  19800  2259    -1    83    100    1
    16200  19800  2261    -1    83    100    1
    16200  19800  1076    -1    83    100    1
    16200  19800  2263    -1    83    100    1
    16200  19800  2190    -1    83    100    1
     1800  19800  2207     0    95    100    2
     1800  19800  2206     0    95    100    2
     1800  19800   674     0    95    100    2
     1800  19800   647     0    95    100    2
     1800  19800   619     0    95    100    2
     1800  19800  2202     0    95    100    2
     1800  19800  2201     0    95    100    2
     1800  19800   533     0    95    100    2
     1800  19800  2026     0    95    100    2
     1800  19800  2027     0    95    100    2
     1800  19800  2213     0    95    100    2
     1800  19800  2212     0    95    100    2
     1800  19800  2023     0    95    100    2
     1800  19800  2022     0    95    100    2
     1800  19800  2313     0    95    100    2
```

A10 SWR (Malfunction from 15:00 to 20:00)

```
//Events
;begintime endtime linknr nrlanes satflow   vfree  type
                               (%)    (%)
    16200  19800  2184    -1    82    100    1
    16200  19800  2185    -1    82    100    1
    16200  19800  2057    -1    82    100    1
    16200  19800  2004    -1    82    100    1
    16200  19800  2005    -1    83    100    1
    16200  19800  2000    -1    83    100    1
    16200  19800  2259    -1    83    100    1
    16200  19800  2261    -1    83    100    1
    16200  19800  1076    -1    83    100    1
    16200  19800  2263    -1    83    100    1
    16200  19800  2190    -1    83    100    1
     1800  19800  2210     0    95    100    2
     1800  19800  2211     0    95    100    2
     1800  19800  2208     0    95    100    2
     1800  19800  2209     0    95    100    2
     1800  19800   488     0    95    100    2
     1800  19800  2199     0    95    100    2
     1800  19800  2200     0    95    100    2
     1800  19800   582     0    95    100    2
     1800  19800   621     0    95    100    2
     1800  19800   650     0    95    100    2
     1800  19800  2204     0    95    100    2
     1800  19800  2205     0    95    100    2
     1800  19800  2203     0    95    100    2
```

Appendix C-3. Dynamic Route Information Panels

ALL 37 DRIPs Implemented in the Network

//UserClasses (these values have been entered hard-coded in the conversion source!)

;userclass percentage teta

1	26	0
2	14	1.0
3	33	1.5
4	27	2.0

//VMSinfo

;linknr routeinfo incident deltaTeta

877	1	0	1.0
2167	1	0	1.0
2740	1	0	1.0
2077	1	0	1.0
536	1	0	1.0
2084	1	0	1.0
2034	1	0	1.0
2032	1	0	1.0
361	1	0	1.0
527	1	0	1.0
2966	1	0	1.0
2625	1	0	1.0
2806	1	0	1.0
2182	1	0	1.0
2177	1	0	1.0
2174	1	0	1.0
2176	1	0	1.0
1885	1	0	1.0
2538	1	0	1.0
2171	1	0	1.0
2169	1	0	1.0
796	1	0	1.0
815	1	0	1.0
763	1	0	1.0
2554	1	0	1.0
694	1	0	1.0
756	1	0	1.0
571	1	0	1.0
568	1	0	1.0
2721	1	0	1.0
2579	1	0	1.0
533	1	0	1.0
2204	1	0	1.0
689	1	0	1.0
2205	1	0	1.0
1360	1	0	1.0

Accident A10NEL with A1L DRIPs

//VMSinfo

;linknr routeinfo incident deltaTeta

2167	0	1	1.0
2740	0	1	1.0

//UserClasses (these values have been entered hard-coded in the conversion source!)

;userclass percentage teta

1	26	0
2	14	1.0
3	33	1.5
4	27	2.0

//Events

;begintime endtime linknr nrlanes satflow vfree type

				(%)	(%)	
16200	19800	2184	-1	82	100	1
16200	19800	2185	-1	82	100	1
16200	19800	2057	-1	82	100	1
16200	19800	2004	-1	82	100	1
16200	19800	2005	-1	83	100	1
16200	19800	2000	-1	83	100	1
16200	19800	2259	-1	83	100	1
16200	19800	2261	-1	83	100	1
16200	19800	1076	-1	83	100	1
16200	19800	2263	-1	83	100	1
16200	19800	2190	-1	83	100	1
1800	9000	2169	-2	50	100	2
1800	9000	2170	-2	33	100	2
1800	9000	938	-2	33	100	2
1800	9000	1882	-2	33	100	2
1800	9000	1883	-2	50	100	2
1800	9000	1042	-2	33	100	2

Accident A10NEL with A1L DRIPs

//VMSinfo

;linknr routeinfo incident deltaTeta

2167	0	1	1.0
2740	0	1	1.0

//UserClasses (these values have been entered hard-coded in the conversion source!)

;userclass percentage teta

1	26	0
2	14	1.0
3	33	1.5
4	27	2.0

//Events

;begintime endtime linknr nrlanes satflow vfree type

				(%)	(%)	
16200	19800	2184	-1	82	100	1
16200	19800	2185	-1	82	100	1
16200	19800	2057	-1	82	100	1
16200	19800	2004	-1	82	100	1
16200	19800	2005	-1	83	100	1
16200	19800	2000	-1	83	100	1
16200	19800	2259	-1	83	100	1
16200	19800	2261	-1	83	100	1
16200	19800	1076	-1	83	100	1
16200	19800	2263	-1	83	100	1
16200	19800	2190	-1	83	100	1
1800	9000	873	-1	50	100	2
1800	9000	860	-2	50	100	2
1800	9000	815	-2	33	100	2
1800	9000	808	-2	50	100	2
1800	9000	762	-2	33	100	2
1800	9000	756	-2	50	100	2
1800	9000	697	-2	50	100	2

ALL 37 DRIPs Implemented in the Network (Rerouting in case rush hour lane A4/A10L not open from 15:00 to 17:00)

//UserClasses (these values have been entered hard-coded in the conversion source!)

;userclass percentage teta

1	26	0
2	14	1.0
3	33	1.5
4	27	2.0

//VMSinfo
;linknr routeinfo incident deltaTeta

877	0	1	1.0
2167	0	1	1.0
2740	0	1	1.0
2077	0	1	1.0
536	0	1	1.0
2084	0	1	1.0
2034	0	1	1.0
2032	0	1	1.0
361	0	1	1.0
527	0	1	1.0
2966	0	1	1.0
2625	0	1	1.0
2806	0	1	1.0
2182	0	1	1.0
2177	0	1	1.0
2174	0	1	1.0
2176	0	1	1.0
1885	0	1	1.0
2538	0	1	1.0
2171	0	1	1.0
2169	0	1	1.0
796	0	1	1.0
815	0	1	1.0
763	0	1	1.0
2554	0	1	1.0
694	0	1	1.0
756	0	1	1.0
571	0	1	1.0
568	0	1	1.0
2721	0	1	1.0
2579	0	1	1.0
533	0	1	1.0
2204	0	1	1.0
689	0	1	1.0
2205	0	1	1.0
1360	0	1	1.0

//Events
;begintime endtime linknr nrlanes satflow vfree type

begintime	endtime	linknr	nrlanes (%)	satflow (%)	vfree	type
16200	19800	2184	-1	82	100	1
16200	19800	2185	-1	82	100	1
16200	19800	2057	-1	82	100	1
16200	19800	2004	-1	82	100	1
16200	19800	2005	-1	83	100	1
16200	19800	2000	-1	83	100	1
16200	19800	2259	-1	83	100	1
16200	19800	2261	-1	83	100	1
16200	19800	1076	-1	83	100	1
16200	19800	2263	-1	83	100	1
16200	19800	2190	-1	83	100	1
1800	9000	361	-1	88	100	2
1800	9000	2317	-1	90	100	2
1800	9000	2319	-1	83	100	2
1800	9000	2030	-1	83	100	2
1800	9000	2314	-1	83	100	2
1800	9000	2593	-1	91	100	2
1800	9000	2592	-1	91	100	2
1800	9000	2720	-1	88	100	2
1800	9000	2721	-1	88	100	2
1800	9000	2725	-1	88	100	2
1800	9000	2724	-1	88	100	2
1800	9000	568	-1	88	100	2
1800	9000	2716	-1	90	100	2

Appendix D. Dynamic Route Information Panels (AMS Network)

Table D- 1. Porperties of DRIPs in AMS network

	Corridor	CI Number	Type	Location	OmniTRANS Link	MARPLE Link
1	**A1**	3187	DRIP	Re 6.79	5112	877
2	**A1**	3186	DRIP	Li 6.36	9157	2167
3	**A1**	3251	BermDRIP	Li 5.46	10403	2740
4	**A2**	3556	BermDRIP	Li 36.0	9041	2077
5	**A2**	3193	DRIP	Re 33.3	2767	536
6	**A2**	3214	BermDRIP	Li 33.1	9049	2084
7	**A2**	3192	DRIP	Li 32.4	9049	2084
8	**A4**	3249	BermDRIP	Li 2.90	8949	2034
9	**A4**	3200	DRIP	Re 2.80	8947	2032
10	**A4**	3198	DRIP	Li 2.20	1866	361
11	**N200**	3237	BermDRIP	Li 2.40	2731	527
12	**A5**	3563	DRIP	Li 10.4	10662	2966
13	**A8**	3567	DRIP	Li 4.40	10221	2625
14	**A8**	3216	BermDRIP	Li 3.10	10482	2806
15	**A10**	3564	DRIP	Li 1.55	9173	2182
16	**A10**	3238	BermDRIP	Re 2.70	9168	2177
17	**A10**	3239	BermDRIP	Li 5.30	9164	2174
18	**A10**	3562	BermDRIP	Re 5.45	9166	2176
19	**A10**	3242	BermDRIP	Re 8.10	8697	1885
20	**A10**	3241	BermDRIP	N 9.82	10089	2538
21	**A10**	3180	DRIP	Re 10.59	9161	2171
22	**A10**	3243	BermDRIP	Li 11.0	9159	2169
23	**A10**	3181	DRIP	Li 12.76	4510	796
24	**A10**	3218	BermDRIP	Re 12.87	4710	815
25	**A10**	3245	BermDRIP	Li 13.52	4162	763
26	**A10**	3244	BermDRIP	N14.02	10107	2554
27	**A10**	3246	BermDRIP	Li 14.34	3711	694
28	**A10**	3182	DRIP	Re 14.58	4099	756
29	**A10**	3561	BermDRIP	Li 16.18	2953	571
30	**A10**	3183	DRIP	Li 17.38	2915	568
31	**A10**	3250	BermDRIP	Li 19.30	10376	2721
32	**A10**	3184	DRIP	Re 20.02	10155	2579
33	**A10**	3185	DRIP	Li 23.10	2752	533
34	**A10**	3234	BermDRIP	Re 26.12	9228	2204
35	**A10**	3233	BermDRIP	N26.12	3690	689
36	**A10**	3236	BermDRIP	Re 26.20	9229	2205
37	**A10**	3235	BermDRIP	Li 28.13	7480	1360

Appendix E. Ramp Metering Systems (AMS Network)

Table E- 1. Properties of ramp metering in AMS netwrok

	Coding number	CI Number	Location	Min green time	Max green time	Link up-stream	On-Ramp Link	Link down-stream	Ending Node	Access capacity
1	**201**	91583	A10 Re, 28.3b	2	12	1364	817	2348	1547	3600
2	**202**	91582	A10 Re, 27.3b	2	12	1339	2630	2447	2458	5700
3	**203**	91581	A10 Re, 25.8b	2	12	650	2784	2204	1348	5700
4	**204**	91580	A10 Re, 25.1b	2	12	582	617	621	1300	5700
5	**305**	243136	A8 Li, 1.8d	2	12	2778	2777	2776	2529	4000
6	**306**	10018476	A8 Re, 2.4b	2	12	964	2501	2056	1709	8600
7	**307**	91599	A10 Li, 31.6d	2	12	2813	968	2391	1698	2150
8	**308**	243135	A10 Re, 32.1b	2	12	982	963	2180	1739	6000
9	**309**	91587	A10 Li, 1.8d	2	12	2310	2504	2182	1777	8600
10	**310**	91572	A10 Re, 1.9b	2	12	2511	2512	2510	2409	6450
11	**311**	91600	A10 Li, 4.3d	2	12	1047	1050	2179	1807	6450
12	**312**	91584	A10 Re, 4.5b	2	12	1039	1043	2176	1808	6450
13	**313**	91585	A10 Re, 7.2b	2	12	1046	1038	1885	1799	6450
14	**314**	91601	A10 Li, 6.8d	2	12	1042	1045	2173	1806	6450
15	**315**	91586	A10 Re, 9.8b	2	12	958	2529	2172	1673	6450
16	**316**	91602	A10 Li, 9.7d	2	12	938	2536	1882	1703	5100
17	**317**	91573	A10 Re, 12.8b	2	12	815	2545	808	1531	6450
18	**318**	91588	A10 Li, 12.7d	2	12	796	806	809	1532	8800
19	**319**	91574	A10 Re, 13.9b	2	12	762	2554	756	1453	6450
20	**320**	91589	A10 Li, 13.9d	2	12	755	2559	763	1466	8600
21	**321**	91575	A10 Re, 14.7b	2	12	697	691	681	1367	8600
22	**322**	91590	A10 Li, 14.7d	2	12	678	686	694	1381	6450
23	**323**	91576	A10 Re, 17.9b	2	12	2578	2583	2722	2439	7400
24	**324**	91591	A10 Li, 17.4d	2	12	568	2572	2716	1239	7400
25	**325**	91577	A10 Re, 20.0b	2	12	2580	2589	2579	2441	7600
26	**326**	91593	A10 Li, 19.8d	2	12	2592	2591	2720	1119	9500
27	**327**	91594	A10 Li, 21.7d	2	12	2212	422	2023	1075	4000
28	**328**	91578	A10 Re, 22.1b	2	12	2211	2653	2208	1105	5400
29	**329**	91595	A10 Li, 23.1d	2	12	533	2646	2026	1141	6000
30	**330**	91579	A10 Re, 23.5b	2	12	488	2643	2199	1200	6000
31	**331**	91596	A10 Li, 24.7d	2	12	619	2638	2202	1256	5700
32	**332**	91597	A10 Li, 26.3d	2	12	674	660	647	1330	5700
33	**333**	91598	A10 Li, 27.0d	2	12	1341	2632	2207	1419	3800
34	**334**	91617	A5 Re, 15.0	2	12	2974	2963	2961	2581	4300
35	**335**	243133	A10 Li, 28.9d	2	12	1367	812	1360	1530	4000

Table E- 2. Corridor divisions of the ramp metering

Malfunction Scenario	Nr of on-ramps	Ramp metering coding
A10 SWL	4	332, 331, 329, 327
A10 SWR	4	328, 330, 204, 203
A10 NWL	2	333, 335
A10 NWR	2	202, 201
A10 NBL	2	307, 309
A10 NBR	2	308, 310
A10 NEL	3	311, 314, 316
A10 NER	3	312, 313, 315
A10 SBL	2	326, 324
A10 SBR	2	325, 323
A10 SEL	3	322, 320, 318
A10 SER	3	321, 319, 317
A10 R (Inner Ring)	16	328, 330, 204, 203, 202, 201, 308, 310, 312, 313, 315, 325, 323, 321, 319, 317
A10 L (Outer Ring)	16	332, 331, 329, 327, 333, 335, 307, 309, 311, 314, 316, 326, 324, 322, 320, 318

Appendix F. Results of Location Scenarios

Appendix F-1. Rush Hour Lane Malfunctions

Table F- 1. Malfunctioning rush hour lane at A4L-A10L

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%
A10NE Rechts (21)	588.24	525.9	-10.6%	437.6	-25.6%	434.8	-26.1%	434.6	-26.1%	434.6	-26.1%
A10SE Rechts (22)	256.95	253.6	-1.3%	249.5	-2.9%	249.3	-3.0%	249.2	-3.0%	249.2	-3.0%
A10SB Rechts (23)	2594.52	2537.5	-2.2%	2486.8	-4.2%	2471.5	-4.7%	2456.6	-5.3%	2456.4	-5.3%
A10SW Rechts (24)	363.18	362.1	-0.3%	365.1	0.5%	365.7	0.7%	366.5	0.9%	366.7	1.0%
A10NW Rechts (25)	1454.35	1453.7	0.0%	1456.0	0.1%	1458.7	0.3%	1464.2	0.7%	1469.4	1.0%
A10NB Links (30)	2665.4	2648.8	-0.6%	2649.5	-0.6%	2649.9	-0.6%	2648.6	-0.6%	2647.7	-0.7%
A10NE Links (31)	880.24	871.7	-1.0%	872.3	-0.9%	872.4	-0.9%	865.4	-1.7%	862.3	-2.0%
A10SE Links (32)	1823.72	1473.5	-19.2%	1309.9	-28.2%	1242.8	-31.9%	1175.8	-35.5%	1173.8	-35.6%
A10SB Links (33)	1617.11	1737.3	7.4%	1690.1	4.5%	1631.6	0.9%	1533.9	-5.1%	1551.7	-4.0%
A10SW Links (34)	511.57	519.5	1.5%	458.2	-10.4%	456.3	-10.8%	429.8	-16.0%	429.8	-16.0%
A10NW Links (35)	46.27	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%
A1 Links (40)	354.96	336.8	-5.1%	322.1	-9.3%	321.7	-9.4%	321.7	-9.4%	321.7	-9.4%
A2 Links (41)	7.34	7.3	-1.1%	7.2	-2.3%	7.2	-2.5%	7.2	-2.5%	7.2	-2.5%
A4 Links (42)	1786.16	3351.1	87.6%	3637.2	103.6%	3424.9	91.7%	3188.5	78.5%	3262.6	82.7%
A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2388.2	-3.6%	2308.2	-6.8%	2314.1	-6.6%	2295.3	-7.3%	2284.1	-7.8%
A2 Rechts (51)	122.36	116.5	-4.8%	91.2	-25.4%	69.9	-42.9%	62.7	-48.8%	62.5	-48.9%
A4 Rechts (52)	265.35	269.0	1.4%	301.4	13.6%	286.0	7.8%	296.3	11.7%	296.2	11.6%
A8 Rechts (53)	1730.44	1730.1	0.0%	1733.0	0.2%	1736.5	0.4%	1735.0	0.3%	1734.1	0.2%
A5 Links (57)	10.63	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%
A5 Rechts (58)	1207.95	1207.9	0.0%	1208.1	0.0%	1209.9	0.2%	1210.8	0.2%	1210.9	0.2%
N200 Rechts (59)	307.74	310.6	0.9%	317.2	3.1%	317.3	3.1%	317.3	3.1%	317.4	3.1%
N200 Links (60)	118.8	118.8	0.0%	118.9	0.1%	119.1	0.2%	119.2	0.3%	119.2	0.3%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	37.9	0.0%	37.9	0.1%	38.0	0.2%	38.0	0.3%	38.0	0.3%
SUM AMS Network	21208.36	22294.4	5.1%	22094.3	4.2%	21714.1	2.4%	21253.2	0.2%	21332.2	0.6%
SUM The Ring	12810.95	12439.1	-2.9%	12030.7	-6.1%	11888.6	-7.2%	11680.3	-8.8%	11697.4	-8.7%
SUM The Inner Ring	5266.64	5142.1	-2.4%	5004.4	-5.0%	4989.4	-5.3%	4980.5	-5.4%	4985.7	-5.3%
SUM The Outer Ring	7544.31	7297.0	-3.3%	7026.2	-6.9%	6899.2	-8.6%	6699.7	-11.2%	6711.6	-11.0%
SUM Corridor	3403.27	5088.3	49.5%	5327.3	56.5%	5056.4	48.6%	4722.3	38.8%	4814.4	41.5%

Table F- 2. Malfunctioning rush hour lane at A10R-A4R

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%
A10NE Rechts (21)	588.24	588.2	0.0%	588.2	0.0%	588.7	0.1%	588.7	0.1%	588.7	0.1%
A10SE Rechts (22)	256.95	257.0	0.0%	256.9	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%
A10SB Rechts (23)	2594.52	2598.6	0.2%	2676.4	3.2%	2814.3	8.5%	2891.8	11.5%	2895.8	11.6%
A10SW Rechts (24)	389.64	389.6	0.0%	389.6	0.0%	389.3	-0.1%	389.7	0.0%	389.7	0.0%
A10NW Rechts (25)	1427.9	1427.9	0.0%	1427.9	0.0%	1428.3	0.0%	1428.4	0.0%	1428.4	0.0%
A10NB Links (30)	2665.4	2665.4	0.0%	2665.4	0.0%	2665.3	0.0%	2665.4	0.0%	2665.4	0.0%
A10NE Links (31)	880.24	880.2	0.0%	880.2	0.0%	880.2	0.0%	880.7	0.0%	880.6	0.0%
A10SE Links (32)	1823.72	1823.7	0.0%	1824.0	0.0%	1824.2	0.0%	1825.7	0.1%	1825.7	0.1%
A10SB Links (33)	1617.11	1617.1	0.0%	1617.5	0.0%	1617.1	0.0%	1616.8	0.0%	1616.7	0.0%
A10SW Links (34)	511.57	511.7	0.0%	511.1	-0.1%	511.2	-0.1%	511.1	-0.1%	511.1	-0.1%
A10NW Links (35)	46.27	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%
A1 Links (40)	354.96	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%
A2 Links (41)	7.34	7.3	0.0%	7.3	0.0%	19.2	161.4%	27.4	273.2%	27.4	273.2%
A4 Links (42)	1786.16	1786.1	0.0%	1778.9	-0.4%	1776.5	-0.5%	1775.8	-0.6%	1775.8	-0.6%
A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2477.3	0.0%	2477.2	0.0%	2477.0	0.0%	2478.7	0.1%	2478.7	0.1%
A2 Rechts (51)	122.36	122.4	0.0%	122.8	0.3%	123.0	0.5%	123.0	0.5%	123.0	0.5%
A4 Rechts (52)	265.35	270.1	1.8%	277.7	4.7%	293.5	10.6%	298.4	12.4%	298.6	12.5%
A8 Rechts (53)	1730.44	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%	1730.7	0.0%	1730.7	0.0%
A5 Links (57)	10.63	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%
A5 Rechts (58)	1207.95	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%
N200 Rechts (59)	307.74	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.8	0.0%	307.8	0.0%
N200 Links (60)	118.8	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%

A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%
SUM AMS Network	21208.37	21217.2	0.0%	21295.8	0.4%	21459.3	1.2%	21553.4	1.6%	21557.5	1.6%
SUM The Ring	12810.96	12815.0	0.0%	12893.0	0.6%	13031.2	1.7%	13110.8	2.3%	13114.7	2.4%
SUM The Inner Ring	5266.65	5270.7	0.1%	5348.5	1.6%	5486.9	4.2%	5564.9	5.7%	5569.0	5.7%
SUM The Outer Ring	7544.31	7544.3	0.0%	7544.5	0.0%	7544.3	0.0%	7545.9	0.0%	7545.7	0.0%
SUM Corridor	2859.87	2868.7	0.3%	2954.2	3.3%	3107.7	8.7%	3190.2	11.5%	3194.4	11.7%

Table F- 3. Malfunctioning rush hour lane at A8R-A7R

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%
A10NE Rechts (21)	588.24	588.2	0.0%	588.2	0.0%	588.2	0.0%	588.2	0.0%
A10SE Rechts (22)	256.95	257.0	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%
A10SB Rechts (23)	2594.52	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%
A10SW Rechts (24)	389.64	389.6	0.0%	389.6	0.0%	389.6	0.0%	389.6	0.0%
A10NW Rechts (25)	1427.9	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%
A10NB Links (30)	2665.4	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%
A10NE Links (31)	880.24	880.2	0.0%	880.2	0.0%	880.2	0.0%	880.2	0.0%
A10SE Links (32)	1823.72	1823.7	0.0%	1823.7	0.0%	1823.7	0.0%	1823.7	0.0%
A10SB Links (33)	1617.11	1617.1	0.0%	1617.1	0.0%	1617.1	0.0%	1617.1	0.0%
A10SW Links (34)	511.57	511.6	0.0%	511.6	0.0%	511.6	0.0%	511.6	0.0%
A10NW Links (35)	46.27	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%
A1 Links (40)	354.96	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%
A2 Links (41)	7.34	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%
A4 Links (42)	1786.16	1786.2	0.0%	1786.2	0.0%	1786.2	0.0%	1786.2	0.0%
A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2477.3	0.0%	2477.3	0.0%	2477.3	0.0%	2477.3	0.0%
A2 Rechts (51)	122.36	122.4	0.0%	122.4	0.0%	122.4	0.0%	122.4	0.0%
A4 Rechts (52)	265.35	265.4	0.0%	265.4	0.0%	265.4	0.0%	265.4	0.0%
A8 Rechts (53)	1730.44	1730.9	0.0%	1731.3	0.1%	1731.7	0.1%	1732.1	0.1%
A5 Links (57)	10.63	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%
A5 Rechts (58)	1207.95	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%
N200 Rechts (59)	307.74	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.7	0.0%
N200 Links (60)	118.8	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	50.0	31.9%	69.2	82.5%	83.5	120.4%	90.7	139.2%
SUM AMS Network	21208.37	21208.8	0.0%	21209.2	0.0%	21209.6	0.0%	21210.1	0.0%
SUM The Ring	12810.96	12810.9	0.0%	12810.9	0.0%	12810.9	0.0%	12811.0	0.0%
SUM The Inner Ring	5266.65	5266.6	0.0%	5266.6	0.0%	5266.6	0.0%	5266.6	0.0%
SUM The Outer Ring	7544.31	7544.3	0.0%	7544.3	0.0%	7544.3	0.0%	7544.3	0.0%
SUM Corridor	1768.34	1780.8	0.7%	1800.5	1.8%	1815.3	2.7%	1822.8	3.1%

Appendix F-2. MTM Malfunctions

Table F- 4. Malfunctioning MTM (AID) at A1L from 15:00

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%
A10NE Rechts (21)	588.24	588.2	0.0%	588.2	0.0%	588.2	0.0%	588.2	0.0%	588.2	0.0%
A10SE Rechts (22)	256.95	257.0	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%
A10SB Rechts (23)	2594.52	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%
A10SW Rechts (24)	389.64	389.6	0.0%	389.6	0.0%	389.6	0.0%	389.6	0.0%	389.6	0.0%
A10NW Rechts (25)	1427.9	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%
A10NB Links (30)	2665.4	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%
A10NE Links (31)	880.24	880.2	0.0%	880.2	0.0%	880.2	0.0%	880.2	0.0%	880.2	0.0%
A10SE Links (32)	1823.72	1823.7	0.0%	1823.7	0.0%	1823.7	0.0%	1823.7	0.0%	1823.7	0.0%
A10SB Links (33)	1617.11	1617.1	0.0%	1617.1	0.0%	1617.1	0.0%	1617.1	0.0%	1617.1	0.0%
A10SW Links (34)	511.57	511.6	0.0%	511.6	0.0%	511.6	0.0%	511.6	0.0%	511.6	0.0%
A10NW Links (35)	46.27	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%
A1 Links (40)	354.96	355.6	0.2%	357.3	0.7%	360.6	1.6%	361.6	1.9%	361.6	1.9%
A2 Links (41)	7.34	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%
A4 Links (42)	1786.16	1786.2	0.0%	1786.2	0.0%	1786.2	0.0%	1786.2	0.0%	1786.2	0.0%
A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2477.2	0.0%	2477.2	0.0%	2477.2	0.0%	2477.2	0.0%	2477.2	0.0%
A2 Rechts (51)	122.36	122.4	0.0%	122.4	0.0%	122.4	0.0%	122.4	0.0%	122.4	0.0%
A4 Rechts (52)	265.35	265.4	0.0%	265.4	0.0%	265.4	0.0%	265.4	0.0%	265.4	0.0%
A8 Rechts (53)	1730.44	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%
A5 Links (57)	10.63	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%
A5 Rechts (58)	1207.95	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%
N200 Rechts (59)	307.74	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.7	0.0%
N200 Links (60)	118.8	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%
SUM AMS Network	21208.37	21208.9	0.0%	21210.6	0.0%	21213.9	0.0%	21214.9	0.0%	21214.9	0.0%
SUM The Ring	12810.96	12810.9	0.0%	12810.9	0.0%	12810.9	0.0%	12810.9	0.0%	12810.9	0.0%
SUM The Inner Ring	5266.65	5266.6	0.0%	5266.6	0.0%	5266.6	0.0%	5266.6	0.0%	5266.6	0.0%
SUM The Outer Ring	7544.31	7544.3	0.0%	7544.3	0.0%	7544.3	0.0%	7544.3	0.0%	7544.3	0.0%
SUM Corridor	354.96	355.6	0.0%	357.3	0.0%	360.6	0.0%	361.6	0.0%	361.6	0.0%

Table F- 5. Malfunctioning MTM (AID) at A1R from 15:00

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%
A10NE Rechts (21)	588.24	582.6	-1.0%	569.0	-3.3%	583.0	-0.9%	584.0	-0.7%	584.0	-0.7%
A10SE Rechts (22)	256.95	256.8	-0.1%	255.4	-0.6%	256.7	-0.1%	256.9	0.0%	256.9	0.0%
A10SB Rechts (23)	2594.52	2593.6	0.0%	2591.0	-0.1%	2591.6	-0.1%	2591.3	-0.1%	2591.3	-0.1%
A10SW Rechts (24)	389.64	389.6	0.0%	389.6	0.0%	389.6	0.0%	389.6	0.0%	389.6	0.0%
A10NW Rechts (25)	1427.9	1427.9	0.0%	1427.8	0.0%	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%
A10NB Links (30)	2665.4	2665.2	0.0%	2649.2	-0.6%	2664.7	0.0%	2665.2	0.0%	2665.4	0.0%
A10NE Links (31)	880.24	880.2	0.0%	879.0	-0.1%	879.6	-0.1%	879.6	-0.1%	881.0	0.1%
A10SE Links (32)	1823.72	1810.6	-0.7%	1793.2	-1.7%	1795.0	-1.6%	1796.0	-1.5%	1800.0	-1.3%
A10SB Links (33)	1617.11	1617.1	0.0%	1617.1	0.0%	1617.1	0.0%	1617.1	0.0%	1617.1	0.0%
A10SW Links (34)	511.57	511.6	0.0%	511.6	0.0%	511.6	0.0%	511.6	0.0%	511.6	0.0%
A10NW Links (35)	46.27	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%
A1 Links (40)	354.96	350.4	-1.3%	345.0	-2.8%	343.4	-3.3%	343.3	-3.3%	343.3	-3.3%
A2 Links (41)	7.34	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%
A4 Links (42)	1786.16	1786.2	0.0%	1786.1	0.0%	1786.1	0.0%	1786.1	0.0%	1786.1	0.0%
A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2506.9	1.2%	2535.1	2.3%	2555.1	3.1%	2574.6	3.9%	2588.7	4.5%
A2 Rechts (51)	122.36	122.4	0.0%	122.3	0.0%	122.3	0.0%	122.3	0.0%	122.3	0.0%
A4 Rechts (52)	265.35	265.3	0.0%	265.3	0.0%	265.3	0.0%	265.3	0.0%	265.3	0.0%
A8 Rechts (53)	1730.44	1730.4	0.0%	1728.5	-0.1%	1730.3	0.0%	1730.3	0.0%	1731.0	0.0%
A5 Links (57)	10.63	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%
A5 Rechts (58)	1207.95	1208.0	0.0%	1207.9	0.0%	1207.9	0.0%	1207.9	0.0%	1207.9	0.0%
N200 Rechts (59)	307.74	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.7	0.0%
N200 Links (60)	118.8	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%
SUM AMS Network	21208.37	21213.3	0.0%	21181.8	-0.1%	21235.9	0.1%	21257.5	0.2%	21278.1	0.3%

SUM The Ring	12810.96	12790.8	-0.2%	12738.6	-0.6%	12772.5	-0.3%	12774.7	-0.3%	12780.4	-0.2%
SUM The Inner Ring	5266.65	5259.9	-0.1%	5242.2	-0.5%	5258.2	-0.2%	5259.0	-0.1%	5259.0	-0.1%
SUM The Outer Ring	7544.31	7530.9	-0.2%	7496.4	-0.6%	7514.3	-0.4%	7515.7	-0.4%	7521.4	-0.3%
SUM Corridor	2477.26	2506.9	1.2%	2535.1	2.3%	2555.1	3.1%	2574.6	3.9%	2588.7	4.5%

Table F- 6. Malfunctioning MTM (AID) at A2L from 15:00

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%
A10NE Rechts (21)	588.24	588.2	0.0%	588.2	0.0%	588.2	0.0%	588.2	0.0%	588.2	0.0%
A10SE Rechts (22)	256.95	257.0	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%
A10SB Rechts (23)	2594.52	2594.6	0.0%	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%
A10SW Rechts (24)	389.64	389.6	0.0%	389.6	0.0%	389.6	0.0%	389.6	0.0%	389.6	0.0%
A10NW Rechts (25)	1427.9	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%
A10NB Links (30)	2665.4	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%
A10NE Links (31)	880.24	880.2	0.0%	880.2	0.0%	880.2	0.0%	880.2	0.0%	880.2	0.0%
A10SE Links (32)	1823.72	1823.8	0.0%	1823.7	0.0%	1823.8	0.0%	1823.8	0.0%	1823.8	0.0%
A10SB Links (33)	1617.11	1617.1	0.0%	1617.1	0.0%	1617.1	0.0%	1617.1	0.0%	1617.1	0.0%
A10SW Links (34)	511.57	511.6	0.0%	511.6	0.0%	511.6	0.0%	511.6	0.0%	511.6	0.0%
A10NW Links (35)	46.27	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%
A1 Links (40)	354.96	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%
A2 Links (41)	7.34	7.4	1.1%	7.5	2.5%	7.6	3.8%	7.6	4.1%	7.6	4.1%
A4 Links (42)	1786.16	1786.2	0.0%	1786.2	0.0%	1786.2	0.0%	1786.2	0.0%	1786.2	0.0%
A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2477.3	0.0%	2477.3	0.0%	2477.2	0.0%	2477.2	0.0%	2477.2	0.0%
A2 Rechts (51)	122.36	122.4	0.0%	122.4	0.0%	122.4	0.0%	122.4	0.0%	122.4	0.0%
A4 Rechts (52)	265.35	265.4	0.0%	265.4	0.0%	265.4	0.0%	265.4	0.0%	265.4	0.0%
A8 Rechts (53)	1730.44	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%
A5 Links (57)	10.63	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%
A5 Rechts (58)	1207.95	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%
N200 Rechts (59)	307.74	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.7	0.0%
N200 Links (60)	118.8	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%
SUM AMS Network	21208.37	21208.5	0.0%	21208.5	0.0%	21208.7	0.0%	21208.7	0.0%	21208.7	0.0%
SUM The Ring	12810.96	12811.0	0.0%	12810.9	0.0%	12811.0	0.0%	12811.0	0.0%	12811.0	0.0%
SUM The Inner Ring	5266.65	5266.7	0.0%	5266.6	0.0%	5266.6	0.0%	5266.6	0.0%	5266.6	0.0%
SUM The Outer Ring	7544.31	7544.3	0.0%	7544.3	0.0%	7544.4	0.0%	7544.4	0.0%	7544.4	0.0%
SUM Corridor	7.34	7.4	1.1%	7.5	2.5%	7.6	3.8%	7.6	4.1%	7.6	4.1%

Table F- 7. Malfunctioning MTM (AID) at A2R from 15:00

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%
A10NE Rechts (21)	588.24	588.0	0.0%	588.5	0.0%	588.5	0.0%	588.5	0.0%	588.5	0.0%
A10SE Rechts (22)	256.95	257.0	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%
A10SB Rechts (23)	2594.52	2610.3	0.6%	2616.5	0.8%	2620.4	1.0%	2623.5	1.1%	2623.5	1.1%
A10SW Rechts (24)	389.64	389.6	0.0%	389.8	0.0%	389.7	0.0%	389.8	0.0%	389.8	0.0%
A10NW Rechts (25)	1427.9	1427.9	0.0%	1428.4	0.0%	1428.2	0.0%	1428.3	0.0%	1428.3	0.0%
A10NB Links (30)	2665.4	2665.6	0.0%	2665.9	0.0%	2666.0	0.0%	2666.1	0.0%	2666.1	0.0%
A10NE Links (31)	880.24	880.2	0.0%	881.3	0.1%	881.9	0.2%	882.4	0.2%	882.4	0.2%
A10SE Links (32)	1823.72	1856.3	1.8%	1865.4	2.3%	1869.1	2.5%	1873.0	2.7%	1873.0	2.7%
A10SB Links (33)	1617.11	1616.9	0.0%	1617.0	0.0%	1616.9	0.0%	1616.7	0.0%	1616.7	0.0%
A10SW Links (34)	511.57	511.7	0.0%	511.7	0.0%	511.7	0.0%	511.7	0.0%	511.7	0.0%
A10NW Links (35)	46.27	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%
A1 Links (40)	354.96	355.0	0.0%	357.9	0.8%	357.9	0.8%	357.9	0.8%	357.9	0.8%
A2 Links (41)	7.34	7.4	0.8%	7.4	1.1%	7.4	1.2%	7.5	1.5%	7.5	1.5%
A4 Links (42)	1786.16	1786.1	0.0%	1786.2	0.0%	1786.0	0.0%	1785.9	0.0%	1785.9	0.0%
A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2477.1	0.0%	2481.7	0.2%	2483.5	0.3%	2485.0	0.3%	2485.0	0.3%
A2 Rechts (51)	122.36	122.3	0.0%	124.5	1.8%	128.3	4.8%	130.0	6.3%	130.1	6.3%
A4 Rechts (52)	265.35	265.3	0.0%	265.4	0.0%	265.4	0.0%	265.4	0.0%	265.4	0.0%
A8 Rechts (53)	1730.44	1730.5	0.0%	1731.8	0.1%	1732.0	0.1%	1732.1	0.1%	1732.1	0.1%
A5 Links (57)	10.63	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%
A5 Rechts (58)	1207.95	1207.9	0.0%	1208.0	0.0%	1207.9	0.0%	1207.9	0.0%	1207.9	0.0%
N200 Rechts (59)	307.74	307.7	0.0%	307.8	0.0%	307.7	0.0%	307.8	0.0%	307.8	0.0%

N200 Links (60)	118.8	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	37.9	0.0%	37.9	0.1%	37.9	0.1%	37.9	0.1%	37.9	0.1%
SUM AMS Network	21208.37	21256.3	0.2%	21285.5	0.4%	21298.8	0.4%	21309.8	0.5%	21309.8	0.5%
SUM The Ring	12810.96	12859.1	0.4%	12877.1	0.5%	12885.0	0.6%	12892.6	0.6%	12892.6	0.6%
SUM The Inner Ring	5266.65	5282.1	0.3%	5289.5	0.4%	5293.2	0.5%	5296.4	0.6%	5296.4	0.6%
SUM The Outer Ring	7544.31	7577.0	0.4%	7587.6	0.6%	7591.8	0.6%	7596.2	0.7%	7596.2	0.7%
SUM Corridor	122.36	122.34	0.0%	124.51	1.8%	128.28	4.8%	130.04	6.3%	130.08	6.3%

Table F- 8. Malfunctioning MTM (AID) at A4L from 15:00

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%
A10NE Rechts (21)	588.24	588.2	0.0%	588.2	0.0%	588.2	0.0%	588.2	0.0%	588.2	0.0%
A10SE Rechts (22)	256.95	257.0	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%
A10SB Rechts (23)	2594.52	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%
A10SW Rechts (24)	389.64	389.6	0.0%	389.6	0.0%	389.6	0.0%	389.6	0.0%	389.6	0.0%
A10NW Rechts (25)	1427.9	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%
A10NB Links (30)	2665.4	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%
A10NE Links (31)	880.24	880.2	0.0%	880.2	0.0%	880.2	0.0%	880.2	0.0%	880.2	0.0%
A10SE Links (32)	1823.72	1823.6	0.0%	1823.6	0.0%	1823.6	0.0%	1823.6	0.0%	1823.6	0.0%
A10SB Links (33)	1617.11	1616.8	0.0%	1616.8	0.0%	1616.8	0.0%	1616.8	0.0%	1616.8	0.0%
A10SW Links (34)	511.57	511.8	0.0%	511.3	-0.1%	511.3	-0.1%	511.3	-0.1%	511.3	-0.1%
A10NW Links (35)	46.27	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%
A1 Links (40)	354.96	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%
A2 Links (41)	7.34	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%
A4 Links (42)	1786.16	1788.3	0.1%	1797.0	0.6%	1811.8	1.4%	1824.1	2.1%	1824.6	2.2%
A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2477.3	0.0%	2477.3	0.0%	2477.3	0.0%	2477.3	0.0%	2477.3	0.0%
A2 Rechts (51)	122.36	122.4	0.0%	122.4	0.0%	122.4	0.0%	122.4	0.0%	122.4	0.0%
A4 Rechts (52)	265.35	265.4	0.0%	265.4	0.0%	265.4	0.0%	265.4	0.0%	265.4	0.0%
A8 Rechts (53)	1730.44	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%
A5 Links (57)	10.63	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%
A5 Rechts (58)	1207.95	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%
N200 Rechts (59)	307.74	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.7	0.0%
N200 Links (60)	118.8	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%
SUM AMS Network	21208.37	21210.2	0.0%	21218.5	0.0%	21233.2	0.1%	21245.5	0.2%	21246.0	0.2%
SUM The Ring	12810.96	12810.7	0.0%	12810.2	0.0%	12810.2	0.0%	12810.2	0.0%	12810.2	0.0%
SUM The Inner Ring	5266.65	5266.6	0.0%	5266.6	0.0%	5266.6	0.0%	5266.6	0.0%	5266.6	0.0%
SUM The Outer Ring	7544.31	7544.1	0.0%	7543.6	0.0%	7543.6	0.0%	7543.6	0.0%	7543.6	0.0%
SUM Corridor	1786.16	1788.3	0.1%	1797.0	0.6%	1811.8	1.4%	1824.1	2.1%	1824.6	2.2%

Table F- 9. Malfunctioning MTM (AID) at A4R from 15:00

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%
A10NE Rechts (21)	588.24	588.7	0.1%	588.2	0.0%	588.2	0.0%	588.2	0.0%	588.2	0.0%
A10SE Rechts (22)	256.95	257.0	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%
A10SB Rechts (23)	2594.52	2654.1	2.3%	2700.3	4.1%	2731.5	5.3%	2755.4	6.2%	2757.4	6.3%
A10SW Rechts (24)	389.64	389.6	0.0%	389.7	0.0%	389.7	0.0%	389.8	0.1%	389.9	0.1%
A10NW Rechts (25)	1427.9	1427.9	0.0%	1428.2	0.0%	1428.3	0.0%	1428.9	0.1%	1429.1	0.1%
A10NB Links (30)	2665.4	2665.4	0.0%	2665.5	0.0%	2665.5	0.0%	2665.5	0.0%	2665.5	0.0%
A10NE Links (31)	880.24	880.2	0.0%	880.1	0.0%	880.1	0.0%	880.1	0.0%	880.1	0.0%
A10SE Links (32)	1823.72	1823.5	0.0%	1824.2	0.0%	1824.6	0.0%	1824.7	0.1%	1824.7	0.1%
A10SB Links (33)	1617.11	1616.6	0.0%	1615.2	-0.1%	1614.3	-0.2%	1613.8	-0.2%	1613.8	-0.2%
A10SW Links (34)	511.57	511.4	0.0%	511.3	-0.1%	521.8	2.0%	525.1	2.6%	525.1	2.6%
A10NW Links (35)	46.27	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%
A1 Links (40)	354.96	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%
A2 Links (41)	7.34	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%
A4 Links (42)	1786.16	1782.5	-0.2%	1768.6	-1.0%	1760.4	-1.4%	1759.0	-1.5%	1759.0	-1.5%
A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2477.2	0.0%	2477.0	0.0%	2476.8	0.0%	2476.8	0.0%	2476.8	0.0%
A2 Rechts (51)	122.36	121.8	-0.5%	122.6	0.2%	122.9	0.4%	122.9	0.4%	122.9	0.4%
A4 Rechts (52)	265.35	267.0	0.6%	270.8	2.1%	273.0	2.9%	275.5	3.8%	275.5	3.8%

A8 Rechts (53)	1730.44	1730.4	0.0%	1730.5	0.0%	1730.5	0.0%	1730.5	0.0%	1730.6	0.0%
A5 Links (57)	10.63	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%
A5 Rechts (58)	1207.95	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%	1208.1	0.0%	1208.1	0.0%
N200 Rechts (59)	307.74	307.7	0.0%	307.7	0.0%	307.8	0.0%	307.8	0.0%	307.8	0.0%
N200 Links (60)	118.8	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%
SUM AMS Network	21208.37	21264.7	0.3%	21300.9	0.4%	21336.0	0.6%	21364.9	0.7%	21367.3	0.7%
SUM The Ring	12810.96	12869.9	0.5%	12915.5	0.8%	12956.5	1.1%	12984.1	1.4%	12986.4	1.4%
SUM The Inner Ring	5266.65	5326.6	1.1%	5372.8	2.0%	5404.0	2.6%	5428.7	3.1%	5430.9	3.1%
SUM The Outer Ring	7544.31	7543.3	0.0%	7542.7	0.0%	7552.5	0.1%	7555.5	0.1%	7555.5	0.1%
SUM Corridor	2859.87	267.0	0.6%	270.8	2.1%	273.0	2.9%	275.5	3.8%	275.5	3.8%

Table F- 10. Malfunctioning MTM (AID) at A5L from 15:00

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%
A10NE Rechts (21)	588.24	588.2	0.0%	588.2	0.0%	588.2	0.0%	588.2	0.0%	588.2	0.0%
A10SE Rechts (22)	256.95	257.0	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%
A10SB Rechts (23)	2594.52	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%
A10SW Rechts (24)	389.64	389.6	0.0%	389.6	0.0%	389.6	0.0%	389.6	0.0%	389.6	0.0%
A10NW Rechts (25)	1427.9	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%
A10NB Links (30)	2665.4	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%
A10NE Links (31)	880.24	880.2	0.0%	880.2	0.0%	880.2	0.0%	880.2	0.0%	880.2	0.0%
A10SE Links (32)	1823.72	1823.7	0.0%	1823.7	0.0%	1823.7	0.0%	1823.7	0.0%	1823.7	0.0%
A10SB Links (33)	1617.11	1617.1	0.0%	1617.1	0.0%	1617.1	0.0%	1617.1	0.0%	1617.1	0.0%
A10SW Links (34)	511.57	511.6	0.0%	511.6	0.0%	511.6	0.0%	511.6	0.0%	511.6	0.0%
A10NW Links (35)	46.27	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%
A1 Links (40)	354.96	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%
A2 Links (41)	7.34	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%
A4 Links (42)	1786.16	1786.2	0.0%	1786.2	0.0%	1786.2	0.0%	1786.2	0.0%	1786.2	0.0%
A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2477.3	0.0%	2477.3	0.0%	2477.3	0.0%	2477.3	0.0%	2477.3	0.0%
A2 Rechts (51)	122.36	122.4	0.0%	122.4	0.0%	122.4	0.0%	122.4	0.0%	122.4	0.0%
A4 Rechts (52)	265.35	265.4	0.0%	265.4	0.0%	265.4	0.0%	265.4	0.0%	265.4	0.0%
A8 Rechts (53)	1730.44	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%
A5 Links (57)	10.63	10.7	0.6%	10.9	2.2%	11.1	4.0%	11.1	4.7%	11.1	4.8%
A5 Rechts (58)	1207.95	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%
N200 Rechts (59)	307.74	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.7	0.0%
N200 Links (60)	118.8	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%
SUM AMS Network	21208.37	21208.4	0.0%	21208.6	0.0%	21208.8	0.0%	21208.9	0.0%	21208.9	0.0%
SUM The Ring	12810.96	12811.0	0.0%	12811.0	0.0%	12811.0	0.0%	12811.0	0.0%	12811.0	0.0%
SUM The Inner Ring	5266.65	5266.7	0.0%	5266.7	0.0%	5266.7	0.0%	5266.7	0.0%	5266.7	0.0%
SUM The Outer Ring	7544.31	7544.3	0.0%	7544.3	0.0%	7544.3	0.0%	7544.3	0.0%	7544.3	0.0%
SUM Corridor	10.63	10.7	0.6%	10.9	2.2%	11.1	4.0%	11.1	4.7%	11.1	4.8%

Table F- 11. Malfunctioning MTM (AID) at A5R from 15:00

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%
A10NE Rechts (21)	588.24	588.2	0.0%	588.2	0.0%	588.7	0.0%	588.7	0.0%	588.7	0.0%
A10SE Rechts (22)	256.95	257.0	0.0%	256.9	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%
A10SB Rechts (23)	2594.52	2594.5	0.0%	2676.4	0.0%	2814.3	0.0%	2891.8	0.0%	2895.8	0.0%
A10SW Rechts (24)	389.64	389.6	0.0%	389.6	0.0%	389.3	0.0%	389.7	0.0%	389.7	0.0%
A10NW Rechts (25)	1427.9	1427.9	0.0%	1427.9	0.0%	1428.3	0.0%	1428.4	0.0%	1428.4	0.0%
A10NB Links (30)	2665.4	2665.4	0.0%	2665.4	0.0%	2665.3	0.0%	2665.4	0.0%	2665.4	0.0%
A10NE Links (31)	880.24	880.2	0.0%	880.2	0.0%	880.2	0.0%	880.7	0.0%	880.6	0.0%
A10SE Links (32)	1823.72	1823.7	0.0%	1824.0	0.0%	1824.2	0.0%	1825.7	0.0%	1825.7	0.0%
A10SB Links (33)	1617.11	1617.1	0.0%	1617.5	0.0%	1617.1	0.0%	1616.8	0.0%	1616.7	0.0%
A10SW Links (34)	511.57	511.6	0.0%	511.1	0.0%	511.2	0.0%	511.1	0.0%	511.1	0.0%
A10NW Links (35)	46.27	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%
A1 Links (40)	354.96	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%
A2 Links (41)	7.34	7.3	0.0%	7.3	0.0%	19.2	0.0%	27.4	0.0%	27.4	0.0%
A4 Links (42)	1786.16	1786.2	0.0%	1778.9	0.0%	1776.5	0.0%	1775.8	0.0%	1775.8	0.0%

A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2477.3	0.0%	2477.2	0.0%	2477.0	0.0%	2478.7	0.0%	2478.7	0.0%
A2 Rechts (51)	122.36	122.4	0.0%	122.8	0.0%	123.0	0.0%	123.0	0.0%	123.0	0.0%
A4 Rechts (52)	265.35	265.4	0.0%	277.7	0.0%	293.5	0.0%	298.4	0.0%	298.6	0.0%
A8 Rechts (53)	1730.44	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%	1730.7	0.0%	1730.7	0.0%
A5 Links (57)	10.63	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%
A5 Rechts (58)	1207.95	1209.6	0.1%	1216.3	0.7%	1223.6	1.3%	1230.9	1.9%	1232.6	2.0%
N200 Rechts (59)	307.74	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.8	0.0%	307.7	0.0%
N200 Links (60)	118.8	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%
SUM AMS Network	21208.37	21210.0	0.0%	21216.7	0.0%	21224.0	0.1%	21231.4	0.1%	21233.0	0.1%
SUM The Ring	12810.96	12811.0	0.0%	12811.0	0.0%	12811.0	0.0%	12811.0	0.0%	12811.0	0.0%
SUM The Inner Ring	5266.65	5266.7	0.0%	5266.7	0.0%	5266.7	0.0%	5266.7	0.0%	5266.7	0.0%
SUM The Outer Ring	7544.31	7544.3	0.0%	7544.3	0.0%	7544.3	0.0%	7544.3	0.0%	7544.3	0.0%
SUM Corridor	1207.95	1209.6	0.1%	1216.3	0.7%	1223.6	1.3%	1230.9	1.9%	1232.6	2.0%

Table F- 12. Malfunctioning MTM (AID) at A8L from 15:00

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%
A10NE Rechts (21)	588.24	588.3	0.0%	588.2	0.0%	588.2	0.0%	588.2	0.0%	588.2	0.0%
A10SE Rechts (22)	256.95	257.0	0.0%	256.9	0.0%	256.9	0.0%	256.9	0.0%	256.9	0.0%
A10SB Rechts (23)	2594.52	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%
A10SW Rechts (24)	389.64	389.6	0.0%	389.6	0.0%	389.6	0.0%	389.6	0.0%	389.6	0.0%
A10NW Rechts (25)	1427.9	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%
A10NB Links (30)	2665.4	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%
A10NE Links (31)	880.24	880.2	0.0%	880.2	0.0%	880.2	0.0%	880.2	0.0%	880.2	0.0%
A10SE Links (32)	1823.72	1823.7	0.0%	1823.7	0.0%	1823.7	0.0%	1823.7	0.0%	1823.7	0.0%
A10SB Links (33)	1617.11	1617.1	0.0%	1617.1	0.0%	1617.1	0.0%	1617.1	0.0%	1617.1	0.0%
A10SW Links (34)	511.57	511.6	0.0%	511.6	0.0%	511.6	0.0%	511.6	0.0%	511.6	0.0%
A10NW Links (35)	46.27	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%
A1 Links (40)	354.96	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%
A2 Links (41)	7.34	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%
A4 Links (42)	1786.16	1786.2	0.0%	1786.2	0.0%	1786.2	0.0%	1786.2	0.0%	1786.2	0.0%
A8 Links (43)	8.42	8.5	1.1%	8.7	3.0%	8.8	4.2%	8.8	4.5%	8.8	4.5%
A1 Rechts (50)	2477.26	2477.3	0.0%	2477.3	0.0%	2477.3	0.0%	2477.3	0.0%	2477.3	0.0%
A2 Rechts (51)	122.36	122.4	0.0%	122.4	0.0%	122.4	0.0%	122.4	0.0%	122.4	0.0%
A4 Rechts (52)	265.35	265.4	0.0%	265.4	0.0%	265.4	0.0%	265.4	0.0%	265.4	0.0%
A8 Rechts (53)	1730.44	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%
A5 Links (57)	10.63	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%
A5 Rechts (58)	1207.95	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%
N200 Rechts (59)	307.74	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.7	0.0%
N200 Links (60)	118.8	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%
SUM AMS Network	21208.37	21208.5	0.0%	21208.6	0.0%	21208.7	0.0%	21208.7	0.0%	21208.7	0.0%
SUM The Ring	12810.96	12811.0	0.0%	12810.9	0.0%	12810.9	0.0%	12810.9	0.0%	12810.9	0.0%
SUM The Inner Ring	5266.65	5266.7	0.0%	5266.6	0.0%	5266.6	0.0%	5266.6	0.0%	5266.6	0.0%
SUM The Outer Ring	7544.31	7544.3	0.0%	7544.3	0.0%	7544.3	0.0%	7544.3	0.0%	7544.3	0.0%
SUM Corridor	8.42	8.5	1.1%	8.7	3.0%	8.8	4.2%	8.8	4.5%	8.8	4.5%

Table F- 13. Malfunctioning MTM (AID) at A8R from 15:00

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.5	0.6%	9.6	1.7%	9.6	2.6%	9.7	2.9%	9.7	2.9%
A10NE Rechts (21)	588.24	600.0	2.0%	622.7	5.9%	643.5	9.4%	649.1	10.4%	649.2	10.4%
A10SE Rechts (22)	256.95	259.3	0.9%	260.5	1.4%	261.2	1.6%	261.7	1.8%	261.7	1.8%
A10SB Rechts (23)	2594.52	2594.8	0.0%	2595.6	0.0%	2596.3	0.1%	2596.9	0.1%	2597.0	0.1%
A10SW Rechts (24)	389.64	389.6	0.0%	389.7	0.0%	389.7	0.0%	389.8	0.0%	389.8	0.0%
A10NW Rechts (25)	1427.9	1428.1	0.0%	1428.6	0.0%	1428.8	0.1%	1429.1	0.1%	1429.3	0.1%
A10NB Links (30)	2665.4	2703.6	1.4%	2718.8	2.0%	2710.5	1.7%	2723.1	2.2%	2726.0	2.3%
A10NE Links (31)	880.24	880.6	0.0%	880.9	0.1%	881.2	0.1%	881.7	0.2%	881.7	0.2%
A10SE Links (32)	1823.72	1823.8	0.0%	1825.7	0.1%	1826.0	0.1%	1827.4	0.2%	1827.4	0.2%
A10SB Links (33)	1617.11	1617.3	0.0%	1617.3	0.0%	1617.3	0.0%	1617.3	0.0%	1617.3	0.0%
A10SW Links (34)	511.57	512.1	0.1%	512.1	0.1%	512.1	0.1%	512.1	0.1%	512.1	0.1%

A10NW Links (35)	46.27	46.5	0.5%	46.5	0.5%	46.5	0.5%	46.5	0.5%	46.5	0.5%
A1 Links (40)	354.96	356.6	0.4%	357.5	0.7%	357.5	0.7%	357.5	0.7%	357.5	0.7%
A2 Links (41)	7.34	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%
A4 Links (42)	1786.16	1786.8	0.0%	1786.5	0.0%	1786.5	0.0%	1786.5	0.0%	1786.5	0.0%
A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2479.9	0.1%	2490.7	0.5%	2491.8	0.6%	2494.8	0.7%	2495.9	0.8%
A2 Rechts (51)	122.36	121.9	-0.4%	121.9	-0.4%	121.9	-0.4%	121.9	-0.4%	121.9	-0.4%
A4 Rechts (52)	265.35	265.8	0.2%	265.8	0.2%	265.8	0.2%	265.8	0.2%	265.8	0.2%
A8 Rechts (53)	1730.44	1714.2	-0.9%	1720.0	-0.6%	1725.9	-0.3%	1734.2	0.2%	1741.3	0.6%
A5 Links (57)	10.63	10.6	0.1%	10.6	0.1%	10.6	0.1%	10.6	0.1%	10.6	0.1%
A5 Rechts (58)	1207.95	1208.1	0.0%	1208.2	0.0%	1208.2	0.0%	1208.2	0.0%	1208.2	0.0%
N200 Rechts (59)	307.74	307.8	0.0%	307.8	0.0%	307.8	0.0%	307.8	0.0%	307.8	0.0%
N200 Links (60)	118.8	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	37.4	-1.3%	36.8	-2.9%	36.3	-4.2%	36.0	-5.1%	35.7	-5.9%
SUM AMS Network	21208.37	21251.3	0.2%	21311.3	0.5%	21333.1	0.6%	21366.3	0.7%	21377.6	0.8%
SUM The Ring	12810.96	12865.1	0.4%	12907.9	0.8%	12922.6	0.9%	12944.3	1.0%	12947.5	1.1%
SUM The Inner Ring	5266.65	5281.2	0.3%	5306.5	0.8%	5329.0	1.2%	5336.2	1.3%	5336.5	1.3%
SUM The Outer Ring	7544.31	7583.9	0.5%	7601.3	0.8%	7593.6	0.7%	7608.1	0.8%	7611.0	0.9%
SUM Corridor	1730.44	1714.2	-0.9%	1720.0	-0.6%	1725.9	-0.3%	1734.2	0.2%	1741.3	0.6%

Table F- 14. Malfunctioning MTM(AID) at A10 SBL from 15:00

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%
A10NE Rechts (21)	588.24	585.1	-0.5%	564.2	-4.1%	564.4	-4.1%	564.3	-4.1%	564.3	-4.1%
A10SE Rechts (22)	256.95	256.9	0.0%	255.3	-0.7%	255.3	-0.7%	255.2	-0.7%	255.2	-0.7%
A10SB Rechts (23)	2594.52	2576.9	-0.7%	2557.1	-1.4%	2551.7	-1.7%	2546.9	-1.8%	2546.7	-1.8%
A10SW Rechts (24)	389.64	389.6	0.0%	389.8	0.0%	388.0	-0.4%	388.1	-0.4%	388.1	-0.4%
A10NW Rechts (25)	1427.9	1427.9	0.0%	1427.9	0.0%	1427.6	0.0%	1427.8	0.0%	1427.8	0.0%
A10NB Links (30)	2665.4	2665.9	0.0%	2649.2	-0.6%	2648.8	-0.6%	2649.0	-0.6%	2649.0	-0.6%
A10NE Links (31)	880.24	881.1	0.1%	880.7	0.0%	879.9	0.0%	880.1	0.0%	879.2	-0.1%
A10SE Links (32)	1823.72	1608.8	-11.8%	1574.7	-13.7%	1496.8	-17.9%	1462.3	-19.8%	1461.3	-19.9%
A10SB Links (33)	1617.11	1696.7	4.9%	1715.4	6.1%	1747.9	8.1%	1793.7	10.9%	1811.2	12.0%
A10SW Links (34)	511.57	600.6	17.4%	638.5	24.8%	783.7	53.2%	821.9	60.7%	822.3	60.7%
A10NW Links (35)	46.27	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%
A1 Links (40)	354.96	349.6	-1.5%	348.3	-1.9%	348.1	-1.9%	348.1	-1.9%	348.1	-1.9%
A2 Links (41)	7.34	7.3	-0.5%	7.3	-0.8%	7.3	-0.8%	7.3	-0.8%	7.3	-0.8%
A4 Links (42)	1786.16	2223.7	24.5%	2488.8	39.3%	2661.6	49.0%	2762.1	54.6%	2766.9	54.9%
A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2477.9	0.0%	2450.5	-1.1%	2448.6	-1.2%	2452.4	-1.0%	2451.2	-1.1%
A2 Rechts (51)	122.36	118.0	-3.6%	106.3	-13.1%	86.6	-29.3%	84.4	-31.0%	84.4	-31.0%
A4 Rechts (52)	265.35	270.6	2.0%	282.1	6.3%	290.4	9.4%	294.9	11.1%	294.9	11.1%
A8 Rechts (53)	1730.44	1731.0	0.0%	1729.4	-0.1%	1729.0	-0.1%	1730.4	0.0%	1730.4	0.0%
A5 Links (57)	10.63	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%
A5 Rechts (58)	1207.95	1208.0	0.0%	1207.9	0.0%	1207.9	0.0%	1207.9	0.0%	1207.9	0.0%
N200 Rechts (59)	307.74	307.7	0.0%	307.7	0.0%	310.3	0.8%	310.3	0.8%	310.3	0.8%
N200 Links (60)	118.8	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%
SUM AMS Network	21208.37	21576.7	1.7%	21774.4	2.7%	22027.3	3.9%	22180.4	4.6%	22200.0	4.7%
SUM The Ring	12810.96	12745.1	-0.5%	12708.2	-0.8%	12799.6	-0.1%	12844.8	0.3%	12860.7	0.4%
SUM The Inner Ring	5266.65	5245.8	-0.4%	5203.5	-1.2%	5196.3	-1.3%	5191.7	-1.4%	5191.5	-1.4%
SUM The Outer Ring	7544.31	7499.4	-0.6%	7504.7	-0.5%	7603.3	0.8%	7653.1	1.4%	7669.2	1.7%
SUM Corridor	1617.11	1696.7	4.9%	1715.4	6.1%	1747.9	8.1%	1793.7	10.9%	1811.2	12.0%

Table F- 15. Malfunctioning MTM(AID) at A10 SBR from 15:00

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%
A10NE Rechts (21)	588.24	588.2	0.0%	588.7	0.1%	588.7	0.1%	588.7	0.1%	588.7	0.1%
A10SE Rechts (22)	256.95	257.0	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%
A10SB Rechts (23)	2594.52	2607.5	0.5%	2665.2	2.7%	2748.4	5.9%	2820.0	8.7%	2825.1	8.9%
A10SW Rechts (24)	389.64	389.7	0.0%	389.6	0.0%	389.7	0.0%	389.8	0.0%	389.8	0.1%
A10NW Rechts (25)	1427.9	1427.9	0.0%	1427.9	0.0%	1428.3	0.0%	1428.8	0.1%	1428.8	0.1%
A10NB Links (30)	2665.4	2665.4	0.0%	2665.3	0.0%	2665.3	0.0%	2665.3	0.0%	2665.3	0.0%

A10NE Links (31)	880.24	880.2	0.0%	880.2	0.0%	880.2	0.0%	880.2	0.0%	880.2	0.0%
A10SE Links (32)	1823.72	1823.7	0.0%	1823.4	0.0%	1823.6	0.0%	1823.5	0.0%	1823.5	0.0%
A10SB Links (33)	1617.11	1616.5	0.0%	1616.7	0.0%	1616.6	0.0%	1616.3	-0.1%	1616.2	-0.1%
A10SW Links (34)	511.57	511.2	-0.1%	510.6	-0.2%	510.5	-0.2%	510.3	-0.2%	510.3	-0.2%
A10NW Links (35)	46.27	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%
A1 Links (40)	354.96	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%
A2 Links (41)	7.34	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%
A4 Links (42)	1786.16	1785.5	0.0%	1782.4	-0.2%	1781.4	-0.3%	1781.0	-0.3%	1781.0	-0.3%
A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2477.2	0.0%	2477.2	0.0%	2477.2	0.0%	2477.1	0.0%	2477.1	0.0%
A2 Rechts (51)	122.36	122.4	0.0%	121.8	-0.5%	122.0	-0.3%	122.0	-0.3%	122.0	-0.3%
A4 Rechts (52)	265.35	265.3	0.0%	265.3	0.0%	265.2	-0.1%	265.2	0.0%	265.3	0.0%
A8 Rechts (53)	1730.44	1730.4	0.0%	1730.4	0.0%	1730.5	0.0%	1730.5	0.0%	1730.5	0.0%
A5 Links (57)	10.63	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%
A5 Rechts (58)	1207.95	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%	1208.1	0.0%	1208.1	0.0%
N200 Rechts (59)	307.74	307.8	0.0%	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.8	0.0%
N200 Links (60)	118.8	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%
SUM AMS Network	21208.37	21219.6	0.1%	21273.2	0.3%	21356.0	0.7%	21427.5	1.0%	21432.5	1.1%
SUM The Ring	12810.96	12823.0	0.1%	12880.3	0.5%	12964.0	1.2%	13035.6	1.8%	13040.6	1.8%
SUM The Inner Ring	5266.65	5279.6	0.2%	5337.7	1.3%	5421.4	2.9%	5493.7	4.3%	5498.8	4.4%
SUM The Outer Ring	7544.31	7543.3	0.0%	7542.6	0.0%	7542.6	0.0%	7541.9	0.0%	7541.8	0.0%
SUM Corridor	2594.52	2607.5	0.5%	2665.2	2.7%	2748.4	5.9%	2820.0	8.7%	2825.1	8.9%

Table F- 16. Malfunctioning MTM(AID) at A10 SWL from 15:00

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%
A10NE Rechts (21)	588.24	588.2	0.0%	588.2	0.0%	588.2	0.0%	588.2	0.0%	588.2	0.0%
A10SE Rechts (22)	256.95	257.0	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%	257.0	0.0%
A10SB Rechts (23)	2594.52	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%	2594.5	0.0%
A10SW Rechts (24)	389.64	389.6	0.0%	389.6	0.0%	389.6	0.0%	389.6	0.0%	389.6	0.0%
A10NW Rechts (25)	1427.9	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%	1427.9	0.0%
A10NB Links (30)	2665.4	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%	2665.4	0.0%
A10NE Links (31)	880.24	880.2	0.0%	880.2	0.0%	880.2	0.0%	880.2	0.0%	880.2	0.0%
A10SE Links (32)	1823.72	1823.6	0.0%	1823.6	0.0%	1823.6	0.0%	1823.6	0.0%	1823.6	0.0%
A10SB Links (33)	1617.11	1616.5	0.0%	1616.5	0.0%	1616.3	0.0%	1616.3	0.0%	1616.3	0.0%
A10SW Links (34)	511.57	513.4	0.4%	519.9	1.6%	531.4	3.9%	541.1	5.8%	541.1	5.8%
A10NW Links (35)	46.27	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%
A1 Links (40)	354.96	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%
A2 Links (41)	7.34	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%
A4 Links (42)	1786.16	1786.2	0.0%	1785.6	0.0%	1785.6	0.0%	1785.6	0.0%	1785.6	0.0%
A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2477.2	0.0%	2477.2	0.0%	2477.2	0.0%	2477.2	0.0%	2477.2	0.0%
A2 Rechts (51)	122.36	122.4	0.0%	122.4	0.0%	122.4	0.0%	122.4	0.0%	122.4	0.0%
A4 Rechts (52)	265.35	265.5	0.1%	265.4	0.0%	265.4	0.0%	265.4	0.0%	265.4	0.0%
A8 Rechts (53)	1730.44	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%	1730.4	0.0%
A5 Links (57)	10.63	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%	10.6	0.0%
A5 Rechts (58)	1207.95	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%	1208.0	0.0%
N200 Rechts (59)	307.74	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.7	0.0%	307.7	0.0%
N200 Links (60)	118.8	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%
SUM AMS Network	21208.37	21209.6	0.0%	21215.3	0.0%	21226.7	0.1%	21236.3	0.1%	21236.4	0.1%
SUM The Ring	12810.96	12812.0	0.0%	12818.5	0.1%	12829.8	0.1%	12839.5	0.2%	12839.5	0.2%
SUM The Inner Ring	5266.65	5266.6	0.0%	5266.6	0.0%	5266.6	0.0%	5266.6	0.0%	5266.6	0.0%
SUM The Outer Ring	7544.31	7545.4	0.0%	7551.9	0.1%	7563.2	0.3%	7572.9	0.4%	7572.9	0.4%
SUM Corridor	511.57	513.4	0.4%	519.9	1.6%	531.4	3.9%	541.1	5.8%	541.1	5.8%

Table F- 17. Malfunctioning MTM(AID) at A10 SWR from 15:00

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%
A10NE Rechts (21)	588.24	588.2	0.0%	588.1	0.0%	588.0	0.0%	587.7	-0.1%	587.7	-0.1%
A10SE Rechts (22)	256.95	256.9	0.0%	256.9	0.0%	256.9	0.0%	256.9	0.0%	256.9	0.0%

A10SB Rechts (23)	2594.52	2674.9	3.1%	2716.7	4.7%	2750.0	6.0%	2774.3	6.9%	2776.2	7.0%
A10SW Rechts (24)	389.64	388.0	-0.4%	375.0	-3.8%	375.1	-3.7%	377.3	-3.2%	378.8	-2.8%
A10NW Rechts (25)	1427.9	1418.0	-0.7%	1417.6	-0.7%	1418.0	-0.7%	1417.7	-0.7%	1419.1	-0.6%
A10NB Links (30)	2665.4	2665.4	0.0%	2666.0	0.0%	2666.1	0.0%	2666.0	0.0%	2666.0	0.0%
A10NE Links (31)	880.24	880.8	0.1%	881.7	0.2%	882.6	0.3%	883.3	0.3%	883.3	0.3%
A10SE Links (32)	1823.72	1824.3	0.0%	1824.8	0.1%	1825.3	0.1%	1825.5	0.1%	1825.5	0.1%
A10SB Links (33)	1617.11	1626.4	0.6%	1637.2	1.2%	1647.3	1.9%	1655.3	2.4%	1655.3	2.4%
A10SW Links (34)	511.57	527.1	3.0%	522.3	2.1%	519.4	1.5%	519.0	1.4%	519.0	1.4%
A10NW Links (35)	46.27	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%	46.3	0.0%
A1 Links (40)	354.96	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%	355.0	0.0%
A2 Links (41)	7.34	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%	7.3	0.0%
A4 Links (42)	1786.16	1931.3	8.1%	2101.7	17.7%	2203.4	23.4%	2242.7	25.6%	2245.4	25.7%
A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2479.3	0.1%	2482.4	0.2%	2485.8	0.3%	2488.2	0.4%	2488.1	0.4%
A2 Rechts (51)	122.36	122.5	0.1%	123.1	0.6%	123.4	0.9%	123.5	0.9%	123.5	0.9%
A4 Rechts (52)	265.35	267.1	0.7%	266.0	0.2%	263.4	-0.7%	263.2	-0.8%	263.3	-0.8%
A8 Rechts (53)	1730.44	1730.8	0.0%	1731.8	0.1%	1732.0	0.1%	1732.4	0.1%	1732.6	0.1%
A5 Links (57)	10.63	10.6	-0.1%	10.6	-0.3%	10.6	-0.4%	10.6	-0.4%	10.6	-0.4%
A5 Rechts (58)	1207.95	1189.5	-1.5%	1187.3	-1.7%	1186.1	-1.8%	1185.3	-1.9%	1185.2	-1.9%
N200 Rechts (59)	307.74	312.6	1.6%	302.4	-1.7%	286.6	-6.9%	284.4	-7.6%	284.4	-7.6%
N200 Links (60)	118.8	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.0%	37.9	0.1%
SUM AMS Network	21208.37	21438.9	1.1%	21636.7	2.0%	21765.1	2.6%	21838.3	3.0%	21846.0	3.0%
SUM The Ring	12810.96	12905.7	0.7%	12942.0	1.0%	12984.4	1.4%	13018.7	1.6%	13023.4	1.7%
SUM The Inner Ring	5266.65	5335.4	1.3%	5363.7	1.8%	5397.4	2.5%	5423.4	3.0%	5428.2	3.1%
SUM The Outer Ring	7544.31	7570.3	0.3%	7578.2	0.4%	7587.0	0.6%	7595.4	0.7%	7595.3	0.7%
SUM Corridor	389.64	388.0	-0.4%	375.0	-3.8%	375.1	-3.7%	377.3	-3.2%	378.8	-2.8%

Table F- 18. Malfunctioning MTM(AID) at A10 outer ring from 15:00

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%	9.4	0.0%
A10NE Rechts (21)	588.24	544.8	-7.4%	527.1	-10.4%	509.9	-13.3%	508.9	-13.5%	508.9	-13.5%
A10SE Rechts (22)	256.95	253.0	-1.6%	252.7	-1.6%	252.8	-1.6%	253.2	-1.5%	253.2	-1.5%
A10SB Rechts (23)	2594.52	2561.4	-1.3%	2542.3	-2.0%	2537.7	-2.2%	2533.8	-2.3%	2533.6	-2.3%
A10SW Rechts (24)	389.64	388.7	-0.2%	388.4	-0.3%	388.5	-0.3%	388.5	-0.3%	388.5	-0.3%
A10NW Rechts (25)	1427.9	1427.3	0.0%	1427.7	0.0%	1427.8	0.0%	1428.4	0.0%	1428.5	0.0%
A10NB Links (30)	2665.4	2576.4	-3.3%	2572.1	-3.5%	2579.4	-3.2%	2596.3	-2.6%	2606.1	-2.2%
A10NE Links (31)	880.24	890.7	1.2%	906.2	2.9%	922.8	4.8%	941.1	6.9%	952.7	8.2%
A10SE Links (32)	1823.72	2239.0	22.8%	2474.6	35.7%	2613.7	43.3%	2714.5	48.8%	2735.0	50.0%
A10SB Links (33)	1617.11	1696.2	4.9%	1776.6	9.9%	1866.8	15.4%	1912.6	18.3%	1930.2	19.4%
A10SW Links (34)	511.57	597.4	16.8%	609.9	19.2%	669.3	30.8%	706.2	38.0%	706.7	38.1%
A10NW Links (35)	46.27	46.9	1.3%	46.2	-0.1%	45.6	-1.5%	45.8	-1.1%	45.8	-1.0%
A1 Links (40)	354.96	428.9	20.8%	573.1	61.4%	658.0	85.4%	683.3	92.5%	683.3	92.5%
A2 Links (41)	7.34	7.3	-0.8%	7.3	-1.0%	7.3	-1.0%	7.3	-1.1%	7.3	-1.1%
A4 Links (42)	1786.16	2216.1	24.1%	2484.4	39.1%	2655.1	48.6%	2754.5	54.2%	2758.8	54.5%
A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2516.8	1.6%	2499.9	0.9%	2516.5	1.6%	2540.7	2.6%	2548.4	2.9%
A2 Rechts (51)	122.36	117.4	-4.1%	103.8	-15.2%	84.1	-31.3%	82.7	-32.4%	82.6	-32.5%
A4 Rechts (52)	265.35	266.4	0.4%	273.9	3.2%	281.1	5.9%	283.2	6.7%	283.2	6.7%
A8 Rechts (53)	1730.44	1731.1	0.0%	1734.8	0.3%	1738.5	0.5%	1741.9	0.7%	1745.8	0.9%
A5 Links (57)	10.63	10.5	-1.2%	10.1	-4.8%	9.7	-8.7%	9.6	-9.9%	9.6	-10.0%
A5 Rechts (58)	1207.95	1205.8	-0.2%	1203.1	-0.4%	1201.2	-0.6%	1200.3	-0.6%	1200.1	-0.6%
N200 Rechts (59)	307.74	310.3	0.8%	308.8	0.3%	308.7	0.3%	308.6	0.3%	308.6	0.3%
N200 Links (60)	118.8	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%	118.8	0.0%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	37.9	0.0%	37.9	0.1%	38.0	0.2%	38.0	0.2%	38.0	0.3%
SUM AMS Network	21208.37	22169.0	4.5%	22859.4	7.8%	23411.0	10.4%	23778.0	12.1%	23853.5	12.5%
SUM The Ring	12810.96	13231.2	3.3%	13533.2	5.6%	13823.6	7.9%	14038.8	9.6%	14098.6	10.1%
SUM The Inner Ring	5266.65	5184.7	-1.6%	5147.6	-2.3%	5126.0	-2.7%	5122.2	-2.7%	5122.0	-2.7%
SUM The Outer Ring	7544.31	8046.5	6.7%	8385.6	11.2%	8697.6	15.3%	8916.6	18.2%	8976.6	19.0%
SUM Regional Network	106564.9	107317.4	0.7%	107951.7	1.3%	108450.1	1.8%	108820.1	2.1%	108898.6	2.2%

Table F- 19. Malfunctioning MTM(AID) at A10 inner ring from 15:00

Corridor & Direction	Base	15:00 to 16:00		15:00 to 17:00		15:00 to 18:00		15:00 to 19:00		15:00 to 20:00	
	VVU	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes	VVU	Changes
A10NB Rechts (20)	9.4	9.5	1.3%	9.7	2.9%	9.8	3.7%	9.7	3.6%	9.7	3.6%
A10NE Rechts (21)	588.24	591.7	0.6%	609.8	3.7%	629.3	7.0%	657.3	11.7%	657.4	11.8%
A10SE Rechts (22)	256.95	269.7	5.0%	276.9	7.8%	279.3	8.7%	282.1	9.8%	282.6	10.0%
A10SB Rechts (23)	2594.52	2617.6	0.9%	2642.4	1.8%	2705.2	4.3%	2769.8	6.8%	2776.7	7.0%
A10SW Rechts (24)	389.64	400.7	2.8%	412.0	5.7%	413.4	6.1%	413.3	6.1%	418.2	7.3%
A10NW Rechts (25)	1427.9	1425.0	-0.2%	1422.9	-0.4%	1434.2	0.4%	1451.6	1.7%	1474.9	3.3%
A10NB Links (30)	2665.4	2600.7	-2.4%	2588.7	-2.9%	2589.2	-2.9%	2587.7	-2.9%	2587.2	-2.9%
A10NE Links (31)	880.24	880.7	0.1%	884.4	0.5%	887.3	0.8%	890.7	1.2%	891.3	1.3%
A10SE Links (32)	1823.72	1809.9	-0.8%	1836.0	0.7%	1845.0	1.2%	1855.2	1.7%	1856.9	1.8%
A10SB Links (33)	1617.11	1625.0	0.5%	1636.4	1.2%	1646.3	1.8%	1653.2	2.2%	1653.0	2.2%
A10SW Links (34)	511.57	530.3	3.7%	529.1	3.4%	529.3	3.5%	527.4	3.1%	527.4	3.1%
A10NW Links (35)	46.27	45.9	-0.9%	45.9	-0.9%	45.9	-0.9%	45.9	-0.9%	45.9	-0.9%
A1 Links (40)	354.96	477.4	34.5%	645.7	81.9%	750.5	111.4%	780.9	120.0%	780.9	120.0%
A2 Links (41)	7.34	7.3	-0.3%	7.3	-0.3%	7.3	-0.3%	7.3	-0.3%	7.3	-0.3%
A4 Links (42)	1786.16	1923.8	7.7%	2089.9	17.0%	2190.6	22.6%	2228.8	24.8%	2231.6	24.9%
A8 Links (43)	8.42	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%	8.4	0.0%
A1 Rechts (50)	2477.26	2490.2	0.5%	2539.2	2.5%	2550.4	3.0%	2561.7	3.4%	2560.4	3.4%
A2 Rechts (51)	122.36	120.4	-1.6%	115.7	-5.4%	106.8	-12.7%	104.7	-14.4%	104.7	-14.4%
A4 Rechts (52)	265.35	266.9	0.6%	266.1	0.3%	265.8	0.2%	265.2	-0.1%	265.3	0.0%
A8 Rechts (53)	1730.44	1713.2	-1.0%	1698.4	-1.9%	1682.5	-2.8%	1686.0	-2.6%	1687.4	-2.5%
A5 Links (57)	10.63	10.6	-0.1%	10.6	0.0%	10.7	0.2%	10.7	0.2%	10.7	0.2%
A5 Rechts (58)	1207.95	1332.1	10.3%	1342.5	11.1%	1326.9	9.8%	1343.7	11.2%	1348.7	11.7%
N200 Rechts (59)	307.74	317.7	3.2%	316.9	3.0%	318.6	3.5%	313.9	2.0%	313.6	1.9%
N200 Links (60)	118.8	118.8	0.0%	118.4	-0.3%	118.5	-0.3%	118.5	-0.3%	118.5	-0.3%
A7 Links (61)	16.58	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%	16.6	0.0%
A7 Rechts (62)	37.9	38.0	0.2%	38.0	0.3%	38.0	0.4%	38.1	0.6%	38.2	0.8%
SUM AMS Network	21208.37	21593.3	1.8%	22053.2	4.0%	22351.0	5.4%	22573.6	6.4%	22618.8	6.7%
SUM The Ring	12810.96	12806.6	0.0%	12894.1	0.6%	13014.1	1.6%	13143.8	2.6%	13181.3	2.9%
SUM The Inner Ring	5266.65	5314.2	0.9%	5373.7	2.0%	5471.1	3.9%	5583.9	6.0%	5619.7	6.7%
SUM The Outer Ring	7544.31	7492.4	-0.7%	7520.5	-0.3%	7543.0	0.0%	7560.0	0.2%	7561.6	0.2%
SUM Regional Network	106564.9	106959.9	0.4%	107403.4	0.8%	107707.2	1.1%	107921.5	1.3%	107962.1	1.3%

Appendix F-3. DRIP Malfunctions

Table F- 20. Effects of all DRIPs in AMS network

Corridor	Without DRIPs (VVU)	With DRIPs (VVU)	VVU Difference	VVU Difference (%)	Speed Difference (%)
A10NB Rechts (20)	9.06	10.18	1.12	12.36%	-0.11%
A10NE Rechts (21)	216.75	403.92	187.17	86.35%	-10.40%
A10SE Rechts (22)	232.89	280.61	47.72	20.49%	-3.71%
A10SB Rechts (23)	2828.73	2293.27	-535.46	-18.93%	14.69%
A10SW Rechts (24)	289.2	358.49	69.29	23.96%	-5.15%
A10NW Rechts (25)	1480.8	1475.93	-4.87	-0.33%	0.25%
A10NB Links (30)	2810.37	2307.61	-502.76	-17.89%	15.37%
A10NE Links (31)	844.78	871.65	26.87	3.18%	-1.18%
A10SE Links (32)	1294.18	1198.99	-95.19	-7.36%	3.69%
A10SB Links (33)	1661.4	1467.75	-193.65	-11.66%	5.21%
A10SW Links (34)	553.75	459.17	-94.58	-17.08%	4.54%
A10NW Links (35)	45.85	44.63	-1.22	-2.66%	0.16%
A1 Links (40)	297.53	325.08	27.55	9.26%	-2.83%
A2 Links (41)	7.31	7.43	0.12	1.64%	-0.03%
A4 Links (42)	2299.11	1175.09	-1124.02	-48.89%	48.58%
A8 Links (43)	8.12	8.92	0.8	9.85%	-0.01%
A1 Rechts (50)	2192.71	2131.6	-61.11	-2.79%	-0.09%
A2 Rechts (51)	58.62	80.84	22.22	37.91%	-1.35%
A4 Rechts (52)	270.45	193.04	-77.41	-28.62%	5.17%
A8 Rechts (53)	1752.46	1717.92	-34.54	-1.97%	1.41%
A5 Links (57)	10.07	12.42	2.35	23.34%	-0.16%
A5 Rechts (58)	1268.98	1286.73	17.75	1.40%	-0.51%
N200 Rechts (59)	282.96	204.73	-78.23	-27.65%	10.25%
N200 Links (60)	162.44	257.32	94.88	58.41%	-14.32%
A7 Rechts (61)	16.5	17.27	0.77	4.67%	-0.06%
A7 Links (62)	33.5	36.07	2.57	7.67%	-0.15%
SUM AMS Network	20878.52	18573.32	-2305.2	-11.04%	5.29%
SUM RING A10	12267.76	11172.2	-1095.56	-8.93%	4.48%
SUM Inner Ring	5057.43	4822.4	-235.03	-4.65%	2.78%
SUM Outer Ring	7210.33	6349.8	-860.53	-11.93%	5.74%
SUM Whole Network	109723.37	105745.05	-3978.32	-3.63%	1.12%

Table F- 21. Effects of DRIPs in AMS network in case of rerouting

Corridor	Without DRIPs (VVU)	With DRIPs (VVU)	VVU Difference	VVU Difference (%)	Speed Difference (%)
A10NB Rechts (20)	9.4	9.05	-0.35	-3.72%	0.04%
A10NE Rechts (21)	437.58	18.66	-418.92	-95.74%	30.75%
A10SE Rechts (22)	249.52	86.28	-163.24	-65.42%	17.31%
A10SB Rechts (23)	2486.81	2752.72	265.91	10.69%	-6.36%
A10SW Rechts (24)	365.09	297.76	-67.33	-18.44%	5.57%
A10NW Rechts (25)	1456.01	1476.34	20.33	1.40%	-0.34%
A10NB Links (30)	2649.5	2498.45	-151.05	-5.70%	2.12%
A10NE Links (31)	872.27	289.85	-582.42	-66.77%	29.95%
A10SE Links (32)	1309.88	27.08	-1282.8	-97.93%	106.80%
A10SB Links (33)	1690.1	1674.99	-15.11	-0.89%	-1.28%
A10SW Links (34)	458.22	437.54	-20.68	-4.51%	0.51%
A10NW Links (35)	46.27	45.42	-0.85	-1.84%	0.03%
A1 Links (40)	322.1	15.18	-306.92	-95.29%	46.45%
A2 Links (41)	7.17	7.05	-0.12	-1.67%	0.01%
A4 Links (42)	3637.21	3710.08	72.87	2.00%	-1.88%
A8 Links (43)	8.42	8.11	-0.31	-3.68%	0.03%
A1 Rechts (50)	2308.2	1412.08	-896.12	-38.82%	32.27%
A2 Rechts (51)	91.23	37.7	-53.53	-58.68%	2.75%
A4 Rechts (52)	301.36	418.84	117.48	38.98%	-7.58%
A8 Rechts (53)	1733.04	1727.62	-5.42	-0.31%	-0.56%
A5 Links (57)	10.63	9.86	-0.77	-7.24%	0.05%
A5 Rechts (58)	1208.13	1278.21	70.08	5.80%	-1.96%
N200 Rechts (59)	317.22	272.09	-45.13	-14.23%	4.99%
N200 Links (60)	118.93	188.47	69.54	58.47%	-12.37%
A7 Rechts (61)	16.58	16.48	-0.1	-0.60%	0.01%
A7 Links (62)	37.93	35.17	-2.76	-7.28%	0.16%
SUM AMS Network	22094.29	18699.43	-3394.86	-15.37%	6.81%
SUM RING A10	12030.65	9614.14	-2416.51	-20.09%	9.47%
SUM Inner Ring	5004.41	4640.81	-363.6	-7.27%	3.16%

SUM Outer Ring	7026.24	4973.33	-2052.91	-29.22%	14.78%
SUM Whole Network	108275.67	108393.37	117.7	0.11%	1.19%

Table F- 22. Location scenarios of DRIP malfunctions (Removing)

(a)

Corridor	**DRIP Base**	**Effects in Malfunction Scenarios**							
		A1L (VVU)	**A1L (%)**	**A1R (VVU)**	**A1R (%)**	**A2L (VVU)**	**A2L (%)**	**A2R (VVU)**	**A2R (%)**
A10NB Rechts (20)	10.2	10.2	0.00%	10.2	0.00%	10.2	0.00%	10.2	0.00%
A10NE Rechts (21)	403.9	403.8	-0.03%	403.9	0.00%	403.5	-0.10%	401.9	-0.51%
A10SE Rechts (22)	280.6	280.9	0.12%	280.6	0.00%	280.8	0.05%	280.7	0.04%
A10SB Rechts (23)	2293.3	2290.8	-0.11%	2293.4	0.00%	2297.1	0.17%	2300.0	0.29%
A10SW Rechts (24)	358.5	358.5	0.00%	358.5	0.00%	360.8	0.64%	360.8	0.64%
A10NW Rechts (25)	1475.9	1475.9	0.00%	1475.9	0.00%	1476.4	0.03%	1476.4	0.03%
A10NB Links (30)	2307.6	2307.2	-0.02%	2307.8	0.01%	2308.0	0.02%	2308.1	0.02%
A10NE Links (31)	871.7	872.0	0.04%	872.1	0.05%	871.9	0.03%	871.9	0.03%
A10SE Links (32)	1199.0	1201.9	0.24%	1201.1	0.18%	1201.0	0.16%	1202.1	0.26%
A10SB Links (33)	1467.8	1467.7	0.00%	1467.8	0.00%	1467.8	0.00%	1467.4	-0.02%
A10SW Links (34)	459.2	459.2	0.00%	459.2	0.00%	459.3	0.02%	459.2	0.01%
A10NW Links (35)	44.6	44.6	0.00%	44.6	0.00%	44.6	0.00%	44.6	0.00%
A1 Links (40)	325.1	340.8	4.83%	325.3	0.06%	325.7	0.19%	324.8	-0.09%
A2 Links (41)	7.4	7.4	0.00%	7.4	0.00%	7.4	-0.13%	7.4	0.00%
A4 Links (42)	1175.1	1175.1	0.00%	1175.1	0.00%	1175.0	0.00%	1172.0	-0.27%
A8 Links (43)	8.9	8.9	0.00%	8.9	0.00%	8.9	0.00%	8.9	0.00%
A1 Rechts (50)	2131.6	2134.4	0.13%	2133.5	0.09%	2133.8	0.10%	2132.1	0.02%
A2 Rechts (51)	80.8	80.8	0.00%	80.8	0.00%	80.9	0.07%	82.4	1.89%
A4 Rechts (52)	193.0	193.1	0.01%	193.0	0.00%	193.3	0.16%	193.3	0.15%
A8 Rechts (53)	1717.9	1718.4	0.03%	1718.2	0.02%	1719.0	0.06%	1718.3	0.02%
A5 Links (57)	12.4	12.4	0.00%	12.4	0.00%	12.4	0.00%	12.4	0.00%
A5 Rechts (58)	1286.7	1286.7	0.00%	1286.7	0.00%	1286.7	0.00%	1286.8	0.00%
N200 Rechts (59)	204.7	204.7	0.00%	204.7	0.00%	205.8	0.53%	205.8	0.51%
N200 Links (60)	257.3	257.3	0.00%	257.3	0.00%	258.0	0.26%	258.0	0.26%
A7 Rechts (61)	17.3	17.3	0.00%	17.3	0.00%	17.3	0.00%	17.3	0.00%
A7 Links (62)	36.1	36.1	0.00%	36.1	0.00%	36.1	0.00%	36.1	0.00%
SUM AMS Network	18573.3	18592.7	0.10%	18578.5	0.03%	18588.3	0.08%	18585.3	0.06%
SUM RING A10	11172.2	11172.7	0.00%	11175.0	0.03%	11181.3	0.08%	11183.2	0.10%
SUM Inner Ring	4822.4	4820.1	-0.05%	4822.5	0.00%	4828.7	0.13%	4829.9	0.16%
SUM Outer Ring	6349.8	6352.6	0.04%	6352.5	0.04%	6352.6	0.04%	6353.3	0.05%
SUM Whole Network	105745.1	105773.0	0.03%	105752.8	0.01%	105798.1	0.05%	105789.2	0.04%

(b)

Corridor	**DRIP Base**	**Effects in Malfunction Scenarios**							
		A4L (VVU)	**A4L (%)**	**A4R (VVU)**	**A4R (%)**	**N200L (VVU)**	**N200L (%)**	**A10 (VVU)**	**A10 (%)**
A10NB Rechts (20)	10.2	10.2	0.00%	10.2	0.00%	10.2	0.00%	10.1	-0.69%
A10NE Rechts (21)	403.9	403.8	-0.02%	402.9	-0.26%	403.9	0.00%	394.5	-2.33%
A10SE Rechts (22)	280.6	280.6	0.00%	280.5	-0.02%	280.6	0.00%	280.6	-0.01%
A10SB Rechts (23)	2293.3	2293.5	0.01%	2293.5	0.01%	2293.3	0.00%	2309.4	0.70%
A10SW Rechts (24)	358.5	360.4	0.53%	360.0	0.42%	360.6	0.58%	354.3	-1.16%
A10NW Rechts (25)	1475.9	1476.2	0.02%	1475.9	0.00%	1475.0	-0.06%	1479.3	0.23%
A10NB Links (30)	2307.6	2307.5	0.00%	2306.8	-0.03%	2307.6	0.00%	2370.7	2.73%
A10NE Links (31)	871.7	871.5	-0.02%	871.5	-0.02%	871.7	0.00%	866.1	-0.64%
A10SE Links (32)	1199.0	1199.0	0.00%	1198.8	-0.01%	1199.1	0.01%	1172.9	-2.18%
A10SB Links (33)	1467.8	1468.8	0.07%	1466.5	-0.09%	1467.5	-0.01%	1469.1	0.09%
A10SW Links (34)	459.2	459.4	0.05%	458.5	-0.14%	459.2	0.01%	460.2	0.22%
A10NW Links (35)	44.6	44.6	0.00%	44.6	0.00%	44.6	0.00%	44.7	0.22%
A1 Links (40)	325.1	325.1	0.00%	325.1	0.00%	325.1	0.00%	326.1	0.30%
A2 Links (41)	7.4	7.4	0.00%	7.4	0.00%	7.4	0.00%	7.4	0.00%
A4 Links (42)	1175.1	1174.2	-0.08%	1166.5	-0.73%	1172.6	-0.21%	1193.2	1.54%
A8 Links (43)	8.9	8.9	0.00%	8.9	0.00%	8.9	0.00%	8.9	-0.11%
A1 Rechts (50)	2131.6	2131.0	-0.03%	2131.4	-0.01%	2131.9	0.01%	2126.2	-0.26%
A2 Rechts (51)	80.8	80.8	0.00%	80.8	0.00%	80.9	0.01%	79.5	-1.63%
A4 Rechts (52)	193.0	193.7	0.36%	194.6	0.83%	193.4	0.18%	195.2	1.10%
A8 Rechts (53)	1717.9	1717.8	-0.01%	1717.7	-0.01%	1717.9	0.00%	1724.1	0.36%
A5 Links (57)	12.4	12.4	0.00%	12.4	0.00%	12.4	0.00%	12.4	0.16%
A5 Rechts (58)	1286.7	1286.8	0.01%	1286.0	-0.05%	1286.2	-0.05%	1289.4	0.21%
N200 Rechts (59)	204.7	205.4	0.34%	204.5	-0.10%	205.2	0.22%	206.5	0.84%
N200 Links (60)	257.3	257.3	-0.03%	255.2	-0.81%	258.4	0.42%	253.6	-1.46%

A7 Rechts (61)	17.3	17.3	0.00%	17.3	0.00%	17.3	0.00%	17.3	0.00%
A7 Links (62)	36.1	36.1	0.00%	36.1	0.00%	36.1	0.00%	36.0	-0.17%
SUM AMS Network	18573.3	18576.5	0.02%	18560.4	-0.07%	18573.6	0.00%	18634.2	0.33%
SUM RING A10	11172.2	11175.6	0.03%	11169.7	-0.02%	11173.3	0.01%	11211.8	0.35%
SUM Inner Ring	4822.4	4824.7	0.05%	4823.0	0.01%	4823.6	0.02%	4828.2	0.12%
SUM Outer Ring	6349.8	6350.9	0.02%	6346.8	-0.05%	6349.7	0.00%	6383.7	0.53%
SUM Whole Network	105745.1	105763.3	0.02%	105750.9	0.01%	105753.3	0.01%	106176.1	0.41%

Table F- 23. Location scenarios after DRIPs implementation

(a)

Corridor	DRIP Base	Effects After Implementation of DRIPs							
		A1L (VVU)	A1L (%)	A1R (VVU)	A1R (%)	A2L (VVU)	A2L (%)	A2R (VVU)	A2R (%)
A10NB Rechts (20)	9.1	10.0	10.49%	10.1	11.15%	10.0	10.38%	10.0	10.60%
A10NE Rechts (21)	216.8	352.1	62.45%	394.7	82.08%	363.3	67.61%	362.1	67.07%
A10SE Rechts (22)	232.9	272.9	17.19%	281.3	20.80%	275.2	18.17%	279.8	20.16%
A10SB Rechts (23)	2828.7	2442.7	-13.65%	2426.8	-14.21%	2360.8	-16.54%	2411.6	-14.75%
A10SW Rechts (24)	289.2	341.3	18.01%	368.6	27.45%	379.3	31.17%	370.8	28.22%
A10NW Rechts (25)	1480.8	1478.8	-0.14%	1486.5	0.39%	1486.0	0.35%	1489.0	0.55%
A10NB Links (30)	2810.4	2387.2	-15.06%	2378.2	-15.38%	2382.3	-15.23%	2391.2	-14.92%
A10NE Links (31)	844.8	849.9	0.60%	856.0	1.33%	866.3	2.54%	851.9	0.84%
A10SE Links (32)	1294.2	1017.2	-21.41%	1055.4	-18.45%	1043.0	-19.41%	1114.9	-13.85%
A10SB Links (33)	1661.4	1528.4	-8.01%	1534.8	-7.62%	1544.9	-7.01%	1483.0	-10.74%
A10SW Links (34)	553.8	478.3	-13.62%	489.6	-11.59%	489.4	-11.63%	468.5	-15.40%
A10NW Links (35)	45.9	44.8	-2.36%	44.6	-2.66%	44.8	-2.25%	44.7	-2.53%
A1 Links (40)	297.5	324.7	9.12%	415.1	39.50%	423.1	42.20%	408.0	37.13%
A2 Links (41)	7.3	7.5	2.60%	7.5	2.33%	7.4	1.64%	7.5	1.92%
A4 Links (42)	2299.1	1463.1	-36.36%	1446.5	-37.09%	1446.1	-37.10%	1268.2	-44.84%
A8 Links (43)	8.1	8.8	8.37%	8.9	9.36%	8.8	8.37%	8.8	8.50%
A1 Rechts (50)	2192.7	2109.7	-3.79%	2130.2	-2.85%	2130.3	-2.85%	2129.6	-2.88%
A2 Rechts (51)	58.6	80.5	37.24%	79.7	35.88%	80.1	36.71%	79.2	35.12%
A4 Rechts (52)	270.5	202.8	-25.01%	206.9	-23.50%	204.7	-24.30%	204.9	-24.25%
A8 Rechts (53)	1752.5	1720.0	-1.85%	1724.2	-1.61%	1724.2	-1.61%	1722.9	-1.69%
A5 Links (57)	10.1	11.9	17.78%	11.9	17.87%	11.9	17.78%	11.9	17.68%
A5 Rechts (58)	1269.0	1262.2	-0.53%	1259.7	-0.73%	1252.2	-1.33%	1270.2	0.10%
N200 Rechts (59)	283.0	192.1	-32.12%	195.3	-30.98%	194.7	-31.21%	195.6	-30.86%
N200 Links (60)	162.4	252.3	55.34%	255.7	57.42%	252.4	55.39%	255.3	57.18%
A7 Rechts (61)	16.5	17.1	3.45%	17.2	4.18%	17.1	3.45%	17.1	3.45%
A7 Links (62)	33.5	36.0	7.34%	36.0	7.43%	36.0	7.37%	36.0	7.37%
SUM AMS Network	20878.5	18839.0	-9.77%	19068.0	-8.67%	18981.1	-9.09%	18839.6	-9.77%
SUM RING A10	12267.8	11203.5	-8.68%	11326.6	-7.67%	11245.2	-8.34%	11277.5	-8.07%
SUM Inner Ring	5057.4	4897.8	-3.16%	4968.0	-1.77%	4874.6	-3.62%	4923.3	-2.65%
SUM Outer Ring	7210.3	6305.7	-12.55%	6358.6	-11.81%	6370.6	-11.65%	6354.2	-11.87%
SUM Whole Network	109723.4	106290.9	-3.13%	106205.4	-3.21%	106451.3	-2.98%	106407.7	-3.02%

(b)

Corridor	DRIP Base	Effects After Implementation of DRIPs							
		A4L (VVU)	A4L (%)	A4R (VVU)	A4R (%)	N200L (VVU)	N200L (%)	A5L (VVU)	A5L (%)
A10NB Rechts (20)	9.1	10.0	10.60%	10.0	10.38%	10.0	10.38%	10.0	10.38%
A10NE Rechts (21)	216.8	355.9	64.19%	355.4	63.94%	354.2	63.39%	353.7	63.16%
A10SE Rechts (22)	232.9	274.8	18.00%	274.3	17.80%	274.2	17.73%	274.8	17.99%
A10SB Rechts (23)	2828.7	2440.5	-13.72%	2317.2	-18.08%	2440.3	-13.73%	2438.6	-13.79%
A10SW Rechts (24)	289.2	335.6	16.04%	370.9	28.25%	346.3	19.75%	342.7	18.50%
A10NW Rechts (25)	1480.8	1475.5	-0.36%	1489.8	0.61%	1483.5	0.18%	1480.3	-0.04%
A10NB Links (30)	2810.4	2389.9	-14.96%	2400.7	-14.58%	2391.3	-14.91%	2395.9	-14.75%
A10NE Links (31)	844.8	852.8	0.95%	851.2	0.76%	853.0	0.97%	852.0	0.85%
A10SE Links (32)	1294.2	1113.8	-13.94%	1027.8	-20.58%	1029.0	-20.49%	1026.8	-20.66%
A10SB Links (33)	1661.4	1464.4	-11.86%	1544.9	-7.01%	1543.9	-7.07%	1533.7	-7.69%
A10SW Links (34)	553.8	459.4	-17.04%	489.6	-11.58%	487.5	-11.97%	481.7	-13.02%
A10NW Links (35)	45.9	44.8	-2.36%	44.8	-2.22%	44.8	-2.33%	44.8	-2.31%
A1 Links (40)	297.5	406.5	36.62%	385.3	29.50%	409.8	37.72%	410.3	37.89%
A2 Links (41)	7.3	7.5	2.05%	7.4	1.50%	7.5	2.05%	7.5	2.05%
A4 Links (42)	2299.1	1239.6	-46.08%	1439.3	-37.40%	1457.6	-36.60%	1466.9	-36.20%
A8 Links (43)	8.1	8.8	8.50%	8.8	8.50%	8.8	8.37%	8.8	8.50%
A1 Rechts (50)	2192.7	2108.0	-3.87%	2121.3	-3.26%	2119.2	-3.35%	2114.7	-3.56%
A2 Rechts (51)	58.6	81.7	39.36%	81.4	38.79%	80.2	36.86%	80.2	36.81%
A4 Rechts (52)	270.5	200.3	-25.95%	198.9	-26.45%	205.4	-24.05%	202.4	-25.17%

A8 Rechts (53)	1752.5	1721.3	-1.78%	1722.8	-1.69%	1723.5	-1.66%	1721.7	-1.75%
A5 Links (57)	10.1	11.9	17.78%	12.4	23.04%	11.9	17.97%	12.4	23.34%
A5 Rechts (58)	1269.0	1283.3	1.13%	1270.3	0.11%	1275.0	0.47%	1271.1	0.17%
N200 Rechts (59)	283.0	194.0	-31.44%	194.8	-31.17%	195.0	-31.09%	206.6	-27.00%
N200 Links (60)	162.4	254.6	56.73%	253.7	56.20%	258.8	59.31%	254.8	56.86%
A7 Rechts (61)	16.5	17.1	3.39%	17.1	3.45%	17.1	3.39%	17.1	3.45%
A7 Links (62)	33.5	36.0	7.34%	36.0	7.46%	36.0	7.37%	36.0	7.31%
SUM AMS Network	20878.5	18734.6	-10.27%	18873.2	-9.60%	19010.6	-8.95%	18992.2	-9.03%
SUM RING A10	12267.8	11217.3	-8.56%	11176.7	-8.89%	11258.0	-8.23%	11234.9	-8.42%
SUM Inner Ring	5057.4	4892.3	-3.27%	4817.6	-4.74%	4908.5	-2.95%	4900.0	-3.11%
SUM Outer Ring	7210.3	6325.0	-12.28%	6359.1	-11.81%	6349.5	-11.94%	6334.8	-12.14%
SUM Whole Network	109723.4	105969.4	-3.42%	106656.7	-2.79%	106312.5	-3.11%	105958.3	-3.43%

Table F- 24. A1L DRIPs Rerouting Malfunction

Corridor	A1L DRIPs Rerouting Malfunction							
	Accident A10NEL				Accident A10SER			
	TTD change	TTD (%)	VVU change	VVU (%)	TTD change	TTD (%)	VVU change	VVU (%)
A10NB Rechts (20)	-2739.2	-3.41%	-1.3	-13.37%	3799.6	5.06%	1.6	21.77%
A10NE Rechts (21)	-1810.5	-1.39%	-152.2	-59.47%	6144.9	4.90%	491.1	40.90%
A10SE Rechts (22)	1524.4	1.78%	-48.7	-24.24%	1407.3	1.99%	20.0	3.37%
A10SB Rechts (23)	4944.8	4.22%	738.7	29.43%	-2778.9	-2.39%	-767.3	-38.98%
A10SW Rechts (24)	-131.2	-0.19%	-11.9	-4.05%	-863.1	-1.22%	-95.8	-25.88%
A10NW Rechts (25)	166.8	0.24%	-45.5	-3.02%	-648.9	-0.91%	-35.5	-2.37%
A10NB Links (30)	-10851.5	-11.69%	-278.2	-48.04%	3612.4	3.75%	24.4	0.91%
A10NE Links (31)	-2534.2	-2.11%	-39.5	-4.42%	-206.4	-0.13%	-11.1	-1.27%
A10SE Links (32)	4435.0	4.39%	-387.4	-12.89%	-1870.8	-1.62%	-410.2	-41.48%
A10SB Links (33)	421.3	0.28%	-227.1	-12.24%	-607.8	-0.40%	-61.3	-3.61%
A10SW Links (34)	-3059.3	-2.74%	-4.2	-0.89%	-3821.0	-3.24%	-239.4	-32.38%
A10NW Links (35)	-3330.1	-5.21%	-5.0	-18.33%	-1090.3	-1.54%	-3.5	-7.15%
A1 Links (40)	1552.8	2.77%	406.7	22.28%	2838.6	5.01%	977.4	115.44%
A2 Links (41)	-401.5	-0.52%	-38.5	-80.04%	-2479.3	-3.19%	-1.3	-15.58%
A4 Links (42)	-293.2	-0.30%	117.8	5.98%	1228.3	1.30%	-11.1	-0.51%
A8 Links (43)	-837.2	-0.96%	-0.5	-6.15%	-257.8	-0.30%	-8.5	-51.14%
A1 Rechts (50)	2217.3	1.95%	-0.1	0.00%	458.1	0.39%	-119.8	-4.93%
A2 Rechts (51)	-13847.0	-8.54%	-116.4	-74.05%	-2710.6	-1.85%	-18.6	-32.77%
A4 Rechts (52)	251.8	0.21%	39.5	22.33%	-2872.3	-2.38%	-68.1	-22.17%
A8 Rechts (53)	-1603.7	-1.44%	-138.4	-11.47%	-844.8	-0.75%	30.6	1.77%
A5 Links (57)	-4944.9	-4.91%	-0.9	-9.88%	-1318.0	-1.23%	-0.2	-2.18%
A5 Rechts (58)	-1424.5	-2.03%	-220.8	-15.15%	-2427.8	-3.41%	-72.3	-5.42%
N200 Rechts (59)	476.9	1.10%	62.9	28.93%	-162.8	-0.37%	15.3	5.71%
N200 Links (60)	-723.7	-2.22%	-10.5	-5.04%	252.8	0.80%	69.6	53.57%
A7 Rechts (61)	246.9	0.21%	0.2	1.05%	-1560.8	-1.29%	-0.9	-4.96%
A7 Links (62)	-687.6	-0.44%	-0.6	-1.66%	-2355.3	-1.47%	-2.5	-6.65%
SUM AMS Network	-32540.6	-1.44%	-361.5	-1.71%	-5218.7	-0.23%	-294.0	-1.34%
SUM RING A10	-12963.7	-1.08%	-462.3	-3.98%	3076.9	0.25%	-1086.9	-8.59%
SUM Inner Ring	1955.1	0.35%	479.2	10.03%	7060.8	1.33%	-385.8	-6.85%
SUM Outer Ring	-14918.8	-2.33%	-941.4	-13.79%	-3983.9	-0.56%	-701.1	-9.98%
SUM Whole Network	-69695.1	-0.58%	1832.4	1.69%	-61174.0	-0.51%	541.6	0.49%

Table F- 25. A2L DRIPs Rerouting Malfunction

Corridor	A2L DRIPs Rerouting Malfunction							
	Accident A10SEL				Accident A10SBR			
	TTD change	TTD (%)	VVU change	VVU (%)	TTD change	TTD (%)	VVU change	VVU (%)
A10NB Rechts (20)	-3971.3	-4.80%	-1.9	-17.5%	442.6	0.56%	0.1	1.2%
A10NE Rechts (21)	-5687.6	-4.17%	-40.5	-68.9%	-124.5	-0.09%	-299.5	-81.0%
A10SE Rechts (22)	-113.1	-0.14%	-59.7	-33.2%	-1403.1	-1.76%	1330.3	192.6%
A10SB Rechts (23)	4587.4	3.97%	1670.4	60.4%	3212.4	3.18%	-110.4	-4.1%
A10SW Rechts (24)	-132.6	-0.19%	44.8	18.3%	-131.4	-0.19%	-54.0	-16.0%
A10NW Rechts (25)	847.1	1.20%	0.1	0.0%	287.4	0.41%	7.8	0.5%
A10NB Links (30)	-6108.0	-6.03%	-784.1	-33.7%	793.4	0.80%	-77.0	-2.8%
A10NE Links (31)	-8089.1	-5.38%	-119.7	-24.2%	-832.0	-0.53%	-232.0	-26.4%
A10SE Links (32)	-793.5	-0.84%	-485.1	-34.2%	-1838.7	-1.58%	-1031.4	-71.1%
A10SB Links (33)	5348.0	3.91%	723.3	18.7%	-1689.4	-1.10%	-68.8	-4.1%
A10SW Links (34)	2256.2	2.05%	390.4	84.5%	-2460.3	-2.11%	-55.1	-10.1%

A10NW Links (35)	-779.2	-1.14%	-1.0	-2.2%	-581.8	-0.83%	-1.8	-3.7%
A1 Links (40)	-1810.8	-2.93%	-49.7	-77.1%	181.8	0.30%	101.4	41.3%
A2 Links (41)	2501.2	3.35%	622.1	1241.4%	271.9	0.36%	-15.3	-67.7%
A4 Links (42)	1902.0	2.05%	685.8	28.8%	-737.6	-0.77%	-213.7	-10.6%
A8 Links (43)	-1410.8	-1.60%	-0.7	-8.4%	-906.5	-1.03%	-0.3	-3.0%
A1 Rechts (50)	-390.2	-0.35%	-387.1	-20.7%	-1187.6	-1.03%	-266.9	-11.8%
A2 Rechts (51)	-1833.1	-1.11%	112.8	56.4%	-9524.4	-5.88%	-76.7	-54.6%
A4 Rechts (52)	3912.2	3.29%	212.8	97.1%	-245.9	-0.22%	-1.7	-0.9%
A8 Rechts (53)	-717.0	-0.64%	48.5	2.9%	-117.0	-0.10%	32.1	1.9%
A5 Links (57)	-6154.4	-5.59%	-1.8	-15.7%	-412.8	-0.39%	0.2	1.8%
A5 Rechts (58)	2551.2	3.85%	-11.5	-0.9%	-126.0	-0.18%	24.3	2.0%
N200 Rechts (59)	347.6	0.80%	-52.9	-15.8%	519.7	1.20%	27.4	10.7%
N200 Links (60)	-1593.5	-4.82%	-82.3	-33.3%	-370.4	-1.15%	9.5	5.0%
A7 Rechts (61)	-392.2	-0.33%	-0.1	-0.7%	-1214.9	-1.01%	-0.6	-3.7%
A7 Links (62)	-571.9	-0.36%	-0.8	-2.1%	-657.5	-0.41%	-1.2	-3.3%
SUM AMS Network	-15331.1	-0.67%	2433.1	11.2%	-16980.3	-0.73%	-971.5	-4.6%
SUM RING A10	-12635.7	-1.04%	1337.1	10.0%	-4325.5	-0.35%	-591.8	-4.6%
SUM Inner Ring	-4470.1	-0.80%	1613.2	34.1%	2283.4	0.43%	874.3	15.8%
SUM Outer Ring	-8165.6	-1.23%	-276.1	-3.2%	-6608.8	-0.93%	-1466.0	-19.9%
SUM Whole Network	-59096.3	-0.49%	2478.9	2.2%	-59958.3	-0.50%	-297.8	-0.3%

Table F- 26. A4L DRIPs Rerouting Malfunction

Corridor	A4L DRIPs Rerouting Malfunction							
	Accident A10SBL				Accident A10SWR			
	TTD change	TTD (%)	VVU change	VVU (%)	TTD change	TTD (%)	VVU change	VVU (%)
A10NB Rechts (20)	-3641.7	-4.42%	-1.7	-16.0%	-1788.6	-2.24%	-0.7	-7.5%
A10NE Rechts (21)	-6751.9	-4.91%	-20.8	-53.1%	-2972.1	-2.22%	-334.5	-94.6%
A10SE Rechts (22)	-1898.2	-2.26%	-173.6	-73.3%	-1131.1	-1.35%	90.4	37.4%
A10SB Rechts (23)	1280.5	1.10%	378.1	17.1%	790.7	0.71%	839.0	27.7%
A10SW Rechts (24)	700.2	1.00%	191.9	173.6%	-298.2	-0.51%	82.8	31.2%
A10NW Rechts (25)	819.2	1.16%	38.0	2.6%	-1425.0	-2.04%	-87.6	-6.8%
A10NB Links (30)	-5290.6	-5.25%	-775.1	-29.7%	-2642.9	-2.64%	-64.0	-2.4%
A10NE Links (31)	-12324.4	-7.95%	-628.0	-76.0%	-5385.2	-3.44%	-430.2	-49.0%
A10SE Links (32)	-9705.9	-8.58%	-490.7	-95.9%	-1510.4	-1.30%	-1359.3	-96.3%
A10SB Links (33)	992.0	0.78%	128.8	8.5%	1386.4	0.90%	106.2	6.4%
A10SW Links (34)	7943.5	7.92%	727.8	58.7%	-645.9	-0.57%	-12.7	-2.3%
A10NW Links (35)	316.3	0.47%	0.4	0.9%	-696.4	-1.00%	-0.5	-1.1%
A1 Links (40)	-284.5	-0.48%	-163.8	-93.6%	-86.4	-0.14%	-303.0	-93.6%
A2 Links (41)	-2718.1	-3.54%	-1.1	-14.1%	367.8	0.49%	11.9	78.7%
A4 Links (42)	4836.2	5.88%	567.9	18.7%	3117.8	3.40%	1141.3	44.8%
A8 Links (43)	-1297.0	-1.47%	-0.7	-8.4%	-1166.1	-1.33%	-0.5	-5.7%
A1 Rechts (50)	-6252.7	-5.47%	-790.8	-49.0%	-1294.6	-1.13%	-568.6	-25.5%
A2 Rechts (51)	-4695.5	-3.37%	-18.0	-34.7%	-2068.6	-1.35%	-6.8	-8.9%
A4 Rechts (52)	2550.8	2.10%	967.3	127.8%	8.1	0.01%	137.2	50.4%
A8 Rechts (53)	-661.4	-0.59%	28.2	1.7%	-2276.3	-2.03%	-12.2	-0.7%
A5 Links (57)	-16294.5	-13.51%	-6.6	-40.4%	-4099.6	-3.76%	-1.0	-9.5%
A5 Rechts (58)	-2051.3	-2.88%	-189.9	-13.1%	-5265.2	-7.10%	-660.3	-56.3%
N200 Rechts (59)	-435.9	-0.98%	-88.6	-23.7%	473.1	1.10%	14.6	7.3%
N200 Links (60)	-1478.1	-4.42%	45.9	29.9%	86.9	0.28%	48.5	41.8%
A7 Rechts (61)	-313.3	-0.26%	-0.1	-0.7%	-947.9	-0.79%	-0.4	-2.5%
A7 Links (62)	-1450.0	-0.92%	-1.8	-4.9%	-3451.4	-2.18%	-2.2	-5.9%
SUM AMS Network	-56343.1	-2.46%	-275.1	-1.4%	-28521.8	-1.23%	-1370.1	-6.5%
SUM RING A10	-27560.9	-2.25%	-624.9	-5.8%	-16318.8	-1.31%	-1171.2	-9.4%
SUM Inner Ring	-9491.8	-1.69%	411.9	10.2%	-6824.4	-1.27%	589.4	11.4%
SUM Outer Ring	-18069.0	-2.72%	-1036.8	-15.4%	-9494.4	-1.34%	-1760.6	-24.2%
SUM Whole Network	-114613.3	-13.51%	2088.1	1.9%	-91469.7	-0.76%	-1384.4	-1.3%

Table F- 27. A8L DRIPs Rerouting Malfunction

Corridor	A8L DRIPs Rerouting Malfunction							
	Accident A10NBR				Accident A10NWL			
	TTD change	TTD (%)	VVU change	VVU (%)	TTD change	TTD (%)	VVU change	VVU (%)
A10NB Rechts (20)	5015.3	7.43%	34.6	5.8%	-552.1	-0.67%	-0.6	-4.7%
A10NE Rechts (21)	-1686.5	-1.32%	253.8	57.7%	-2186.3	-1.53%	-419.9	-53.2%
A10SE Rechts (22)	-1038.4	-1.26%	6.7	3.9%	-2032.0	-2.34%	-77.7	-26.2%

A10SB Rechts (23)	148.6	0.13%	-184.0	-7.1%	569.8	0.48%	133.6	4.9%
A10SW Rechts (24)	-565.9	-0.80%	85.0	41.6%	-849.5	-1.20%	-27.0	-9.0%
A10NW Rechts (25)	138.3	0.20%	262.6	16.9%	-315.5	-0.44%	-9.8	-0.7%
A10NB Links (30)	-261.4	-0.28%	-292.4	-10.5%	-515.4	-0.58%	164.4	6.1%
A10NE Links (31)	-2678.6	-1.71%	-446.1	-47.9%	-900.8	-0.58%	-386.2	-37.7%
A10SE Links (32)	-2768.4	-2.37%	-944.8	-91.5%	-2100.9	-1.80%	-810.1	-72.6%
A10SB Links (33)	-1466.1	-0.95%	-104.8	-6.0%	-1637.7	-1.07%	-103.1	-6.4%
A10SW Links (34)	-1367.9	-1.19%	-188.7	-27.2%	-1152.0	-1.07%	-64.0	-14.1%
A10NW Links (35)	-1031.1	-1.46%	-2.9	-6.0%	1363.4	2.49%	21.0	4.1%
A1 Links (40)	-1248.6	-2.05%	-128.5	-93.3%	326.9	0.55%	-197.1	-87.4%
A2 Links (41)	-1281.3	-1.69%	-0.5	-7.0%	-730.2	-0.96%	-0.3	-4.4%
A4 Links (42)	89.7	0.09%	-255.4	-10.4%	-592.1	-0.61%	-441.3	-21.1%
A8 Links (43)	6399.0	8.20%	947.0	161.3%	1640.1	1.92%	275.9	49.0%
A1 Rechts (50)	-2491.2	-2.19%	-181.9	-9.7%	-1319.5	-1.14%	-263.2	-11.4%
A2 Rechts (51)	-4351.5	-2.89%	-19.0	-32.7%	-7596.5	-4.91%	-27.8	-41.2%
A4 Rechts (52)	-213.3	-0.18%	-176.8	-40.2%	-808.3	-0.68%	-14.8	-6.4%
A8 Rechts (53)	-385.5	-0.34%	15.9	0.9%	-662.4	-0.58%	19.6	1.1%
A5 Links (57)	-4959.3	-4.48%	-1.3	-11.9%	-2192.7	-2.39%	-0.1	-0.9%
A5 Rechts (58)	-1111.1	-1.59%	67.5	5.7%	-1294.7	-1.85%	-16.7	-1.4%
N200 Rechts (59)	495.1	1.14%	34.3	13.8%	762.9	1.78%	55.8	27.3%
N200 Links (60)	505.5	1.61%	84.4	73.4%	138.7	0.44%	67.1	54.0%
A7 Rechts (61)	8252.1	7.46%	580.4	4606.7%	67.8	0.06%	23.9	129.3%
A7 Links (62)	-1379.5	-0.86%	-1.5	-4.0%	-2493.1	-1.55%	-2.8	-7.3%
SUM AMS Network	-16114.6	-0.70%	-1135.3	-5.2%	-22636.7	-0.98%	-2122.3	-9.7%
SUM RING A10	-7562.0	-0.61%	-1521.2	-11.9%	-10309.0	-0.82%	-1579.4	-12.2%
SUM Inner Ring	2011.5	0.37%	458.6	8.2%	-5365.6	-0.94%	-401.4	-7.2%
SUM Outer Ring	-9573.4	-1.35%	-1979.7	-27.4%	-4943.4	-0.73%	-1178.0	-15.9%
SUM Whole Network	-83812.9	-0.70%	-2094.8	-1.9%	-74692.7	-0.62%	-1346.9	-1.2%

Table F- 28. A5L DRIPs Rerouting Malfunction

Corridor	A5L DRIPs Rerouting Malfunction							
	Accident A10NWR				Accident A10SWL			
	TTD change	TTD (%)	VVU change	VVU (%)	TTD change	TTD (%)	VVU change	VVU (%)
A10NB Rechts (20)	-1974.5	-2.59%	-0.8	-10.2%	-2166.0	-2.67%	-1.0	-10.3%
A10NE Rechts (21)	-2693.8	-2.08%	-192.9	-92.3%	-4610.5	-3.39%	-285.8	-93.8%
A10SE Rechts (22)	-2578.5	-3.06%	-135.3	-68.8%	-2629.1	-3.08%	-171.5	-65.5%
A10SB Rechts (23)	348.9	0.30%	1004.9	59.1%	244.7	0.21%	209.3	8.3%
A10SW Rechts (24)	1108.8	1.67%	135.0	24.2%	-406.8	-0.58%	55.9	16.0%
A10NW Rechts (25)	862.2	1.52%	30.8	2.7%	205.3	0.29%	21.4	1.4%
A10NB Links (30)	-10791.7	-9.91%	-854.5	-67.5%	-4745.3	-4.69%	-43.1	-1.7%
A10NE Links (31)	-7881.3	-5.00%	-457.7	-51.4%	-8091.8	-5.17%	-439.7	-51.4%
A10SE Links (32)	-3290.2	-2.83%	-1719.9	-97.6%	-5679.5	-4.88%	-1306.2	-96.8%
A10SB Links (33)	-1225.2	-0.80%	-23.5	-1.4%	-7186.7	-4.67%	-482.1	-32.8%
A10SW Links (34)	-592.7	-0.52%	69.8	12.5%	2538.1	2.69%	413.2	27.9%
A10NW Links (35)	-3291.4	-4.90%	-9.2	-23.3%	-410.2	-0.60%	25.9	37.2%
A1 Links (40)	-580.9	-0.96%	-355.4	-97.1%	-163.4	-0.27%	-313.5	-94.5%
A2 Links (41)	-2967.7	-3.80%	-1.1	-13.3%	-1523.5	-1.99%	-0.5	-6.1%
A4 Links (42)	259.2	0.27%	90.6	4.2%	-6085.0	-5.98%	-1370.5	-66.4%
A8 Links (43)	-748.8	-0.85%	-0.5	-5.8%	-320.9	-0.37%	-0.4	-4.1%
A1 Rechts (50)	-2850.7	-2.51%	-766.1	-35.3%	-4542.3	-3.93%	-676.7	-30.8%
A2 Rechts (51)	-9307.6	-5.99%	-40.5	-50.8%	-12126.9	-7.77%	-24.8	-39.2%
A4 Rechts (52)	919.5	0.77%	87.3	33.1%	1328.8	1.16%	42.6	16.2%
A8 Rechts (53)	-1428.4	-1.26%	-482.2	-31.4%	-1190.7	-1.06%	-0.5	0.0%
A5 Links (57)	-11661.2	-10.40%	-3.3	-26.0%	-7773.8	-6.15%	-4.3	-19.1%
A5 Rechts (58)	1178.7	1.89%	86.0	6.9%	-43.5	-0.06%	34.3	2.6%
N200 Rechts (59)	4491.2	9.96%	295.4	50.8%	1687.7	3.78%	121.5	37.7%
N200 Links (60)	-2694.6	-7.71%	-63.6	-21.8%	1127.8	3.66%	77.3	61.4%
A7 Rechts (61)	81.2	0.07%	0.1	0.9%	-418.5	-0.35%	-0.2	-1.0%
A7 Links (62)	-1142.3	-0.73%	-0.6	-1.6%	-2095.0	-1.32%	-2.0	-5.4%
SUM AMS Network	-57390.7	-2.47%	-3306.8	-17.7%	-62563.3	-2.66%	-4119.3	-19.4%
SUM RING A10	-31999.3	-2.57%	-2153.4	-21.6%	-32937.7	-2.63%	-2003.8	-15.7%
SUM Inner Ring	-4926.9	-0.93%	841.6	22.2%	-9362.4	-1.67%	-171.8	-3.5%
SUM Outer Ring	-27072.4	-3.78%	-2995.0	-48.4%	-23575.3	-3.41%	-1832.0	-23.4%
SUM Whole Network	-93651.9	-0.78%	-1266.3	-1.2%	-126987.1	-1.05%	-1851.8	-1.7%

Table F- 29. N200L DRIPs Rerouting Malfunction

Corridor	N200L DRIPs Rerouting Malfunction							
	Accident A10NWR				Accident A10SWL			
	TTD change	TTD (%)	VVU change	VVU (%)	TTD change	TTD (%)	VVU change	VVU (%)
A10NB Rechts (20)	-1935.6	-2.54%	-0.8	-10.0%	-2144.6	-2.65%	-1.1	-10.4%
A10NE Rechts (21)	-2660.1	-2.06%	-187.0	-92.1%	-4575.4	-3.36%	-285.6	-93.8%
A10SE Rechts (22)	-2560.5	-3.04%	-134.9	-68.8%	-2662.6	-3.12%	-171.3	-65.5%
A10SB Rechts (23)	496.0	0.42%	1036.8	62.2%	654.6	0.56%	281.9	11.5%
A10SW Rechts (24)	1277.1	1.93%	147.5	27.1%	-360.3	-0.51%	66.6	19.7%
A10NW Rechts (25)	976.7	1.73%	41.2	3.7%	370.2	0.52%	28.6	1.9%
A10NB Links (30)	-10827.4	-9.94%	-856.9	-67.5%	-4674.6	-4.62%	-45.4	-1.7%
A10NE Links (31)	-7985.7	-5.06%	-458.1	-51.5%	-8073.8	-5.16%	-440.0	-51.4%
A10SE Links (32)	-3404.4	-2.93%	-1678.2	-97.5%	-5817.8	-4.99%	-1330.7	-96.8%
A10SB Links (33)	-1688.3	-1.10%	-33.7	-2.0%	-7289.0	-4.73%	-485.3	-32.9%
A10SW Links (34)	-1675.4	-1.46%	39.5	6.7%	1975.8	2.08%	401.4	26.9%
A10NW Links (35)	-3395.0	-5.04%	-9.2	-23.1%	-365.6	-0.54%	26.1	37.4%
A1 Links (40)	-519.0	-0.86%	-352.0	-97.1%	-95.0	-0.16%	-306.4	-94.3%
A2 Links (41)	-2984.1	-3.82%	-1.1	-13.4%	-1241.7	-1.63%	-0.4	-5.7%
A4 Links (42)	-223.6	-0.23%	-73.1	-3.2%	-6337.9	-6.21%	-1489.0	-68.2%
A8 Links (43)	-699.5	-0.80%	-0.5	-5.7%	-293.1	-0.34%	-0.4	-4.1%
A1 Rechts (50)	-2951.2	-2.59%	-769.5	-35.4%	-4564.1	-3.95%	-679.4	-30.9%
A2 Rechts (51)	-10079.6	-6.46%	-39.0	-49.9%	-12148.3	-7.78%	-25.3	-39.7%
A4 Rechts (52)	380.6	0.32%	84.7	31.8%	1128.3	0.98%	44.3	16.9%
A8 Rechts (53)	-1448.2	-1.28%	-486.5	-31.6%	-1041.1	-0.92%	7.3	0.4%
A5 Links (57)	-9903.2	-8.97%	-2.9	-24.0%	-5761.5	-4.63%	-3.6	0.0%
A5 Rechts (58)	916.7	1.47%	85.9	6.9%	113.1	0.16%	50.6	3.9%
N200 Rechts (59)	4245.3	9.37%	461.5	111.2%	2035.8	4.60%	100.0	29.1%
N200 Links (60)	-2456.2	-7.07%	82.8	56.7%	824.4	2.65%	71.0	53.7%
A7 Rechts (61)	67.2	0.06%	0.1	0.9%	-439.3	-0.37%	-0.2	-1.0%
A7 Links (62)	-1149.5	-0.73%	-0.6	-1.6%	-2012.5	-1.27%	-2.0	-5.5%
SUM AMS Network	-59104.7	-2.54%	-3103.4	-16.8%	-60344.3	-2.57%	-4186.1	-19.7%
SUM RING A10	-33382.6	-2.67%	-2093.7	-21.1%	-32963.2	-2.63%	-1954.8	-15.4%
SUM Inner Ring	-4406.4	-0.83%	902.8	24.2%	-8718.2	-1.55%	-80.9	-1.7%
SUM Outer Ring	-28976.2	-4.03%	-2996.5	-48.4%	-24245.0	-3.51%	-1873.9	-23.8%
SUM Whole Network	-99702.4	-0.83%	-980.6	-0.9%	-121002.5	-1.00%	-1780.7	-1.7%

Appendix F-4. Ramp Metering Malfunctions

Table F- 30. Effects of RM malfunction (201,202,203,204)

Corridor	RM Base	Effects in Malfunction Scenarios							
		201 (VVU)	201 (%)	202 (VVU)	202 (%)	203 (VVU)	203 (%)	204 (VVU)	204 (%)
A10NB Rechts (20)	9.8	-0.3	-3.2%	-0.3	-3.4%	-0.3	-3.4%	-0.3	-3.5%
A10NE Rechts (21)	367.7	143.2	38.9%	168.5	45.8%	165.7	45.1%	165.5	45.0%
A10SE Rechts (22)	249.6	8.3	3.3%	10.6	4.2%	9.5	3.8%	9.3	3.7%
A10SB Rechts (23)	2519.4	-494.2	-19.6%	-497.0	-19.7%	-517.8	-20.6%	-531.8	-21.1%
A10SW Rechts (24)	304.6	144.6	47.5%	81.4	26.7%	91.2	29.9%	85.4	28.0%
A10NW Rechts (25)	1447.8	-375.5	-25.9%	22.7	1.6%	17.8	1.2%	16.6	1.1%
A10NB Links (30)	2655.6	-153.6	-5.8%	-70.8	-2.7%	-63.8	-2.4%	-65.2	-2.5%
A10NE Links (31)	816.0	53.0	6.5%	52.2	6.4%	51.8	6.3%	52.1	6.4%
A10SE Links (32)	1268.0	292.7	23.1%	309.3	24.4%	329.7	26.0%	310.8	24.5%
A10SB Links (33)	1644.1	-21.8	-1.3%	-20.6	-1.3%	-16.9	-1.0%	-13.4	-0.8%
A10SW Links (34)	520.6	3.9	0.8%	-1.6	-0.3%	-0.1	0.0%	-1.1	-0.2%
A10NW Links (35)	45.3	0.8	1.8%	1.0	2.1%	1.1	2.4%	1.0	2.3%
A1 Links (40)	311.0	48.8	15.7%	25.0	8.0%	24.6	7.9%	5.6	1.8%
A2 Links (41)	7.6	0.7	9.7%	0.7	9.1%	0.8	9.9%	0.7	9.4%
A4 Links (42)	1930.6	-53.7	-2.8%	-137.7	-7.1%	-93.3	-4.8%	-86.9	-4.5%
A8 Links (43)	8.5	0.0	0.0%	0.0	-0.4%	0.0	-0.4%	0.0	-0.5%
A1 Rechts (50)	2192.3	223.8	10.2%	228.5	10.4%	234.7	10.7%	236.2	10.8%
A2 Rechts (51)	76.2	43.0	56.5%	41.1	54.0%	44.4	58.3%	45.0	59.1%
A4 Rechts (52)	257.2	5.1	2.0%	12.5	4.9%	3.6	1.4%	8.7	3.4%
A8 Rechts (53)	1726.4	-14.0	-0.8%	-1.9	-0.1%	-1.5	-0.1%	-0.9	-0.1%
A5 Links (57)	10.1	0.9	9.3%	1.7	17.1%	1.6	15.4%	1.6	15.6%
A5 Rechts (58)	1217.9	46.8	3.8%	37.4	3.1%	24.7	2.0%	29.5	2.4%
N200 Rechts (59)	303.6	3.4	1.1%	-1.0	-0.3%	19.5	6.4%	-7.6	-2.5%
N200 Links (60)	102.2	27.5	26.9%	14.8	14.5%	10.2	9.9%	14.3	14.0%
A7 Rechts (61)	16.5	0.0	-0.2%	0.0	-0.1%	0.0	-0.1%	0.0	-0.2%
A7 Links (62)	37.3	-1.2	-3.2%	-0.8	-2.2%	-0.9	-2.4%	-0.9	-2.4%
SUM AMS Network	19991.9	-66.4	-0.3%	276.7	1.4%	336.8	1.7%	274.9	1.4%
SUM RING A10	11848.5	-398.9	-3.4%	55.5	0.5%	67.7	0.6%	28.8	0.2%
SUM Inner Ring	4898.8	-573.9	-11.7%	-214.1	-4.4%	-234.0	-4.8%	-255.4	-5.2%
SUM Outer Ring	6949.6	175.1	2.5%	269.6	3.9%	301.7	4.3%	284.2	4.1%
SUM Whole Network	106693.5	-2135.1	-2.0%	-1499.9	-1.4%	-1528.6	-1.4%	-1424.7	-1.3%

Table F- 31. Effects of RM malfunction (305,306,307,308)

Corridor	RM Base	Effects in Malfunction Scenarios							
		305 (VVU)	305 (%)	306 (VVU)	306 (%)	307 (VVU)	307 (%)	308 (VVU)	308 (%)
A10NB Rechts (20)	9.8	-0.4	-4.1%	-0.4	-4.2%	-1.2	-12.1%	-0.4	-3.9%
A10NE Rechts (21)	367.7	225.9	61.4%	221.5	60.3%	223.1	60.7%	215.6	58.6%
A10SE Rechts (22)	249.6	13.2	5.3%	12.5	5.0%	7.4	3.0%	13.4	5.4%
A10SB Rechts (23)	2519.4	-473.7	-18.8%	-433.9	-17.2%	-470.3	-18.7%	-535.7	-21.3%
A10SW Rechts (24)	304.6	84.6	27.8%	85.8	28.2%	93.4	30.7%	76.1	25.0%
A10NW Rechts (25)	1447.8	23.0	1.6%	12.4	0.9%	18.7	1.3%	17.0	1.2%
A10NB Links (30)	2655.6	-58.2	-2.2%	-63.2	-2.4%	-51.5	-1.9%	-146.8	-5.5%
A10NE Links (31)	816.0	54.7	6.7%	57.6	7.1%	56.3	6.9%	54.7	6.7%
A10SE Links (32)	1268.0	375.0	29.6%	332.1	26.2%	378.3	29.8%	420.5	33.2%
A10SB Links (33)	1644.1	-20.0	-1.2%	-17.7	-1.1%	-13.2	-0.8%	-18.9	-1.2%
A10SW Links (34)	520.6	5.6	1.1%	-0.9	-0.2%	14.1	2.7%	-4.5	-0.9%
A10NW Links (35)	45.3	1.1	2.5%	1.2	2.7%	1.4	3.0%	0.8	1.9%
A1 Links (40)	311.0	53.5	17.2%	44.6	14.4%	38.5	12.4%	54.1	17.4%
A2 Links (41)	7.6	0.7	9.5%	0.7	9.4%	0.8	10.1%	0.8	10.3%
A4 Links (42)	1930.6	-126.3	-6.5%	-81.9	-4.2%	-106.2	-5.5%	-93.2	-4.8%
A8 Links (43)	8.5	0.0	-0.4%	-0.1	-0.8%	0.1	0.7%	0.0	-0.5%
A1 Rechts (50)	2192.3	257.0	11.7%	252.9	11.5%	242.9	11.1%	265.7	12.1%
A2 Rechts (51)	76.2	44.4	58.3%	43.2	56.7%	48.9	64.2%	50.1	65.8%
A4 Rechts (52)	257.2	16.9	6.6%	6.1	2.4%	23.4	9.1%	9.1	3.6%
A8 Rechts (53)	1726.4	1.9	0.1%	3.6	0.2%	2.6	0.2%	-5.4	-0.3%
A5 Links (57)	10.1	1.5	14.6%	1.5	15.3%	1.5	15.0%	1.4	13.4%
A5 Rechts (58)	1217.9	37.0	3.0%	12.5	1.0%	25.6	2.1%	28.7	2.4%
N200 Rechts (59)	303.6	-0.3	-0.1%	0.8	0.3%	8.6	2.8%	-15.5	-5.1%
N200 Links (60)	102.2	17.0	16.6%	12.1	11.8%	32.8	32.1%	13.2	12.9%
A7 Rechts (61)	16.5	0.0	-0.1%	0.0	-0.1%	0.0	0.0%	0.0	0.0%
A7 Links (62)	37.3	-0.9	-2.4%	-1.0	-2.6%	-0.8	-2.1%	-1.0	-2.6%

SUM AMS Network	19991.9	534.2	2.7%	503.1	2.5%	576.1	2.9%	400.7	2.0%
SUM RING A10	11848.5	230.9	1.9%	207.2	1.7%	256.5	2.2%	91.7	0.8%
SUM Inner Ring	4898.8	-127.4	-2.6%	-102.0	-2.1%	-128.9	-2.6%	-214.1	-4.4%
SUM Outer Ring	6949.6	358.3	5.2%	309.2	4.4%	385.3	5.5%	305.8	4.4%
SUM Whole Network	106693.5	-1380.1	-1.3%	-1155.4	-1.1%	-1131.5	-1.1%	-1705.3	-1.6%

Table F- 32. Effects of RM malfunction (309,310,311,312)

Corridor	RM Base	Effects in Malfunction Scenarios							
		309 (VVU)	309 (%)	310 (VVU)	310 (%)	311 (VVU)	311 (%)	312 (VVU)	312 (%)
A10NB Rechts (20)	9.8	-0.4	-3.8%	-1.1	-10.8%	0.5	5.3%	-0.3	-3.1%
A10NE Rechts (21)	367.7	232.9	63.3%	675.8	183.8%	162.8	44.3%	230.2	62.6%
A10SE Rechts (22)	249.6	13.7	5.5%	14.3	5.7%	5.5	2.2%	13.5	5.4%
A10SB Rechts (23)	2519.4	-492.9	-19.6%	-598.6	-23.8%	-309.6	-12.3%	-445.3	-17.7%
A10SW Rechts (24)	304.6	82.9	27.2%	67.8	22.3%	109.7	36.0%	84.7	27.8%
A10NW Rechts (25)	1447.8	24.2	1.7%	24.2	1.7%	30.2	2.1%	23.0	1.6%
A10NB Links (30)	2655.6	-43.0	-1.6%	-417.8	-15.7%	302.0	11.4%	-58.3	-2.2%
A10NE Links (31)	816.0	55.3	6.8%	78.2	9.6%	66.1	8.1%	54.9	6.7%
A10SE Links (32)	1268.0	379.2	29.9%	471.3	37.2%	276.9	21.8%	370.8	29.2%
A10SB Links (33)	1644.1	-19.1	-1.2%	-18.3	-1.1%	-25.1	-1.5%	-15.0	-0.9%
A10SW Links (34)	520.6	0.1	0.0%	40.1	7.7%	-1.1	-0.2%	8.3	1.6%
A10NW Links (35)	45.3	1.1	2.5%	0.5	1.1%	1.0	2.2%	1.1	2.5%
A1 Links (40)	311.0	45.9	14.8%	37.3	12.0%	31.3	10.0%	56.9	18.3%
A2 Links (41)	7.6	0.8	9.9%	0.8	10.7%	0.7	9.1%	0.7	9.3%
A4 Links (42)	1930.6	-104.6	-5.4%	-70.9	-3.7%	-176.6	-9.1%	-98.1	-5.1%
A8 Links (43)	8.5	0.0	-0.2%	8.9	104.5%	0.3	3.8%	0.0	-0.4%
A1 Rechts (50)	2192.3	263.0	12.0%	380.6	17.4%	207.3	9.5%	257.4	11.7%
A2 Rechts (51)	76.2	47.6	62.5%	37.8	49.6%	46.0	60.4%	47.2	62.0%
A4 Rechts (52)	257.2	10.1	3.9%	42.2	16.4%	17.8	6.9%	10.1	3.9%
A8 Rechts (53)	1726.4	3.0	0.2%	-1.5	-0.1%	22.2	1.3%	2.4	0.1%
A5 Links (57)	10.1	1.6	15.4%	0.9	8.6%	1.8	17.6%	1.6	15.6%
A5 Rechts (58)	1217.9	25.7	2.1%	21.9	1.8%	41.3	3.4%	18.7	1.5%
N200 Rechts (59)	303.6	20.2	6.7%	-13.0	-4.3%	-17.4	-5.7%	14.4	4.7%
N200 Links (60)	102.2	13.9	13.6%	1.1	1.0%	17.0	16.6%	52.4	51.3%
A7 Rechts (61)	16.5	0.1	0.4%	0.2	1.1%	0.9	5.6%	0.1	0.4%
A7 Links (62)	37.3	-0.8	-2.1%	-0.8	-2.1%	-0.6	-1.7%	-0.9	-2.5%
SUM AMS Network	19991.9	561.3	2.8%	782.5	3.9%	810.6	4.1%	631.2	3.2%
SUM RING A10	11848.5	234.2	2.0%	336.4	2.8%	618.9	5.2%	267.6	2.3%
SUM Inner Ring	4898.8	-139.5	-2.8%	182.4	3.7%	-1.0	0.0%	-94.2	-1.9%
SUM Outer Ring	6949.6	373.7	5.4%	154.0	2.2%	619.9	8.9%	361.8	5.2%
SUM Whole Network	106693.5	-1131.6	-1.1%	-879.0	-0.8%	-329.2	-0.3%	-1231.6	-1.2%

Table F- 33. Effects of RM malfunction (313,314,315,316)

Corridor	RM Base	Effects in Malfunction Scenarios							
		313 (VVU)	313 (%)	314 (VVU)	314 (%)	315 (VVU)	315 (%)	316 (VVU)	316 (%)
A10NB Rechts (20)	9.8	-0.4	-3.8%	0.5	4.6%	-0.3	-3.4%	-0.4	-3.7%
A10NE Rechts (21)	367.7	223.6	60.8%	-339.9	-92.4%	222.6	60.5%	238.4	64.9%
A10SE Rechts (22)	249.6	13.8	5.5%	-121.0	-48.5%	11.7	4.7%	14.2	5.7%
A10SB Rechts (23)	2519.4	-434.7	-17.3%	-622.5	-24.7%	-486.9	-19.3%	-483.4	-19.2%
A10SW Rechts (24)	304.6	98.0	32.2%	90.4	29.7%	83.1	27.3%	86.7	28.5%
A10NW Rechts (25)	1447.8	20.3	1.4%	21.8	1.5%	14.1	1.0%	21.3	1.5%
A10NB Links (30)	2655.6	-64.4	-2.4%	-46.3	-1.7%	-54.1	-2.0%	-51.1	-1.9%
A10NE Links (31)	816.0	55.9	6.9%	44.2	5.4%	55.3	6.8%	58.1	7.1%
A10SE Links (32)	1268.0	309.5	24.4%	75.2	5.9%	368.9	29.1%	371.6	29.3%
A10SB Links (33)	1644.1	-21.3	-1.3%	-19.9	-1.2%	-19.1	-1.2%	-22.0	-1.3%
A10SW Links (34)	520.6	3.3	0.6%	-30.4	-5.8%	-6.7	-1.3%	1.5	0.3%
A10NW Links (35)	45.3	1.0	2.3%	0.6	1.3%	1.1	2.4%	1.0	2.3%
A1 Links (40)	311.0	38.9	12.5%	47.8	15.4%	38.1	12.2%	52.4	16.8%
A2 Links (41)	7.6	0.7	9.4%	1.0	12.8%	0.7	9.5%	0.7	9.4%
A4 Links (42)	1930.6	-115.2	-6.0%	-85.6	-4.4%	-98.4	-5.1%	-126.7	-6.6%
A8 Links (43)	8.5	-0.1	-0.7%	0.2	2.0%	0.0	-0.5%	-0.1	-0.7%
A1 Rechts (50)	2192.3	249.0	11.4%	-104.0	-4.7%	258.1	11.8%	268.9	12.3%
A2 Rechts (51)	76.2	44.1	57.9%	33.8	44.4%	46.1	60.6%	46.9	61.5%
A4 Rechts (52)	257.2	13.7	5.3%	6.4	2.5%	3.3	1.3%	12.4	4.8%
A8 Rechts (53)	1726.4	4.4	0.3%	-6.7	-0.4%	2.5	0.1%	3.4	0.2%
A5 Links (57)	10.1	1.6	15.4%	2.2	21.4%	1.5	15.0%	1.6	15.5%
A5 Rechts (58)	1217.9	46.7	3.8%	19.3	1.6%	28.5	2.3%	38.9	3.2%

N200 Rechts (59)	303.6	-19.6	-6.5%	1.6	0.5%	-22.0	-7.2%	5.4	1.8%
N200 Links (60)	102.2	12.8	12.5%	14.8	14.5%	10.0	9.8%	13.6	13.3%
A7 Rechts (61)	16.5	0.0	0.0%	-0.1	-0.8%	0.0	0.1%	0.0	0.1%
A7 Links (62)	37.3	-0.9	-2.4%	-0.7	-1.9%	-0.9	-2.5%	-0.8	-2.2%
SUM AMS Network	19991.9	481.6	2.4%	-1016.5	-5.1%	458.1	2.3%	553.2	2.8%
SUM RING A10	11848.5	204.7	1.7%	-1037.7	-8.0%	189.6	1.6%	236.1	2.0%
SUM Inner Ring	4898.8	-79.3	-1.6%	-970.8	-19.8%	-155.7	-3.2%	-123.2	-2.5%
SUM Outer Ring	6949.6	284.0	4.1%	23.4	0.3%	345.3	5.0%	359.2	5.2%
SUM Whole Network	106693.5	-1112.8	-1.0%	-4252.8	-4.0%	-1416.5	-1.3%	-1339.4	-1.3%

Table F- 34. Effects of RM malfunction (317,318,319,320)

Corridor	RM Base	Effects in Malfunction Scenarios							
		317 (VVU)	317 (%)	318 (VVU)	318 (%)	319 (VVU)	319 (%)	320 (VVU)	320 (%)
A10NB Rechts (20)	9.8	-0.3	-3.4%	-0.4	-4.0%	-0.1	-0.8%	-0.4	-4.6%
A10NE Rechts (21)	367.7	226.0	61.5%	248.1	67.5%	24.4	6.6%	264.9	72.1%
A10SE Rechts (22)	249.6	14.0	5.6%	15.0	6.0%	9.0	3.6%	14.7	5.9%
A10SB Rechts (23)	2519.4	-449.1	-17.8%	-709.3	-28.2%	-752.9	-29.9%	-601.8	-23.9%
A10SW Rechts (24)	304.6	82.3	27.0%	98.0	32.2%	-29.8	-9.8%	92.6	30.4%
A10NW Rechts (25)	1447.8	23.3	1.6%	20.1	1.4%	-19.6	-1.4%	23.5	1.6%
A10NB Links (30)	2655.6	-63.4	-2.4%	-86.1	-3.2%	-146.7	-5.5%	-84.2	-3.2%
A10NE Links (31)	816.0	53.6	6.6%	52.8	6.5%	-28.1	-3.4%	56.8	7.0%
A10SE Links (32)	1268.0	337.7	26.6%	313.3	24.7%	-143.7	-11.3%	413.6	32.6%
A10SB Links (33)	1644.1	-18.0	-1.1%	-18.3	-1.1%	-29.5	-1.8%	-20.6	-1.2%
A10SW Links (34)	520.6	0.6	0.1%	4.9	0.9%	-25.5	-4.9%	5.9	1.1%
A10NW Links (35)	45.3	1.1	2.3%	1.0	2.3%	0.3	0.8%	1.2	2.7%
A1 Links (40)	311.0	38.7	12.4%	46.5	15.0%	23.7	7.6%	57.1	18.3%
A2 Links (41)	7.6	0.7	9.4%	1.2	16.3%	1.3	16.5%	1.1	14.8%
A4 Links (42)	1930.6	-104.2	-5.4%	-103.1	-5.3%	-52.3	-2.7%	-124.6	-6.5%
A8 Links (43)	8.5	-0.1	-0.7%	0.0	-0.6%	0.0	0.2%	-0.1	-0.9%
A1 Rechts (50)	2192.3	244.9	11.2%	260.4	11.9%	-43.4	-2.0%	334.1	15.2%
A2 Rechts (51)	76.2	47.6	62.4%	30.9	40.6%	43.8	57.5%	38.1	50.0%
A4 Rechts (52)	257.2	8.1	3.1%	28.2	11.0%	4.9	1.9%	11.8	4.6%
A8 Rechts (53)	1726.4	2.0	0.1%	1.0	0.1%	-13.1	-0.8%	1.2	0.1%
A5 Links (57)	10.1	1.5	15.1%	1.9	18.5%	1.8	17.5%	1.6	16.1%
A5 Rechts (58)	1217.9	32.3	2.7%	24.9	2.0%	-37.1	-3.0%	36.6	3.0%
N200 Rechts (59)	303.6	-10.6	-3.5%	1.9	0.6%	-23.4	-7.7%	-4.6	-1.5%
N200 Links (60)	102.2	32.9	32.2%	16.1	15.8%	-1.5	-1.4%	12.8	12.6%
A7 Rechts (61)	16.5	0.0	-0.1%	0.0	-0.1%	-0.1	-0.4%	0.0	-0.1%
A7 Links (62)	37.3	-1.0	-2.6%	-0.7	-2.0%	-1.3	-3.6%	-0.8	-2.1%
SUM AMS Network	19991.9	501.4	2.5%	249.0	1.2%	-1237.6	-6.2%	531.4	2.7%
SUM RING A10	11848.5	207.6	1.8%	-60.9	-0.5%	-1142.1	-9.6%	166.3	1.4%
SUM Inner Ring	4898.8	-103.9	-2.1%	-328.5	-6.7%	-768.9	-15.7%	-206.6	-4.2%
SUM Outer Ring	6949.6	311.5	4.5%	267.6	3.9%	-373.2	-5.4%	372.8	5.4%
SUM Whole Network	106693.5	-1309.7	-1.2%	-2119.1	-2.0%	-3774.1	-3.5%	-1274.7	-1.2%

Table F- 35. Effects of RM malfunction (321,322,323,324)

Corridor	RM Base	Effects in Malfunction Scenarios							
		321 (VVU)	321 (%)	322 (VVU)	322 (%)	323 (VVU)	323 (%)	324 (VVU)	324 (%)
A10NB Rechts (20)	9.8	-0.4	-4.0%	-0.4	-4.1%	0.0	-0.1%	-0.3	-2.7%
A10NE Rechts (21)	367.7	220.9	60.1%	245.6	66.8%	-36.9	-10.0%	113.3	30.8%
A10SE Rechts (22)	249.6	13.7	5.5%	11.9	4.8%	2.1	0.8%	6.7	2.7%
A10SB Rechts (23)	2519.4	-400.7	-15.9%	-133.4	-5.3%	-95.7	-3.8%	22.8	0.9%
A10SW Rechts (24)	304.6	97.8	32.1%	77.2	25.3%	-23.8	-7.8%	67.7	22.2%
A10NW Rechts (25)	1447.8	21.1	1.5%	21.7	1.5%	-10.4	-0.7%	9.9	0.7%
A10NB Links (30)	2655.6	-88.1	-3.3%	-18.0	-0.7%	-25.4	-1.0%	-18.0	-0.7%
A10NE Links (31)	816.0	44.3	5.4%	60.7	7.4%	-10.2	-1.2%	40.5	5.0%
A10SE Links (32)	1268.0	348.1	27.4%	416.6	32.9%	-101.9	-8.0%	484.3	38.2%
A10SB Links (33)	1644.1	-17.4	-1.1%	-17.6	-1.1%	16.8	1.0%	-18.8	-1.1%
A10SW Links (34)	520.6	10.6	2.0%	-0.4	-0.1%	3.5	0.7%	-7.5	-1.4%
A10NW Links (35)	45.3	1.1	2.4%	1.4	3.1%	0.2	0.5%	0.8	1.9%
A1 Links (40)	311.0	29.1	9.4%	47.4	15.3%	-8.2	-2.6%	42.2	13.6%
A2 Links (41)	7.6	0.6	7.8%	0.2	2.2%	0.2	2.0%	-0.1	-0.8%
A4 Links (42)	1930.6	-123.8	-6.4%	-135.5	-7.0%	106.4	5.5%	-38.1	-2.0%
A8 Links (43)	8.5	0.0	-0.6%	-0.1	-0.8%	0.0	0.1%	0.0	-0.6%
A1 Rechts (50)	2192.3	239.0	10.9%	302.1	13.8%	-46.0	-2.1%	125.8	5.7%
A2 Rechts (51)	76.2	48.3	63.4%	45.5	59.8%	-19.3	-25.4%	55.3	72.6%

A4 Rechts (52)	257.2	13.5	5.3%	8.6	3.4%	8.7	3.4%	40.5	15.7%
A8 Rechts (53)	1726.4	1.1	0.1%	5.8	0.3%	-3.3	-0.2%	2.7	0.2%
A5 Links (57)	10.1	1.7	17.2%	1.4	14.0%	1.9	18.7%	1.7	17.1%
A5 Rechts (58)	1217.9	15.8	1.3%	14.9	1.2%	-19.4	-1.6%	25.3	2.1%
N200 Rechts (59)	303.6	28.6	9.4%	-12.5	-4.1%	0.3	0.1%	5.6	1.8%
N200 Links (60)	102.2	16.5	16.2%	13.2	12.9%	13.5	13.2%	16.4	16.0%
A7 Rechts (61)	16.5	0.0	0.1%	0.1	0.4%	0.0	-0.1%	0.0	0.2%
A7 Links (62)	37.3	-0.9	-2.4%	-1.1	-3.0%	-1.7	-4.4%	-1.4	-3.7%
SUM AMS Network	19991.9	521.2	2.6%	956.3	4.8%	-247.1	-1.2%	978.7	4.9%
SUM RING A10	11848.5	250.8	2.1%	665.2	5.6%	-281.7	-2.4%	701.6	5.9%
SUM Inner Ring	4898.8	-47.6	-1.0%	222.5	4.5%	-164.7	-3.4%	220.1	4.5%
SUM Outer Ring	6949.6	298.4	4.3%	442.7	6.4%	-117.0	-1.7%	481.5	6.9%
SUM Whole Network	106693.5	-1075.1	-1.0%	-428.2	-0.4%	318.5	0.3%	-503.4	-0.5%

Table F- 36. Effects of RM malfunction (325,326.327,328)

Corridor	RM Base	Effects in Malfunction Scenarios							
		325 (VVU)	325 (%)	326 (VVU)	326 (%)	327 (VVU)	327 (%)	328 (VVU)	328 (%)
A10NB Rechts (20)	9.8	-0.4	-4.1%	-0.2	-1.7%	0.0	-0.1%	-0.6	-5.8%
A10NE Rechts (21)	367.7	11.1	3.0%	-20.1	-5.5%	-3.6	-1.0%	-41.8	-11.4%
A10SE Rechts (22)	249.6	-8.0	-3.2%	-1.3	-0.5%	0.7	0.3%	-10.1	-4.0%
A10SB Rechts (23)	2519.4	179.8	7.1%	38.3	1.5%	23.5	0.9%	68.0	2.7%
A10SW Rechts (24)	304.6	-45.3	-14.9%	-51.2	-16.8%	-18.1	-6.0%	-10.7	-3.5%
A10NW Rechts (25)	1447.8	-21.8	-1.5%	-11.4	-0.8%	0.6	0.0%	-3.3	-0.2%
A10NB Links (30)	2655.6	34.5	1.3%	-9.7	-0.4%	-5.6	-0.2%	-15.8	-0.6%
A10NE Links (31)	816.0	2.2	0.3%	20.1	2.5%	2.5	0.3%	-8.7	-1.1%
A10SE Links (32)	1268.0	15.6	1.2%	-21.8	-1.7%	-40.4	-3.2%	-43.5	-3.4%
A10SB Links (33)	1644.1	-66.5	-4.0%	-492.1	-29.9%	0.4	0.0%	-126.8	-7.7%
A10SW Links (34)	520.6	-92.0	-17.7%	49.8	9.6%	-2.9	-0.6%	-244.2	-46.9%
A10NW Links (35)	45.3	1.4	3.0%	0.7	1.6%	0.5	1.1%	1.8	4.0%
A1 Links (40)	311.0	4.9	1.6%	4.9	1.6%	0.3	0.1%	8.8	2.8%
A2 Links (41)	7.6	-0.1	-1.7%	0.0	-0.5%	0.0	-0.3%	0.0	-0.4%
A4 Links (42)	1930.6	-443.8	-23.0%	258.0	13.4%	39.0	2.0%	-282.3	-14.6%
A8 Links (43)	8.5	-0.1	-1.5%	0.0	-0.6%	0.0	0.0%	-0.2	-1.8%
A1 Rechts (50)	2192.3	-14.8	-0.7%	-6.3	-0.3%	-7.9	-0.4%	-48.4	-2.2%
A2 Rechts (51)	76.2	-11.9	-15.6%	-12.1	-15.9%	-12.1	-15.9%	-14.4	-19.0%
A4 Rechts (52)	257.2	-15.8	-6.2%	5.2	2.0%	0.6	0.2%	-144.5	-56.2%
A8 Rechts (53)	1726.4	-2.9	-0.2%	-1.1	-0.1%	-2.7	-0.2%	-5.6	-0.3%
A5 Links (57)	10.1	-0.1	-1.4%	2.1	21.2%	1.6	16.0%	-1.7	-17.0%
A5 Rechts (58)	1217.9	-82.2	-6.7%	-5.8	-0.5%	-21.2	-1.7%	-61.4	-5.0%
N200 Rechts (59)	303.6	2.9	0.9%	-11.7	-3.8%	-13.1	-4.3%	7.2	2.4%
N200 Links (60)	102.2	-0.9	-0.9%	0.7	0.7%	-0.1	-0.1%	-0.7	-0.6%
A7 Rechts (61)	16.5	0.1	0.7%	0.0	0.1%	0.0	0.1%	0.1	0.7%
A7 Links (62)	37.3	-1.9	-5.0%	-1.8	-4.7%	-1.7	-4.5%	-1.5	-4.0%
SUM AMS Network	19991.9	-554.3	-2.8%	-264.9	-1.3%	-58.1	-0.3%	-978.9	-4.9%
SUM RING A10	11848.5	10.7	0.1%	-498.8	-4.2%	-42.4	-0.4%	-435.7	-3.7%
SUM Inner Ring	4898.8	115.4	2.4%	-45.8	-0.9%	3.0	0.1%	1.5	0.0%
SUM Outer Ring	6949.6	-104.8	-1.5%	-452.9	-6.5%	-45.5	-0.7%	-437.2	-6.3%
SUM Whole Network	106693.5	-1455.2	-1.4%	-435.5	-0.4%	-450.7	-0.4%	-3166.8	-3.0%

Table F- 37. Effects of RM malfunction (329, 330, 331, 332)

Corridor	RM Base	Effects in Malfunction Scenarios							
		329 (VVU)	329 (%)	330 (VVU)	330 (%)	331 (VVU)	331 (%)	332 (VVU)	332 (%)
A10NB Rechts (20)	9.8	0.0	-0.4%	-0.2	-2.0%	-0.1	-0.9%	-0.1	-1.4%
A10NE Rechts (21)	367.7	11.5	3.1%	10.6	2.9%	27.3	7.4%	17.6	4.8%
A10SE Rechts (22)	249.6	1.2	0.5%	-0.3	-0.1%	1.9	0.7%	1.9	0.8%
A10SB Rechts (23)	2519.4	-10.9	-0.4%	46.4	1.8%	-17.3	-0.7%	20.7	0.8%
A10SW Rechts (24)	304.6	11.1	3.7%	31.9	10.5%	57.8	19.0%	10.1	3.3%
A10NW Rechts (25)	1447.8	-5.6	-0.4%	13.3	0.9%	15.7	1.1%	3.5	0.2%
A10NB Links (30)	2655.6	8.5	0.3%	11.8	0.4%	13.3	0.5%	-0.5	0.0%
A10NE Links (31)	816.0	5.9	0.7%	2.8	0.3%	22.2	2.7%	16.7	2.0%
A10SE Links (32)	1268.0	22.9	1.8%	18.2	1.4%	47.1	3.7%	26.8	2.1%
A10SB Links (33)	1644.1	15.9	1.0%	-5.0	-0.3%	-4.9	-0.3%	2.6	0.2%
A10SW Links (34)	520.6	8.5	1.6%	-38.8	-7.5%	-20.9	-4.0%	-14.5	-2.8%
A10NW Links (35)	45.3	0.5	1.1%	0.9	1.9%	0.6	1.3%	0.6	1.4%
A1 Links (40)	311.0	4.3	1.4%	25.5	8.2%	8.6	2.8%	17.9	5.7%
A2 Links (41)	7.6	0.0	0.1%	-0.1	-1.2%	0.0	-0.5%	0.0	-0.5%

A4 Links (42)	1930.6	83.9	4.3%	-62.7	-3.2%	-75.0	-3.9%	10.9	0.6%
A8 Links (43)	8.5	0.0	-0.1%	0.0	-0.6%	0.0	0.0%	0.0	-0.4%
A1 Rechts (50)	2192.3	8.3	0.4%	18.2	0.8%	17.8	0.8%	15.7	0.7%
A2 Rechts (51)	76.2	0.4	0.6%	-0.5	-0.7%	0.0	0.1%	-12.6	-16.5%
A4 Rechts (52)	257.2	9.3	3.6%	-66.1	-25.7%	-19.8	-7.7%	-18.0	-7.0%
A8 Rechts (53)	1726.4	-0.4	0.0%	3.2	0.2%	3.8	0.2%	0.7	0.0%
A5 Links (57)	10.1	1.7	17.1%	0.0	-0.1%	0.5	5.5%	1.4	13.8%
A5 Rechts (58)	1217.9	-19.3	-1.6%	7.0	0.6%	12.2	1.0%	-9.1	-0.7%
N200 Rechts (59)	303.6	-23.6	-7.8%	-14.3	-4.7%	8.9	2.9%	9.8	3.2%
N200 Links (60)	102.2	12.7	12.4%	19.9	19.5%	10.0	9.8%	3.0	2.9%
A7 Rechts (61)	16.5	0.0	-0.1%	0.0	0.2%	0.0	0.2%	0.0	0.2%
A7 Links (62)	37.3	-1.8	-4.7%	-1.6	-4.3%	-1.5	-4.1%	-1.7	-4.7%
SUM AMS Network	19991.9	146.9	0.7%	21.6	0.1%	109.8	0.5%	105.0	0.5%
SUM RING A10	11848.5	69.6	0.6%	91.7	0.8%	142.6	1.2%	85.5	0.7%
SUM Inner Ring	4898.8	7.3	0.1%	101.8	2.1%	85.3	1.7%	53.7	1.1%
SUM Outer Ring	6949.6	62.3	0.9%	-10.1	-0.1%	57.4	0.8%	31.8	0.5%
SUM Whole Network	106693.5	301.8	0.3%	-437.4	-0.4%	-301.5	-0.3%	-187.2	-0.2%

Table F- 38. Effects of RM malfunction (333,334,335,A10)

Corridor	RM Base	Effects in Malfunction Scenarios							
		333 (VVU)	333 (%)	334 (VVU)	334 (%)	335 (VVU)	335 (%)	A10 (VVU)	A10 (%)
A10NB Rechts (20)	9.8	0.0	-0.1%	0.0	-0.1%	0.0	-0.2%	-0.3	-3.4%
A10NE Rechts (21)	367.7	16.0	4.3%	4.4	1.2%	14.1	3.8%	144.2	39.2%
A10SE Rechts (22)	249.6	2.4	1.0%	1.2	0.5%	1.1	0.5%	-1.0	-0.4%
A10SB Rechts (23)	2519.4	-11.0	-0.4%	-0.2	0.0%	-3.5	-0.1%	98.4	3.9%
A10SW Rechts (24)	304.6	-9.0	-3.0%	3.6	1.2%	-3.6	-1.2%	128.5	42.2%
A10NW Rechts (25)	1447.8	-1.8	-0.1%	-0.1	0.0%	-1.9	-0.1%	-381.0	-26.3%
A10NB Links (30)	2655.6	0.9	0.0%	3.9	0.1%	4.4	0.2%	-29.7	-1.1%
A10NE Links (31)	816.0	17.1	2.1%	13.7	1.7%	8.9	1.1%	68.0	8.3%
A10SE Links (32)	1268.0	6.8	0.5%	12.4	1.0%	4.7	0.4%	433.1	34.2%
A10SB Links (33)	1644.1	10.0	0.6%	6.0	0.4%	6.8	0.4%	-497.3	-30.2%
A10SW Links (34)	520.6	11.7	2.2%	6.1	1.2%	-0.4	-0.1%	59.4	11.4%
A10NW Links (35)	45.3	0.5	1.1%	0.3	0.7%	0.7	1.6%	1.4	3.1%
A1 Links (40)	311.0	18.3	5.9%	8.0	2.6%	12.9	4.1%	50.9	16.4%
A2 Links (41)	7.6	-0.1	-0.8%	0.0	-0.4%	0.0	-0.1%	-0.2	-2.8%
A4 Links (42)	1930.6	28.0	1.4%	32.8	1.7%	51.1	2.6%	162.8	8.4%
A8 Links (43)	8.5	0.0	0.2%	0.0	0.1%	0.0	0.0%	0.0	-0.6%
A1 Rechts (50)	2192.3	18.3	0.8%	8.0	0.4%	12.2	0.6%	249.5	11.4%
A2 Rechts (51)	76.2	-11.0	-14.4%	-9.8	-12.9%	-9.9	-12.9%	39.1	51.3%
A4 Rechts (52)	257.2	13.2	5.1%	9.8	3.8%	-1.2	-0.5%	17.0	6.6%
A8 Rechts (53)	1726.4	0.4	0.0%	-0.4	0.0%	-1.3	-0.1%	-5.1	-0.3%
A5 Links (57)	10.1	1.4	13.9%	0.9	8.8%	1.5	14.9%	2.0	19.5%
A5 Rechts (58)	1217.9	-16.7	-1.4%	1.9	0.2%	-26.7	-2.2%	30.3	2.5%
N200 Rechts (59)	303.6	-10.5	-3.5%	-9.8	-3.2%	6.3	2.1%	-16.6	-5.5%
N200 Links (60)	102.2	33.6	32.9%	13.3	13.0%	0.8	0.8%	27.4	26.8%
A7 Rechts (61)	16.5	0.0	0.1%	0.0	0.1%	0.0	0.1%	0.2	1.2%
A7 Links (62)	37.3	-1.6	-4.3%	-1.8	-4.8%	-1.7	-4.4%	-1.8	-4.7%
SUM AMS Network	19991.9	118.5	0.6%	105.8	0.5%	77.0	0.4%	580.6	2.9%
SUM RING A10	11848.5	43.5	0.4%	51.3	0.4%	31.3	0.3%	23.6	0.2%
SUM Inner Ring	4898.8	-3.4	-0.1%	8.9	0.2%	6.3	0.1%	-11.3	-0.2%
SUM Outer Ring	6949.6	46.9	0.7%	42.4	0.6%	25.0	0.4%	34.9	0.5%
SUM Whole Network	106693.5	120.0	0.1%	-47.2	-0.0%	-183.7	-0.2%	-613.7	-0.6%

Appendix G. Capacity Adjustment

Table G- 1. Capacity Adjustment Measures

Link Number	Original Lane Numbers	Adjusted Lane Numbers	Original Saturation Rate	Adjusted Saturation Rate
1459	-	-	2150	1800
1505	-	-	2150	1800
1539	-	-	2000	1800
1561	-	-	1600	2200
1622	-	-	2000	2200
1754	-	-	2150	1900
1780	-	-	2150	1900
1785	-	-	1888	1900
1822	-	-	2150	1900
1983	-	-	2150	1900
2006	-	-	1600	1400
2083	-	-	1600	1400
2231	-	-	1800	2200
2423	3	5	-	-
2465	1	2	-	-
2768	-	-	2150	2200
2953	3	4	-	-
3082	3	4	-	-
3254	-	-	1100	2200
3542	2	3	-	-
3608	-	-	1888	1800
3691	-	-	2150	2200
3711	4	5	-	-
3721	3	4	-	-
3887	3	4	-	-
4097	3	4	-	-
4333	2	3	-	-
4510	3	4	2000	2200
4615	4	6	-	-
5112	3	5	2150	2200
5115	3	5	1900	2200
5175	3	4	1900	2200
5549	-	-	2150	1700
5722	3	4	-	-
5963	2	1	-	-
5977	3	4	-	-
6041	3	4	-	-
7392	2	3	-	-
8694	-	-	2150	1700
8874	2	3	-	-
8877	2	1	-	-
8879	2	3	1900	2000
8880	2	3	-	-
8886	-	-	2150	2200
8889	-	-	1900	2200
8907	4	6	1900	2200
8909	3	5	-	-
8910	4	5	1900	2200
8940	-	-	1800	2150
8948	1	2	-	-
8949	-	-	1888	2200
8996	-	-	1200	1900
9001	2	3	-	-
9019	2	3	-	-
9024	-	-	1700	2200
9027	1	2	-	-
9035	2	3	1800	2200
9036	2	3	-	-
9048	3	4	-	-
9051	3	4	-	-

9092	-	-	1800	2200
9133	-	-	2150	1900
9135	-	-	2150	1900
9136	-	-	2150	1900
9137	-	-	2000	1900
9138	-	-	2000	1900
9139	-	-	2150	1900
9141	-	-	2150	2000
9143	2	3	-	-
9144	2	3	-	-
9149	2	4	-	-
9150	2	4	-	-
9155	3	5	-	-
9156	3	5	-	-
9158	-	-	2000	1800
9159	-	-	1900	2200
9160	4	3	1500	1700
9163	-	-	2150	2200
9164	3	5	2150	1900
9170	3	4	-	-
9173	-	-	1400	2200
9183	2	3	-	-
9184	2	3	-	-
9222	4	3	-	-
9223	4	3	-	-
9232	4	3	-	-
9233	4	3	-	-
9234	3	2	-	-
9328	-	-	2150	2200
9330	-	-	2150	1900
9347	2	3	-	-
9357	-	-	1700	2200
9371	-	-	1800	1600
9455	3	4	-	-
9474	-	-	1900	2200
9475	-	-	1800	2200
9528	-	-	1600	1400
9531	-	-	1900	1400
9537	-	-	2150	1400
9538	-	-	2150	1600
9539	-	-	2150	1400
9870	4	6	1200	1900
9894	2	4	-	-
9898	4	2	-	-
9901	-	-	1900	2200
9902	-	-	1800	2200
10155	-	-	1200	2200
10171	3	4	-	-
10200	-	-	2150	1800
10312	2	1	-	-
10369	-	-	1710	1850
10370	4	4	1710	1850
10372	4	5	1888	1800
10383	2	3	-	-
10387	-	-	1900	1700
10394	-	-	1900	1700
10395	-	-	1900	1700
10398	2	3	-	-
10406	4	5	-	-
10408	2	3	2150	2200
10409	1	2	-	-
10455	-	-	1000	1800
10488	-	-	1500	2200
10663	-	-	2150	1800
10640	1	2	-	-
10641	-	-	1700	2200

Appendix H. Motorway Accidents Records

Table H- 1. IMN motorway accidents per trajectory

wegvak	van - tot	2018	2017	2016	2015	2014	2013	2012	2011	2010
A1 Li	5-10	22	35	42	42	56	53	61	73	43
A1 Re	5-10	41	26	50	74	81	50	36	44	66
A2 Li	30 - 35	42	36	48	96	77	47	65	77	47
A2 Re	30 - 35	19	20	23	32	16	20	10	16	23
A4 Li	0 - 5	54	68	44	49	44	48	45	83	63
A4 Re	0 - 5	50	84	61	53	42	44	78	49	62
A5 Li	10-15	12	18	6	8	5	-	-	-	-
A5 Li	15 - 20	6	6	1	4	1	1	-	-	-
A5 Re	10-15	8	14	7	6	2	1	-	-	-
A5 Re	15 - 20	14	12	9	6	7	2	-	-	-
A8 Li	0 - 5	68	55	56	52	50	46	33	39	26
A8 Re	0 - 5	41	72	71	46	40	15	25	30	30
A10 Li	0 - 5	29	30	24	36	39	52	45	42	34
A10 Li	5-10	23	27	22	15	20	15	26	29	17
A10 Li	10-15	70	58	58	52	70	64	81	86	50
A10 Li	15 - 20	53	69	58	58	64	77	78	74	42
A10 Li	20 - 25	99	108	71	84	87	80	104	100	65
A10 Li	25 - 30	48	31	34	37	29	41	25	41	16
A10 Li	30 - 35	62	62	64	46	51	99	50	58	37
A10 Re	0 - 5	23	23	24	17	18	42	42	26	40
A10 Re	5-10	25	29	20	20	24	20	25	16	19
A10 Re	10-15	97	114	125	132	132	134	100	82	75
A10 Re	15 - 20	91	69	75	75	120	88	46	60	60
A10 Re	20 - 25	83	69	63	75	61	71	82	85	57
A10 Re	25 - 30	63	73	51	37	51	42	75	79	52
A10 Re	30 - 35	35	25	26	24	18	23	26	22	23

Table H- 2. BRON accident records (2015-2017)

Location	hc van (km)	hc tot (km)	Aantal rijstroken	Ernstige Ongevallen(a)	Slachtoffer Ongevallen (b)	#Black spots	#Bijna-black spots	Assumed day cost (a) euros	Assumed day cost (b) euros
A1L	3.117	4.585	2	8	11	0	0	17323.7	5113.9
	4.585	5.725	3	0	0	0	0		
	5.725	6.942	4	1	2	0	0		
	6.942	8.96	3	2	3	0	0		
A1R	4.931	5.894	5	1	1	0	0	8933.3	2719.5
	5.894	8.995	4	3	5	0	0		
A2L	30.6	32.109	2	4	6	0	0	9494.2	3082.9
	32.109	32.749	3	1	1	0	0		
	32.749	34.182	4	0	0	0	0		
	34.182	35.646	2	0	0	0	0		
	35.646	37.373	3	0	1	0	0		
A2R	30.6	31.413	2	1	2	0	0	10508.0	2985.6
	31.413	31.966	1	1	2	0	0		
	31.966	33.935	4	1	1	0	0		
	33.935	36.712	2	2	2	0	0		
A4L	0	0.879	2	1	1	0	0	5213.6	2116.2
	0.879	4.739	3	2	5	0	2		
A4R	0.021	6.355	3	10	10	0	0	13208.3	2680.5
A5L	8.3	19.373	2	3	5	0	0	7154.8	2420.1
A5R	8.3	18.99	2	2	2	0	0	4769.9	968.0
A8L	0.525	2.65	2	1	1	0	0	5386.4	1093.2
	2.65	4.689	4	1	1	0	0		
A8R	0.527	2.417	2	6	7	0	2	19844.9	4602.8
	2.417	3.463	5	0	0	0	0		
	3.463	4.5	4	1	1	0	0		
A10SBL	12.591	17.277	4	7	11	0	0	20067.1	5430.1
	17.277	19.471	3	2	2	0	0		
	19.471	20.895	4	3	3	0	0		
A10SBR	15.385	21.2	3	7	8	1	0	12751.5	3805.7
A10SWL	20.895	22.938	2	5	5	0	0	19914.2	4939.7
	22.938	27.286	3	4	6	0	0		
A10SWR	21.2	27.4	3	10	17	3	0	20856.1	7195.6