Performance of Online Traffic Management in a Municipality

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TripService

Bachelor Thesis

Performance of Online Traffic Management in a Municipality

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Preface

This research will be my Bachelor Thesis, named “Performance of Online Traffic Management in a Municipality”. I did my internship at TripService, a relatively small company in Aalten. I came in contact with them via my supervisor, Oskar Eikenbroek. TripService gave me a lot of freedom to choose a subject for my research and informed me of problems or opportunities in their workfield to elaborate on. I chose to investigate the effectiveness of online traffic management, since this research would not only include traffic data, but also personal experiences from road users and conversations with project stakeholders, something that attracted me. During my time at TripService, I also did several tasks and was invited for meetings with various contractors and road operators, offering a great opportunity to get into contact with my future field of work. I was included in many aspects of the company and was able to learn a lot, and I could also really appreciate the team spirit within the company. I want to thank TripService a lot for the chances they gave me during the internship, and the memorable times they gave me.

I also want to thank Oskar Eikenbroek for getting me in contact with TripService and helping me in shaping this research, in both the research proposal and during the internship. The feedback was concrete and valuable for the final report.

Hoping this research could be of value for TripService and other parties, I look forward to what I will encounter in the future in the field of civil engineering.

Joris Ruiter

9th of July 2024

Table of Contents

Summary

This research evaluates the effectiveness of online traffic management (OTM) in informing drivers about diversions, analyzing road user behavior, and gathering feedback from road operators, users, and residents. TripService, specializing in digital traffic management, collaborates with major navigation providers and offers real-time traffic updates, map adjustments, and event traffic management. Online traffic management, another service provided, uses targeted online means like social media and Google Ads to inform specific groups about roadworks, aiming to improve traffic flow and reduce congestion. This study will develop a framework using Key Performance Indicators (KPIs) to assess OTM's effectiveness and provide recommendations for improvement based on recent project data.

Three case studies were used to analyze: the closure of Prinsenbrug in Haarlem, road construction on Van Muijlwijkstraat in Arnhem, and a directional closure of the A12 highway between Grijsoord and Waterberg. Each case involved different scales and types of roads under municipal and Rijkswaterstaat authority. The cases are analyzed using floating car data from the NDW Dexter portal, analyzing travel times and traffic intensity, especially during peak hours. The data shows how diversions and road closures affected traffic flow and congestion. Additional insights were gained from advertisement campaigns targeting affected commuters and from surveys conducted by TripService post-project. Expert interviews further contextualized the findings.

The assessment framework for Online Traffic Management (OTM) focuses on evaluating key performance indicators across three main areas: campaign reach, follow-up behavior and traffic changes, and communication clarity. For campaign reach, the framework looks at total views, clicks, the percentage of users informed by OTM, and the engagement of non-frequent travelers. Findings show that while the A12 project had significantly higher views and engagement, challenges remain in accurately estimating the percentage of the target audience reached. Follow-up behavior and traffic changes indicate that informed users are more likely to adjust their travel plans, such as changing routes, staying home, or altering travel times. Data from the A12 project revealed a 40% reduction in peak hour traffic intensity and effective detour route usage, suggesting OTM's positive impact on managing traffic flow during disruptions. Conversely, the Prinsenbrug project saw only a 10% reduction, highlighting varying effectiveness based on project scope and communication strategies. Overall, it can be seen that when online traffic management is used, road users are informed better and use the advised detour more frequently, while overall traffic decreases more significantly.

Experts emphasize that OTM can be particularly beneficial in municipalities where traditional methods may be less effective due to diverse road user types and more complex traffic environments. Suggested improvements include developing real-time dashboards to provide continuous insights into campaign reach and traffic behavior, enhancing the measurability and visibility of OTM's impact. This would help contractors and road operators make more informed decisions and improve the overall effectiveness of traffic management strategies. The study's results are project-specific, which should be considered when using the results. However, the framework offers a foundation for future OTM evaluations, though enhanced data collection and survey methodologies are necessary for more reliable insights.

1. Introduction

In today’s road closures in cities, managing traffic effectively is crucial to avoid congestion and minimize disruptions for residents. A common problem occurs when the detour routes advised by road operators, often indicated on the familiar yellow signs, conflict with the directions given by navigation systems, like Waze, Google Maps or Apple Maps. These apps usually direct drivers along the shortest route, or they take into account personal preferences, without considering the overall traffic flow or the impact on local neighborhoods. This can lead to increased traffic jams, especially during roadworks or closures.

It is essential to inform drivers about roadworks and preferred detour routes in advance. This allows them to make better travel choices, such as using different routes, changing their departure times, or opting for other forms of transportation. The main goal of this research is to evaluate how well online traffic management (OTM) by TripService informs drivers about road closures and detours.

TripService's online traffic management service aims to pre-inform commuters about traffic conditions and monitor real-time traffic situations. This service allows commuters to be informed and diverted via online channels and navigation systems, with real-time traffic monitoring through a dashboard. For municipalities, it is crucial to determine whether this service effectively manages traffic diversions and maintains a healthy traffic network with minimal disruption to residents.

This study aims to provide a clear assessment of OTM on secondary roads operated by the municipality, showing its importance and identifying areas for improvement. We will develop a framework using Key Performance Indicators (KPIs) to measure the effectiveness of these systems, using data from recent projects. In the data, we will look at how OTM affects driver behavior and traffic patterns. We will also gather feedback from road operators, drivers, and residents to understand the overall effectiveness of these systems. The findings will help inform TripService, contractors, and other stakeholders, enhancing the value and effectiveness of OTM in a municipality.

This research will primarily evaluate the effectiveness of online traffic management on the Van Muijlwijkstraat in Arnhem, the Prinsenbrug in Haarlem and the A12 between Grijsoord and Waterberg. The evaluation will utilize traffic data, surveys, interviews, and literature research to assess the impact and effectiveness of online traffic management. The final outcome will be a framework for assessing online traffic management in municipalities, ideally tested on the mentioned projects.

2. Research Background

2.1. Problem statement and research goal

As highlighted in the introduction, a significant issue is that diversion routes recommended by road operators and marked with physical signs can conflict with those suggested by navigation systems, which often direct users along the shortest path to their destination. These navigation systems may not account for what is best for the overall traffic network or local residents. It is therefore important to inform commuters before their trip, so they are aware of the roadworks and know about the advised detour routes, as preferred by the road operator or contractor. Additionally, some commuters not using navigation remain unaware of road blockages or closures until they encounter them, missing opportunities to use alternative transport modes, adjust their departure times, or cancel their trips altogether. This can lead to traffic network problems or disturbances for local residents.

The objective of this research is to evaluate the effectiveness of online traffic management in informing road users about these diversions. This involves assessing the impact of information on potential commuters, analyzing commuter behavior, identifying changes in the traffic network, and gathering feedback from road operators, road users, and local residents. The goal of this research is to conduct a performance assessment of online traffic management within a specific municipal project. It will inform TripService, road users, contractors and other parties about the performance of OTM in municipalities, highlighting its importance, or identifying areas for enhancement to boost its effectiveness and value in such projects. The research will result in the development of a framework for evaluating effectiveness through Key Performance Indicators (KPIs) and will ideally include the KPIs from recently completed projects.

2.2. Theoretical framework

The theoretical framework in the research proposal examined the travel behavior of commuters, focusing on route choice, the functions of Advanced Traveler Information Systems (ATIS), commuter behavior in response to route guidance, and problems associated with route guidance. A summary of this theoretical framework is given and the application of the framework in this research will be explained. By including the theoretical framework in the research, the goal is to ensure that the research will cover the subjects that are most relevant according to route guidance and travel behavior theory.

Commuters' route choices are influenced by several factors, with travel time being the most significant. Other factors include road type, congestion, and signage. Personal characteristics such as adventurousness and road familiarity also play a role. Drivers familiar with the road network are less likely to rely on navigation systems and more likely to find their own alternative routes. Additionally, commuters are more likely to divert from their usual routes if they are informed about congestion in advance. Many drivers rely on habitual routes based on routine travel, such as daily commutes, and may not regularly check route information (Khattak, 1993). Habitual traffic choice is influenced by past behavior, intention, and the current situation. Past behavior can be tracked via GPS data, while intention is harder to gauge and may require surveys. In this research, GPS data and survey data is

available to reveal the travel behavior and analyze the effect of online traffic management in a municipality. It is important to understand that the route choice is based on a lot of factors and cannot be awarded to a single cause.

ATIS provides commuters with traffic information, supporting their route, mode, and departure time choices. Information is disseminated through various channels such as television, radio, computers, and cell phones. ATIS systems are categorized into those that provide information before a trip, influencing decisions like switching transport modes or departure times, and those that provide real-time information during a trip, offering alternative routes (Polydoropoulou et al., 1996). Effective ATIS must be clear and consistent to prevent increased congestion. Online traffic management is an example of ATIS, and contains both the information before the trip, like the advertisement campaigns, and the information during the trip, via the traffic roadwork dashboard. This research, however, will only focus on the information before the trip.

Alternative routes used by commuters during road closures can lead to congestion on other parts of the network, affecting other road users. It's essential to monitor and communicate these changes to road users. Increased traffic in small towns or neighborhoods can cause nuisance and safety risks, so it is crucial to provide travel information that minimizes such impacts and prioritizes routes that avoid residential areas. Stakeholder preferences must be considered to address these issues effectively. Most of these factors will be taken into account during this research, with surveys and expert interviews giving background information about the project developments. The travel times on surrounding roads are also analyzed to give an indication of the congestions in other parts of the traffic network.

2.3. TripService

TripService specializes in the use of navigation systems, the influence of travel behavior, and digital traffic management. They provide advanced services and strategic collaborations with well-known navigation systems, including Google Maps, Waze, TomTom, and Apple Maps. Their services are designed to help road managers, contractors, and event organizers plan and manage traffic more effectively (TripService - Nationale Verkeer Expo, z.d.).

For road managers, TripService offers real-time updates on traffic conditions, roadworks, accidents, and other relevant events. This enables road managers to influence travel behavior directly, helping to avoid congestion and improve traffic flow. This can be done with a personalized traffic dashboard or via their free platform wegstatus.nl. For Event Organizers**,** TripService aids in managing traffic for events by integrating real-time traffic information into planning and management systems. This helps in optimizing routes to events, organizing parking efficiently, and managing visitor flows effectively, ensuring a smooth and safe experience for attendees.

Another service that TripService offers is map adjustments. For events, roadworks or faults in navigation systems, TripService can make adjustments in multiple navigation systems to for example implement a complete road closure for a certain period of time, designate a road for local traffic only or change certain routes permanently when they are indicated incorrectly in navigation systems. But the service that will be looked at in this research is Online Traffic Management.

2.4. Online Traffic Management

The online traffic management service (OTM) is going to be evaluated in this research. The goal of OTM is to inform traffic about the upcoming roadworks via online means. The service is typically used for large-scale projects like roadworks on highways, but it is also used in smaller projects, like the road closure of a regional road in a city (Online Traffic Management - TripService, 2024).

Informing is mostly done via Waze takeovers, messages and stories on Facebook and Instagram and Google Ads. The biggest advantage of informing via these online means with respect to other means, is the possibility to target very specific groups. For example, it is possible to target specific regions or target people who have a certain interest. Some of these groups are hard to inform in a different way, since they might travel not that frequently or don't live near the project area. This way, OTM can be a very effective way to inform road users, while it could also reach a new type of audience, increasing the reach of the campaign.

Next to informing about upcoming roadworks, online traffic management gives the possibility to make map adjustments in navigation systems, monitor traffic via the roadwork traffic dashboard showing the traffic situation in and around the project area, and conduct a post-trip analysis on the road users, to find out how travel behavior changed during the roadworks and what the commuters' experience was. The effectiveness of map adjustments will not be evaluated in this research, since these adjustments are done for almost every road closure, also when online traffic management is not used. The sentiment analysis is purely for feedback about the project and itself has no influence on the performance of online traffic management, although it could give some information. It is therefore used in this research as a data source and will not be evaluated itself.

2.5. Report structure

In the following chapters, the investigated cases will be introduced, as well as the experts that were interviewed, after which information is given about the data collection. The different data sources are explained, and for the traffic data specifically, the locations where data was collected are discussed. After the data collection, the data is analyzed and the results are discussed. Finally, an assessment framework is made where these results are used for, and from this, some recommendations are done.

3. Case Description

In this research, three cases will be evaluated, from which two are on regional (secondary) roads under the authority of the municipality and one is a highway under the authority of Rijkswaterstaat. The first case is the closure of the Prinsenbrug in Haarlem, which was closed from the 15th of March until the 30th of March in 2024. The second case is the road construction on the Van Muijlwijkstraat in Arnhem from Friday the 24th of February 2023 until November 2023. The last case is the road closure in one direction on the A12 between Grijsoord and Waterberg from the 31st of July until the 9th of August 2023.

3.1. Prinsenbrug

The Prinsenbrug is a traffic bridge over the Spaarne in Haarlem. It is used by motorized traffic, cyclists and pedestrians, and is part of the N200 through Haarlem. The N200 is an important traffic connection between Knooppunt Rottepolderplein and the city of Haarlem, and especially the train station. There are only limited options to cross the Spaarne: the Schoterbrug in the north and Lange Brug and Buitenrustbrug in the south are the closest bridges with lanes for motorized traffic in both directions, as shown in figure 3.1.

Figure 3.1: *Overview of detours and bridges in Haarlem*

From the 15th of March 2024 after the afternoon rush hour until the 30th of March 2024, the bridge was closed for all traffic in both directions due to maintenance work (Mariette, 2024). Traffic was advised to make use of the following detour routes, also shown in red in figure 3.1:

- Traffic between Centre/North and the A9 followed a diversion over the Schoterbrug
- Traffic between Zandvoort and the A9 followed a diversion over the N205 and Prins Bernhardlaan (Buitenrustbrug)
- Pedestrian, bicycle and moped traffic followed a diversion over the Catharijnebrug

During the period of the maintenance work, a ferry was deployed as well, running back and forth between 7am and 6pm from 16 to 30 March, which could transport pedestrians and disabled. Dura Vermeer was the main contractor in the project, commissioned by the municipality of Haarlem. Dura Vermeer was responsible for the maintenance of the bridge, but also for diverting traffic.

Maurice Leenen, traffic advisor at Dura Vermeer, was responsible for traffic around the closed bridge. He studied Spatial Development and Mobility in Almere and did his graduation project about cycling and pedestrian behavior around roadworks at Dura Vermeer. After that, he did a traineeship, and gained experience as traffic manager, infrastructure manager and infrastructure planner. Right now, he gets involved in various projects, like he also was with the Prinsenbrug in Haarlem. He is one of the experts interviewed in this research, and his answers can be found back in appendix IV, just like the answers of the other experts.

Traffic Service Nederland (TSNed), a company for 25% owned by Dura Vermeer, placed yellow detour signs along the road according to the guidelines. Next to that, Dura Vermeer chose to deploy Online Traffic Management by TripService. Maurice Leenen came across TripService through a traffic exhibition in Houten, and that triggered him to look into this. Maurice suggested the environment manager of the project at Prinsenbrug to use Online Traffic management. TSNed also gets data from TripService, which already makes some sort of connection, and Dura Vermeer used OTM on this project as a kind of pilot. The municipality of Haarlem was keen to try OTM and therefore, a budget was also allocated for this.

Dura Vermeer steered very much on preparation and on the environment, making sure that people were aware of the works in advance, so that on the very days the bridge was closed, people were less inconvenienced and had time to adjust their behavior, prior to the works. In the campaign, Dura Vermeer stressed that commuters not could, but had to follow a diversion route, as the bridge was closed and only taking other routes was possible. They wanted to convince people that it would be chaos and to let them drive via the diversion route as that works best. People were also advised to stay home, choose other means of transport, take public transport, and otherwise follow a detour route.

Figure 3.2: *Advertisement about the closure of the Prinsenbrug*

For the Prinsenbrug, Dura Vermeer chose to only deploy an information campaign, and decided not to use a dashboard and do a post-trip analysis. The information campaign was done on Waze, Spotify, Facebook and Google Ads. An advertisement like in figure 3.2 could be seen, with a link to the Bouwapp when people clicked on the advertisement. The Bouwapp was used by Dura Vermeer to communicate with the road users and local residents.

An overview of communication in the Prinsenbrug project is shown in figure 3.3. The client is the municipality of Haarlem, the contractor is Dura Vermeer Infra Regio Noordwest. For the

maintenance work of the bridge, there were a few subcontractors, but most work was done by Dura Vermeer itself. Maurice Leenen hired both TripService and Traffic Service Nederland, who both helped in informing the road user. Traffic Service Nederland did that via road signage, TripService via online advertising and social media.

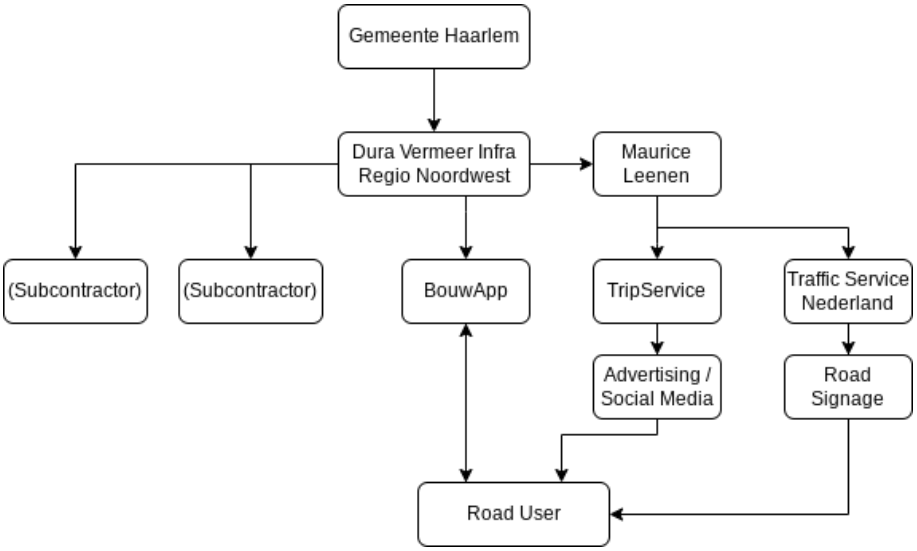

***Figure 3.3**: Communication overview Prinsenbrug*

When asked about the importance of the stakeholders, Maurice Leenen answers that residents and business associations were included and there was a lot of participation from the municipality of Haarlem. It was insurmountable that people living there would be inconvenienced by the closure, and there are many businesses around the Spaarnseweg that would get impacted.

The municipality of Haarlem wanted to carry out the project in phases so the road was still accessible, because it is an important traffic artery. What that would look like and how that could be realized was worked out by Dura Vermeer. This ended up with a number of eight phases, which were not entirely desirable for traffic flow and road safety, because with each phasing there is more complexity. It makes it hard to understand for the road user, since it is more complicated to follow 8 phases with different dates. That is why it was decided to close the bridge completely but briefly. This causes more inconvenience, but then the work is also over sooner. In that, traffic flow and safety for both road workers and road users are prioritized.

3.2. Van Muijlwijkstraat

The Van Muijlwijkstraat is a road that connects the Velperweg to the Velperplein, which is part of an important route around the city center. The train station of Velperpoort is also located on the Van Muijlwijkstraat. The street is partly a one-direction street, which is the part from the Velperweg to the Bloemstraat. The part between Bloemstraat and Velperplein is a two-direction street. Next to that, there are separate trolley bus lanes, mostly in both directions, and there are separate cycling lanes. The Van Muijlwijkstraat was known as “the ugliest street in Arnhem”, which encouraged the municipality to redesign this street, with more green and more space for walking and cycling (Arnhem, 2023).

***Figure 3.4**: Overview of the detours and streets in Arnhem*

In the project, there were multiple phases with major traffic disruption. The campaign by TripService was focused on the project phase starting from the 27th of February 2023. During this period, traffic on the Velperweg was advised to use the IJssellaan and the Johan de Wittlaan, while traffic to the Hommelstraat was advised to use the Spoorwegstraat. The diversion plan can be found in Appendix I. The contractor in this project was NTP, while Save Traffic Nederland was responsible for the yellow detour signs along the road.

Edwin Leenders was the project manager of this project. He was involved in making EMVI plans (Most Economically Advantageous Tender), and after the tender was awarded, was also involved in the preparation and execution. Online traffic management can be included in such an EMVI as an added value, but it is up to the client to choose if it will be used in the project. The municipality of Arnhem was enthusiastic about the use of OTM, since they wanted to inform the road users in the best possible way. The Van Muijlwijkstraat is, just like the rest of the city, a crowded area in terms of traffic, and with informing the road user well, the municipality hoped to minimize congestions.

***Figure 3.5**: Advertisement about the closure of the Van Muijlwijkstraat*

The goal of the Online Traffic Management in this project was that traffic would be guided on navigation and traffic could be steered. This would allow traffic to take other routes to relieve Van Muijlwijkstraat. For this project, a campaign was deployed via Waze, Facebook and Google Ads. By clicking on the advertisement, like shown in figure 3.5, people were sent to the website of NTP with more information about the project. A sentiment analysis was done afterwards by TripService, to gain feedback and information about the choices of road users.

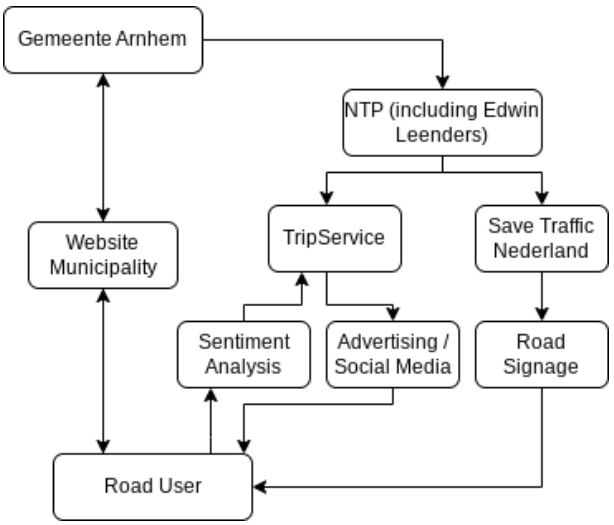

Figure 3.6: *Communication overview Van Muijlwijkstraat*

Figure 3.6 gives an overview of the communication in the Van Muijlwijkstraat project. The municipality commissioned NTP to execute the project. They hired TripService and Save Traffic Nederland to inform road users about the roadworks via advertisement and road signage respectively. The road user was able to ask questions on the website of the municipality and give feedback via the sentiment analysis done by TripService. Execution of the work itself was mainly done by NTP.

When asked about priority of the road users, Edwin Leenders answers that buses were post important, because they should not be delayed. Pedestrians and cyclists were second most important and cars third. Between safety, residents, road users, it's always a bit of customisation. If there are complaints from one party, the situation can be adjusted a bit.

3.3. A12 Grijsoord-Waterberg

The A12 is a national highway in the Netherlands, starting in Den Haag and continuing to the German border. It is one of the most important connections between the west and the east of the Netherlands and between Knooppunt Grijsoord and Knooppunt Waterberg, it has three lanes in both directions (*A12 (Nederland) - Wegenwiki*, z.d.).

From the 31st of July 2023 at 5:00 until the 9th of August 2023 at 4:00 the A12 was closed in one direction from Knooppunt Grijsoord to Knooppunt Waterberg (Rijkswaterstaat & Ministerie van Infrastructuur en Waterstaat, 2023). During this closure, there was major maintenance on the road, as part of multiple projects in the region Arnhem-Nijmegen assisted by the regional traffic management team. An overview of these projects is in Appendix I. Traffic was advised to alternative routes over a highway by signs next to and above the highway. Rijkswaterstaat was the client in the project, while the regional traffic management team was set up to make decisions about closures, diversions and pre-announcements. The location of Knooppunt Grijsoord and the advised detour routes are outlined in figure 3.7.

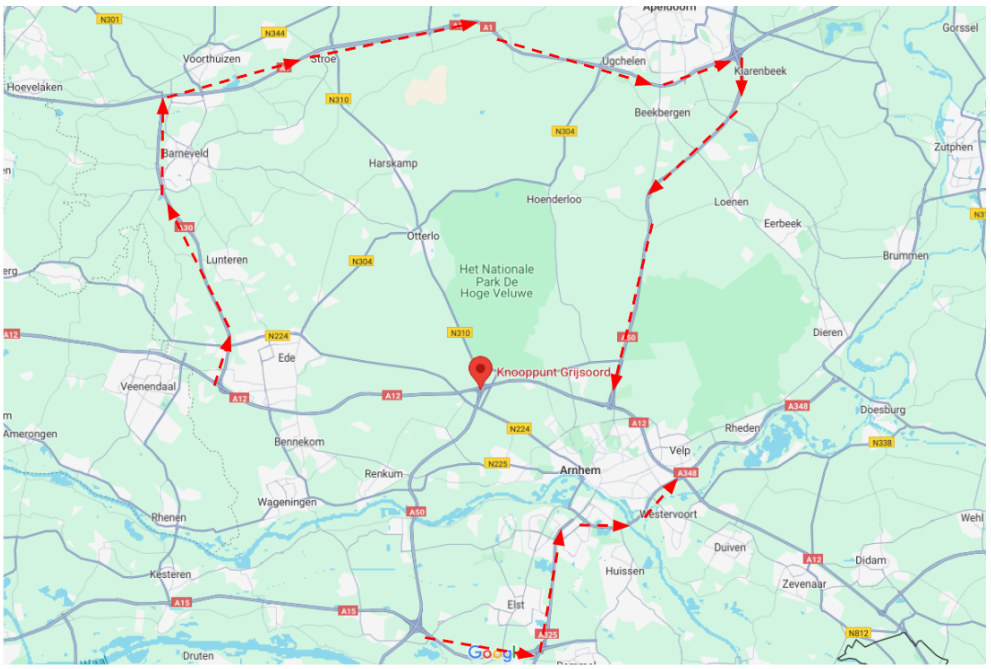

***Figure 3.7**: Overview of the detours for th A12*

Chairman of the regional traffic management team was Alex Smienk, who is a traffic advisor and project manager, previously with Rijkswaterstaat, but now as self-employed. The reason for the regional traffic management team to deploy Online Traffic Management was to maximize coverage. The diversion routes were large-scale diversion routes, and it was expected that Arnhem would also be very busy due to local diversions and cut-through traffic. They wanted to avoid precisely that, which is why they wanted to reach as many people as possible through social media and advertisements, as well as through other service providers.

***Figure 3.8**: Advertisement about the closure of the A12 Arnhem*

For the campaign, advertisements were placed on Waze, Facebook and Google Ads. By clicking on the advertisement, people were directed to the website of Rijkswaterstaat showing an overview of projects they work on. From the regional traffic management team, it was particularly chosen to do the pre-announcements regionally as well, given the amount of major works and events in the area. This was 4 weeks before the roadworks and 2 weeks before the roadworks. For traffic on the A12 itself, there was also a pre-announcement 2 weeks in advance about the closure.

Next to that, a sentiment analysis was conducted, which gave insight into what road users did and how they experienced the road closure. A complete road closure was chosen in order to do the work properly, so the stakeholder priority was from the contractor's perspective and for the safety of the road workers. In addition, the municipality of Arnhem and major attractions in Arnhem were also taken into account by large-scale diverting as much as possible, keeping local residents and local interests in mind.

4. Data Collection

4.1. Data description

4.1.1. Floating car data

To know how the traffic situation changed during the road constructions in all cases, it makes sense to look at traffic data. The traffic data used in this research is obtained from Dexter, a portal from the Nationaal Dataportaal Wegverkeer (NDW). In Dexter, it is possible to explore and export travel time data, speed data and traffic intensity data on various roads throughout the Netherlands. In this research, most of the data comes from graphs created in Dexter, which can be chosen for a specific location in a specific period of time. The traffic data, which could be either the travel time or traffic intensity, is then shown in (average) per hour. In this research, the focus is on peak hours, since these are the moments that could disrupt traffic most significantly. There are also graphs made showing daily averages of traffic intensity using exported data from Dexter.

Travel time data is available on the main traffic arteries inside and outside the cities and is given in seconds. Part of these arteries are amongst others the Van Muijlwijkstraat, the N200 over the Prinsenbrug and the various important roads through Arnhem as well as Haarlem. The information is shown for a particular route, rather than a measuring point, since the travel time can only be shown for a route segment, while a measuring point on itself cannot show travel time data. A longer route will probably show a larger travel time, but the percentage of increase or decrease makes it possible to compare the travel time data to other routes. Traffic intensity gives valuable information about the behavior of commuters during the road constructions, since it could show exact numbers of vehicles per hour that take a particular route, unlike travel time data, which can only give an indication whether or not the road became more congested. However, traffic intensity data is available on fewer locations, only on highways and important national roads. This makes it more difficult to see on which roads traffic increased or decreased or whether or not commuters decided to stay home, changed mode or departed on a different moment, especially for the Van Muijlwijkstraat and Prinsenbrug project.

Nevertheless, the A12 Grijsoord-Waterberg project can be used to look for relations in travel time and traffic intensity, or at least show what the travel behavior is during road construction on a highway. These relations or findings in travel behavior can be compared to the Van Muijlwijkstraat and Prinsenbrug project, to show possible differences between use in a municipality or on a highway. Next to that, the closure of a roundabout on the N271 in Mook is analyzed as a situation where no Online Traffic Management is used. In this chapter, the locations for data collection are identified and explained. The obtained data can be found in appendix V, appendix VI, appendix VII and in chapter 5, where the results will also be analyzed.

4.1.2. Advertisement data collection

From all three cases, there is data available about the reach and the engagement of the advertisements that were part of the online traffic management campaign. This data might

help to support findings in the information provision to road users. In this chapter, the target groups for the advertisement and social media campaigns are explained. The reach and engagement numbers of the campaign can be found in Appendix II.

The Facebook advertisements are shown both as messages and stories in Facebook and Instagram. The Google Display advertisements can be seen in apps that are available in their Google Play Store and on websites like Marktplaats.nl and Buienradar.nl. The Waze advertisements are shown as “Takeovers”, where stationary drivers receive a notification in Waze about the upcoming road constructions.

4.1.3. Survey collection

The surveys used in this research have been conducted just after each campaign by TripService, as part of their sentiment analysis. The questions in these surveys can be found in Appendix III and concern topics like awareness of the road construction, response behavior from this road construction and opinions about the project and communication.

The survey collection will be split into two parts: information about awareness of and response to the constructions, and sentiment in the project, including a rating of the respondents about communication. The results of the survey analysis are integrated in chapter 5.

4.1.4. Expert interview

For each case, an expert interview has been conducted, to gain more information about the project in various aspects, like planning, communication, observed traffic change, etcetera. The questionnaire and answers can be found in Appendix IV. The experts have been introduced in their respective cases in chapter 3. This chapter will not elaborate further on the expert interviews. The answers in the interviews are used to support or explain certain results or findings in this research.

4.1.5. Literature research

Literature provides valuable insights that may not be obtainable through data, surveys, or interviews, offering background information and contextual understanding of patterns found in research. However, it was decided to mainly focus on the other data available, since this is unique data available for the research about OTM in a municipality. A little literature is used to find relations between the increase in travel time and the increase in traffic intensity, while for the cases, background information mainly comes from news articles or official websites. There has not been literature research about other researches concerning online traffic management, although it could have been a valuable addition.

4.2. Locations Floating Car Data

4.2.1. A12 Grijsoord - Waterberg

The A12 was closed from the 31st of July until the 9th of August in one direction from Knooppunt Grijsoord to Knooppunt Waterberg. The data analysis will be done in the period

from the 17th of July until the 20th of August, to be able to compare the situation during the road closure to the situation in the two weeks before, and to also see what happened in terms of traffic situation after the road closure. On the A12 and A50 highway, data about traffic intensity is available, giving more information about the increase or decrease in traffic than when travel time data is used. Figure 4.1 shows an overview of the location of the closed A12 road segment and the detour routes.

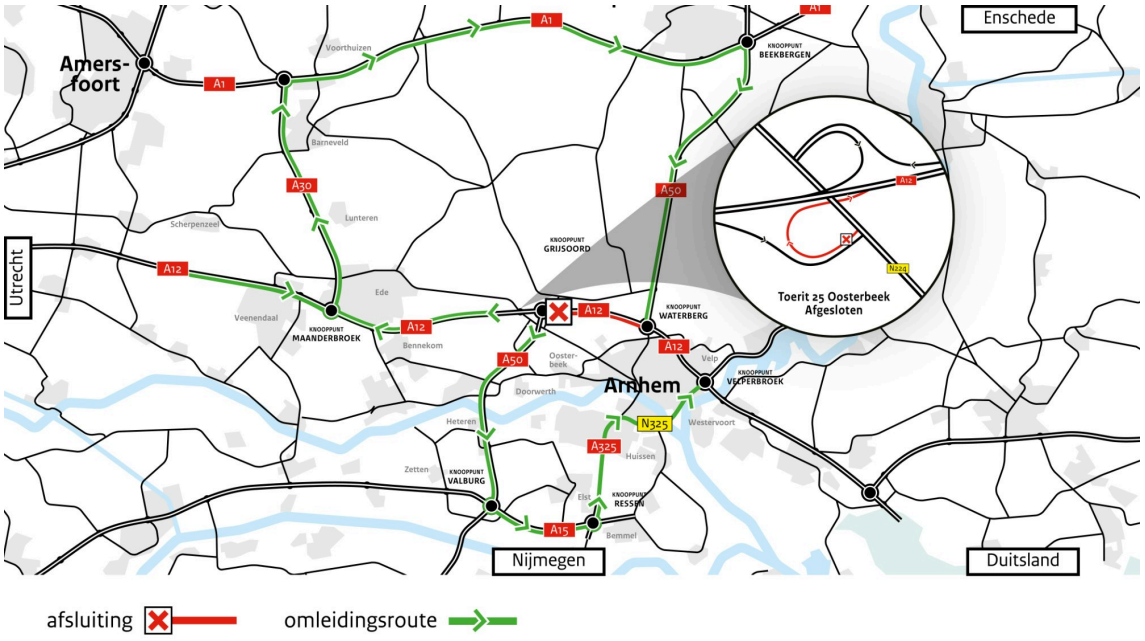

Figure 4.1: Detour routes for A12 Grijsoord-Waterberg closure
(Rijkswaterstaat & Ministerie van Infrastructuur en Waterstaat, 2023)

The A12 was closed between Knooppunt Grijsoord and Knooppunt Waterberg, and two detour routes were advised. One follows the A30 beginning at Knooppunt Maanderbroek, and then via the A1 over the A50 back to Knooppunt Waterberg, the other follows the A50 from Grijsoord to Knooppunt Valburg and runs via the A15 and A325/N325 to Knooppunt Velperbroek. According to Alex Smienk, the reason for designating those routes was the fact that they were part of a calamity scenario, which can be used when there are traffic incidents on the A12. Since traffic had to go somewhere during the road closure and cut-through traffic was undesired, these routes were chosen.

During the project, cut-through traffic was observed on various roads, creating congestion and longer travel times. According to Alex Smienk, these roads were mainly in Arnhem, but there might also be some provincial roads that could have experienced cut-through traffic. The most noticeable shortcut routes were the access roads to Arnhem, like the N224, while also different attractions, like the Burgers Zoo and Openluchtmuseum, but also the hospital, were less accessible. For the shortcut routes, it makes sense to look at the exit points on the highway before the road closure, like Afslag Oosterbeek and Afslag Renkum, and the entrance points on the highway just after the road closure, like Afslag Arnhem-Noord and Afslag Schaarsbergen, where increases are expected due to cut-through traffic. Figure 4.2 shows four different study areas, where different measuring points were chosen to see how traffic changed approaching Knooppunt Grijsoord or driving away from Knooppunt

Waterberg. Appendix V zooms in on these study areas, giving a better understanding of where the measuring points are and what they indicate.

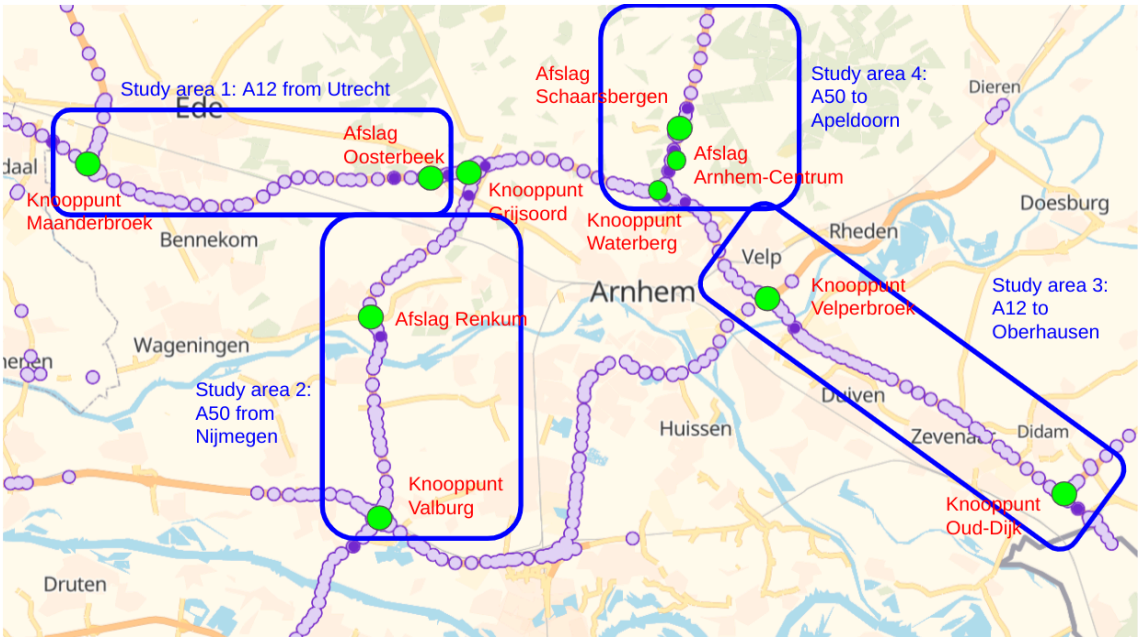

Figure 4.2: Study areas for

The graphs on study area 1 will show how traffic on the A12 decreased when approaching Knooppunt Grijsoord and graphs on study area 2 will show how traffic on the A50 decreased approaching Knooppunt Grijsoord. The graphs on study area 3 will show how traffic increases on the A12 to Germany from the A50, from Afslag Arnhem-Noord and after Knooppunt Velperbroek. In study area 4, the traffic increase of the A50 from Knooppunt Waterberg is analyzed before Afslag Arnhem-Centrum, between Afslag Arnhem-Centrum and Afslag Schaarsbergen and after Afslag Schaarsbergen.

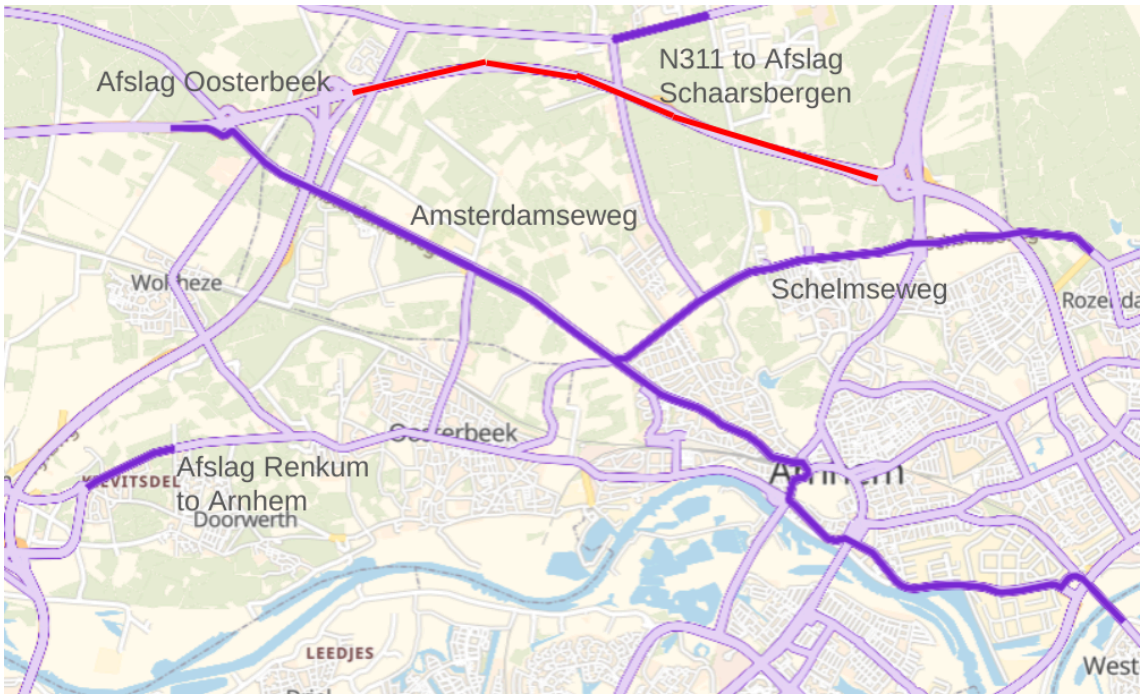

Figure 4.3: *Measuring points for shortcut routes through or around Arnhem*

Next to the locations on highways, four shortcuts through or around Arnhem are analyzed, shown in figure 4.3. The first one is a road segment from Afslag Renkum in direction of Arnhem, the second one is a route from Afslag Oosterbeek to Westervoort, a route that mainly consists of the Amsterdamseweg, which was expected to be a shortcut route, the third route is from the Amsterdamseweg to Rozendaal via the Schelmseweg, connecting the Amsterdamseweg to Afslag Arnhem-Noord, and the last one is a segment of the N311, which runs parallel to the closed part of the A12 and connects Afslag Oosterbeek and Afslag Schaarsbergen.

Cut-through traffic from Utrecht to Germany on the A12 is expected to have used Afslag Oosterbeek and follow the Amsterdamseweg and/or the Schelmseweg. Cut-through traffic from the A50 from Nijmegen to either the A50 to Apeldoorn or A12 to Germany is expected to have used Afslag Renkum. Commuters taking a shortcut from the A12 from Utrecht and A50 from Nijmegen to the A50 to Apeldoorn are expected to have used the N311 to Afslag Schaarsbergen.

4.2.2. Prinsenbrug Haarlem

The Prinsenbrug was closed for little more than two weeks, from March 15th until March 30th. In this period, no cars, buses, cyclists, pedestrians or other traffic was allowed on the bridge. The time frames in which data is collected starts on the 4th of March and ends on the 7th of April. This way, it is possible to see the traffic situation before and during the road closure. During the road closure, an increase in travel time on the alternative routes is expected compared to before the closure.

Figure 4.4: *Measuring point travel time Haarlem*

With the Prinsenbrug closed, commuters should find another way to cross the Spaarne. As mentioned by Maurice Leenen, two detour routes were prepared for motorized traffic, with physical yellow signs directing traffic. Traffic between the A9 (in the east) to the center or north of Haarlem was directed over the Schoterbrug, while traffic between the A9 and Zandvoort or the south of Haarlem was directed over the N205-Buitenrustbrug via the Prins Bernhardlaan (Mariette, 2024). The Prinsenbrug carries a two-lane road, and according to the guidelines for detour routes, the advised detour routes should be at least equivalent to the two-lane road over the Prinsenbrug. The N205 and Prins Bernhardlaan can be seen as equivalent roads, while the Schoterbrug, as a one-lane road, is not equivalent, but used as an alternative route nonetheless, since it was expected that commuters would use this route either way. These two routes are included in the analysis.

Next to these two routes, the two bridges close to the Prinsenbrug, the Waarderbrug and the Catherijnebrug, are analyzed, since both are likely to be used by cut-through traffic. The Waarderbrug is a small bridge, where motorized traffic can cross the bridge in both directions in turns, but where cyclists can always use both directions (Wikipedia, 2024). The route was not appointed as a detour route, but since it is located near a detour route, it makes sense that the bridge could be used by diverted traffic. The Catharijnebrug was appointed as a detour route, but only for cyclists and pedestrians. But since the bridge is closely located to the Prinsenbrug and easily accessible from the N200, which is the road over the Prinsenbrug, cut-through traffic could be expected on the bridge. Similar to the Waarderbrug, motorized traffic can cross the bridge in both directions in turns.

For these routes, shown in figure 4.4, only travel time data is available, which means that an increase in traffic volume can be suggested, but not proved, since an increase in travel time data can be caused by other factors than only the road closure. Nevertheless, the traffic intensities are estimated in chapter 5 using calculations and assumptions.

***Figure 4.5**: Measuring points traffic intensity Haarlem*

There are a few access routes in Haarlem that have information about traffic intensity: the N200 from and to Zandvoort, the A200 to Oudeweg and to Amsterdamsevaart and the N205 to the Buitenrustbrug. The exact locations are marked in dark purple in figure 4.5 and all of

the directions are shown on the map. The locations might indicate whether total traffic intensity due to the closure of the Prinsenbrug increased, decreased or remained the same. The N205 to the Buitenrustbrug and the A200 to the Oudeweg are also used for estimating the traffic intensities on the Schoterbrug, Buitenrustbrug and Prinsenbrug.

4.2.3. Van Muijlwijkstraat Arnhem

The timeframe of obtained data is chosen from the 13th of February until the 12th of March. The new phase road construction started on the 24th of February and the announcement campaign from TripService ran from the 17th of February until the 23th of February. The timeframe shows the situation before and during the road constructions and could show differences in traffic between those periods.

For the Van Muijlwijkstraat Project, the routes chosen are the Velperweg, the IJssellaan and Johan de Wittlaan, the Wichard van Pontlaan and the Huijgenslaan. The reason for choosing the Velperweg is that the Velperweg can be seen as the extension of the Van Muijlwijkstraat as the route from the A12 highway or the N785 to the center of Arnhem. It is likely that most commuters on the Van Muijlwijkstraat originate from the Velperweg. The reason for choosing the IJssellaan and the Johan de Wittlaan was that this route as a diversion route has a high capacity, and therefore it was also provided with detour signs. The Wichard van Pontlaan is also part of the diversion route, connecting the Velperweg to the IJssellaan. The Huijgenslaan connects the Velperweg to an alternative route to the Apeldoornsestraat in the west.

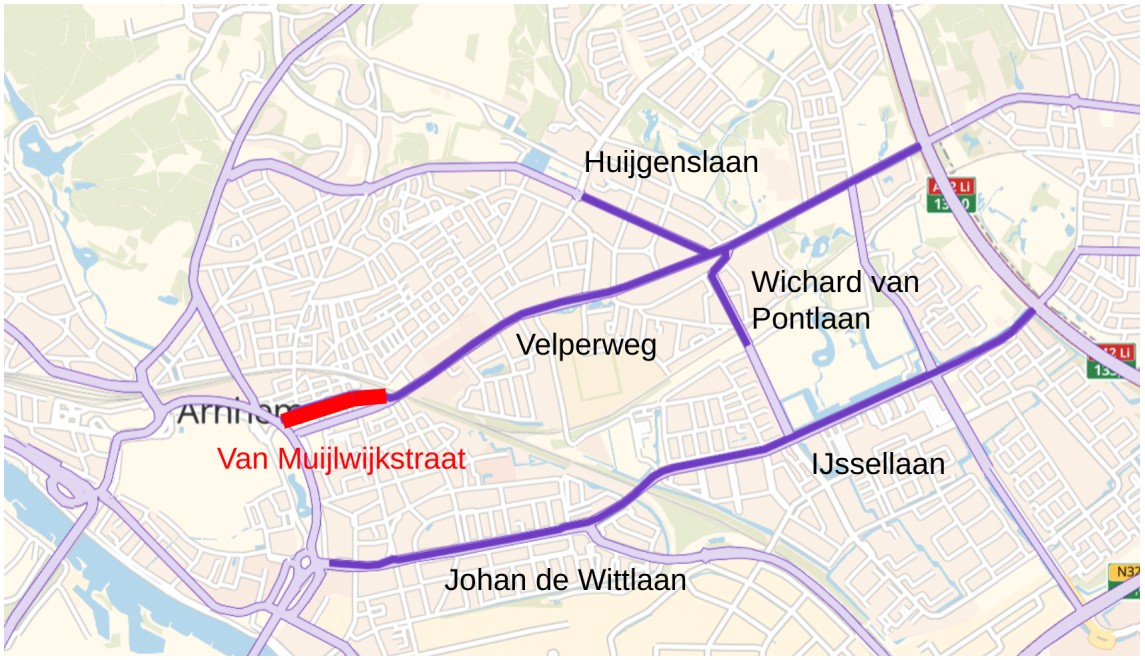

Figure 4.6: *Measuring points travel time Van Muijlwijkstraat Arnhem*

For these roads shown in figure 4.6, only travel time data is available, which means that it is possible to show possible congestions or traffic jams. These congestion could indicate increases in traffic intensities, but are uncertain and could also have other causes, like road accidents. It is also possible that the traffic intensities increased, but did not affect the travel time, since the road capacity was not exceeded. Therefore, the travel time data gives an indication of the traffic intensity, but no direct conclusion.

4.2.4. N271 Mook

In Mook, road constructions were done on a roundabout on the N271, which is the intersection with the Groesbeekseweg. The whole roundabout was closed from the 2nd of April until the 10th of April. Through traffic in northern and southern directions on the N271 was advised to travel via the A73 and N271, traffic from Gennep towards Groesbeek via the N843 and traffic from Malden towards Groesbeek via the N271, A73 and N843 (*Werkzaamheden N271 | Gemeente Gennep*, z.d.).

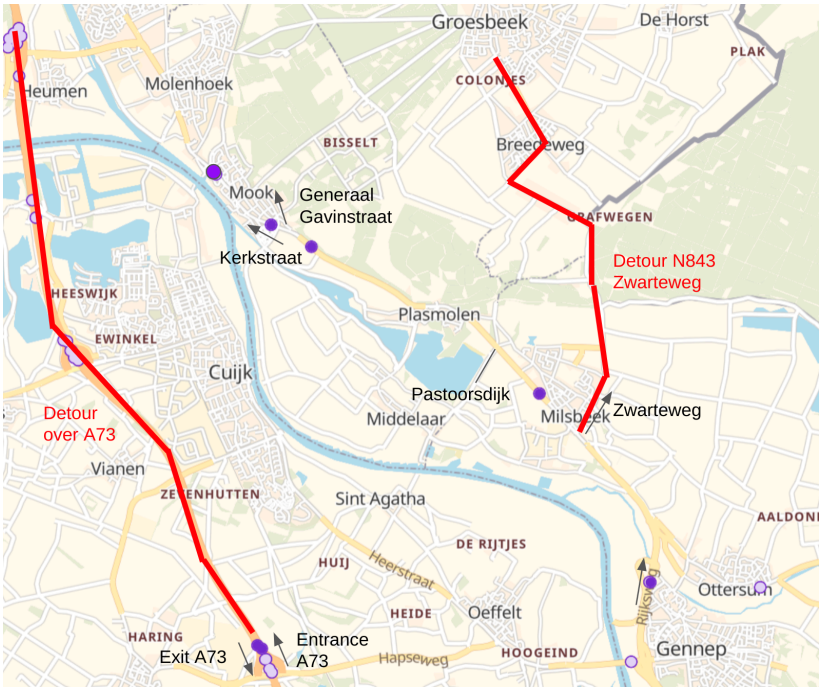

Figure 4.7: *Measuring points and detours N271 Mook*

Figure 4.7 shows where the measuring points are. The period in which data is collected is from the 25th of March 2024 until the 21st of April 2024. The intensities on the entrance and exit on the A73, on the N271 between Gennep and Zwarteweg, Zwarteweg and Pastoorsdijk, Pastoorsdijk and Generaal Gavinstraat, and in Mook just before and after the roundabout are analyzed. This gives the possibilities to see increases or decreases in traffic from the highway, to the Zwarteweg, to the Generaal Gavinstraat and other shortcuts.

4.3. Target Group Advertisements

In most advertisement targeting, geofences are used, where the advertisements are only shown in a certain area, which is in most cases a radius around a location pin. In Ẁaze, the advertisement was shown to commuters with an active route through the area. Geofences can be used in Waze, Facebook and Google Display. Next to that, it is possible to target groups in Facebook and Google Display using certain interests.

4.3.1. A12 Grijsoord-Waterberg

In the A12 Grijsoord-Waterberg campaign, the advertisement campaign included Waze, Facebook and Google Display. The geofence in Waze had a radius of 10 kilometers around Arnhem. The geofence in Facebook had a radius of 15 kilometers, while also vacation traffic

was targeted, since the road constructions took place in the summer holidays. The geofence in Google Display had a 25 kilometers radius and also included people interested in locations inside this geofence and vacation traffic in the Netherlands.

In the expert interview, Alex Smienk mentioned that they also targeted freight traffic, since this group mostly uses the same route, and the A12 is a frequently used road for freight traffic to Germany. Targeting vacation traffic was hard, since this group cannot always be identified in Facebook and Google Display, but it was a big group that would have a significant share in the traffic composition. One of the locations inside the geofence where targeted was Burgers Zoo, where they also informed travelers via the website of Burgers Zoo itself. The last goal mentioned by Alex Smienk was trying to limit rush hour traffic.

4.3.2. Prinsenbrug Haarlem

The advertisement campaign around the closure of the Prinsenbrug in Haarlem included Waze, Spotify, Facebook and Google Display. The geofences in Waze were set on the wide environment, while the target group on Spotify is not known. The geofence in Facebook had a 7 kilometer radius around Haarlem, while also through traffic on the N200 was targeted. The geofence in Google Display also had a radius of 7 kilometers, and other target groups were people interested in locations inside of this geofence and people interested in locations/events like Zandvoort Paasraces, Circuit Zandvoort, Haarlem Centrum and OV Haarlem (Kiss and Ride).

According to Maurice Leenen, these locations were potentially the most attractable places. The Zandvoort Paasraces was a big event, starting in the weekend where the road constructions finished. It was also important to target people that wanted to go to or leave Station Haarlem, since it is 500 meters away from the Prinsenbrug and connected to the N200. Dura Vermeer also looked into including waterway traffic, but this was not included as a target group since there was very little recreational waterway traffic.

4.3.3. Van Muijlwijkstraat Arnhem

For the Van Muijlwijkstraat, Waze, Facebook and Google Display have been used. In Waze, the geofence was set on 2 kilometers around train station Arnhem Velperpoort. In Facebook, the geofences were set on the neighborhoods of ‘t Broek, Spijkerkwartier, Presikhaaf, Velperweg, Geitenkamp, Monnikenhuizen, Klarendal and Sint Marten, and targeted both local residents and through traffic. The geofences in Google Display were set on the neighborhoods of Spijkerkwartier, Velperweg, Geitenkamp and Klarendal and targeted local residents and people interested in locations or events in that area.

According to Edwin Leenders, it was decided to not target cyclists and pedestrians specifically but completely focus on motorized traffic. The information in the advertisement campaign was mostly focused on alternative routes, rather than staying home, switching modality or departing on a different time, since the road constructions were active for a long period of time, and changing commuters’ behavior this drastically would be very hard and was therefore not issued.

5. Results

5.1. Route Choice and Traffic Analysis

The data collected from Dexter is analyzed for the routes (travel time) and measuring points (traffic intensity) chosen in chapter 4. The changes in traffic intensity and travel time are shown in various graphs, from which some conclusions can be drawn. There is not always a clear conclusion possible, mainly in the travel time data, but it is possible to find trends and make assumptions.

5.1.1. A12 Grijsoord-Waterberg

The locations of the traffic intensity measuring points for all 4 study areas can be found in Appendix V, together with a table where the results of the graphs are given as traffic intensity values and the increase in traffic intensity on detours and shortcuts and decrease on highway segments is clarified. The graph in figure 5.1 shows the traffic intensities in vehicles per hour on the locations on the A12 from Utrecht in the east direction, starting just before Knooppunt Maanderbroek. The results show how traffic decreased when approaching Knooppunt Grijsoord.

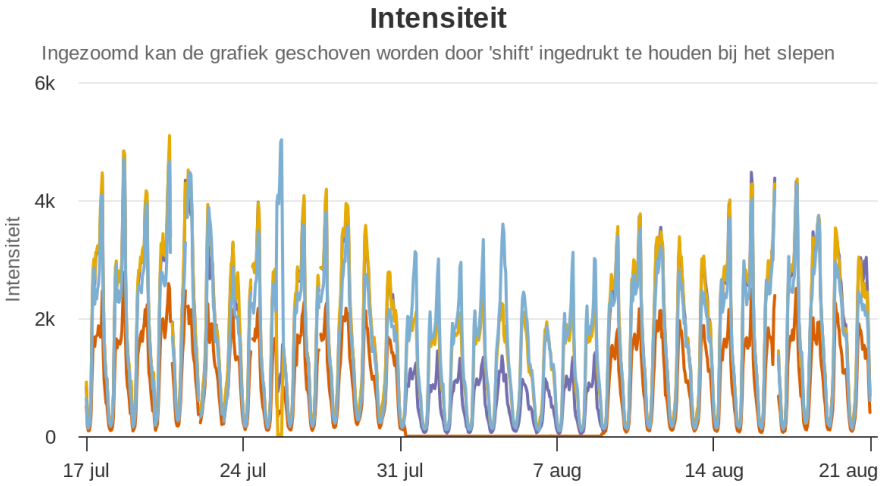

Figure 5.1: *Study area 1: Blue: before Knooppunt Maanderbroek, Yellow: before Afslag Oosterbeek, Purple: after Afslag Oosterbeek, Orange: after Knooppunt Grijsoord*

In the approach of Knooppunt Grijsoord on the A12 from Utrecht, it can be seen that in the weeks before the road closure, the traffic intensity before Knooppunt Maanderbroek up to Knooppunt Grijsoord is approximately equal during peak times at the measuring locations, while after Knooppunt Grijsoord, the traffic intensity is a little lower. During the road closure, the overall traffic intensity before Knooppunt Maanderbroek, seems to decrease. Before the A12 closure, the daily peaks had an intensity of approximately 4000 vehicles per hour, while during the road closure, this peak decreased to approximately 3000 vehicles per hour, a decrease of 25%. Traffic between Knooppunt Maanderbroek and Afslag Oosterbeek decreased from approximately 4000 vehicles per hour to 2000. From this, it can be derived that approximately 1000 vehicles per hour took the detour via the A30. After Afslag Oosterbeek, the traffic intensity on the A12 decreases even more, to peaks of approximately 1500 vehicles per hour. This indicates that with respect to the situation before the A12

closure, more vehicles exit the A12 at Afslag Oosterbeek, whereas before the road closure, this percentage was significantly lower. It can therefore be said that a significant part of traffic, around 500 vehicles during peak times, exited the A12 and used regional roads, while normally using the A12.

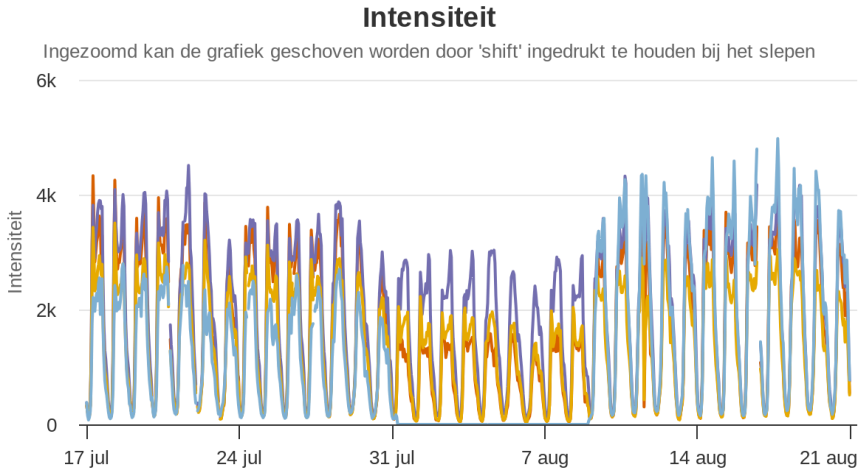

Figure 5.2: *Study area 2: Purple: before Knooppunt Valburg, Yellow: before Afrit Renkum, Orange: after Afrit Renkum, Blue: after Knooppunt Grijsoord*

The graph in figure 5.2 shows that in the weeks before the closure of the A12 between Grijsoord and Waterberg, the traffic intensity was highest before Knooppunt Valburg, decreased between Knooppunt Valburg and Afslag Renkum and increased after. On the A50 from Nijmegen to Arnhem, it can be seen that the traffic intensity peaks before Knooppunt Valburg decreased from 4000 vehicles per hour to approximately 3000 vehicles per hour during the road constructions, again a decrease of 25%. The decrease in traffic density between Knooppunt Valburg and Afslag Renkum, from 3500 vehicles per hour before the closure to 2000 vehicles per hour during the road closure, shows 500 vehicles per hour taking a detour via the A15 and N325. Traffic between Afslag Renkum and Knooppunt Grijsoord, halved from 3500 vehicles per hour to 1500 vehicles per hour. Approximately 500 vehicles per hour exited the A50 at Afslag Renkum and probably took a shortcut over the N225 to Arnhem. Remarkable is the increase of approximately 500 vehicles per hour in the direction of Utrecht. This increase in traffic, however, can be explained by the fact that this traffic used Afslag Oosterbeek as well, as the increase of approximately 300 vehicles per hour in graph 5.3 shows.

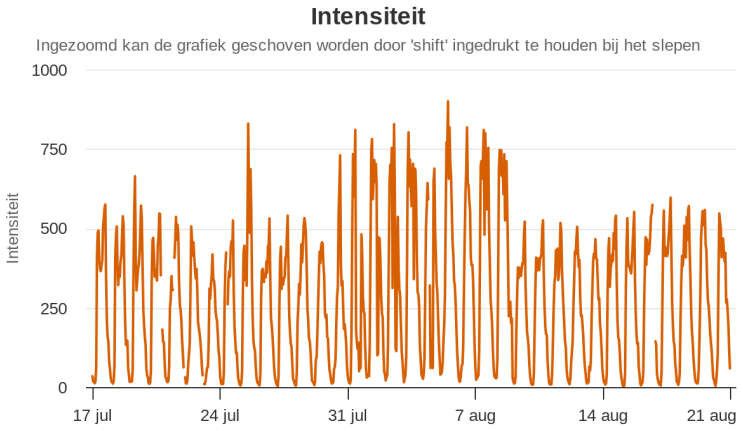

Figure 5.3: *Afslag Oosterbeek from the A50 Nijmegen*

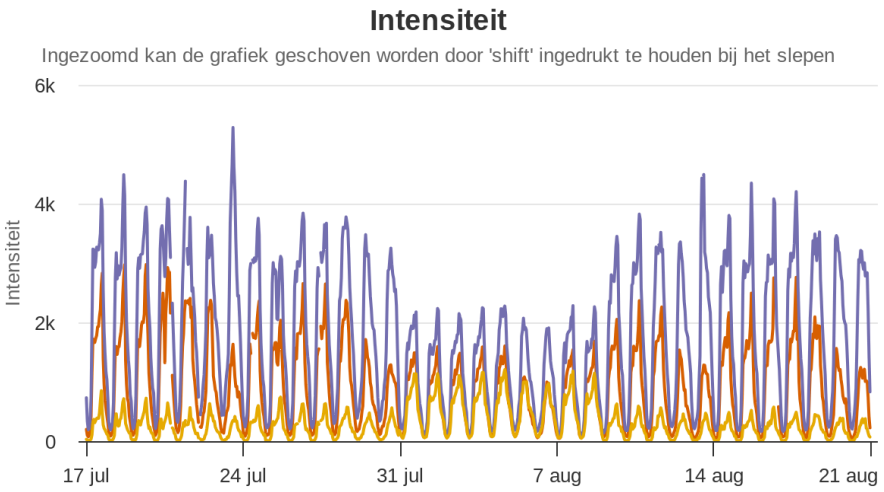

Figure 5.4: *Study area 3: Orange: from Afslag Arnhem-Noord, Blue: from A50, Orange: after Knooppunt Velperbroek*

As shown in figure 5.4, during the road closure on the A12, traffic intensity from Afslag Arnhem-Noord doubled from 600 to approximately 1200 during peak hours, indicating 600 vehicles per hour took the shortcut route through Arnhem, while traffic from the A12/A50 decreased drastically from 3400 to 1000 vehicles per hour. The last event can mainly be explained by the closure of the A12, where the traffic intensity was approximately 2200 vehicles per hour. After Knooppunt Velperbroek, the intensity on the A12 to Oberhausen decreased before the closure between Grijsoord and Waterberg with 1200 vehicles per hour, but during the A12 closure, the decrease is only 500 vehicles per hour, which could indicate that 700 extra vehicles per hour from the N325 joined the A12 to Oberhausen.

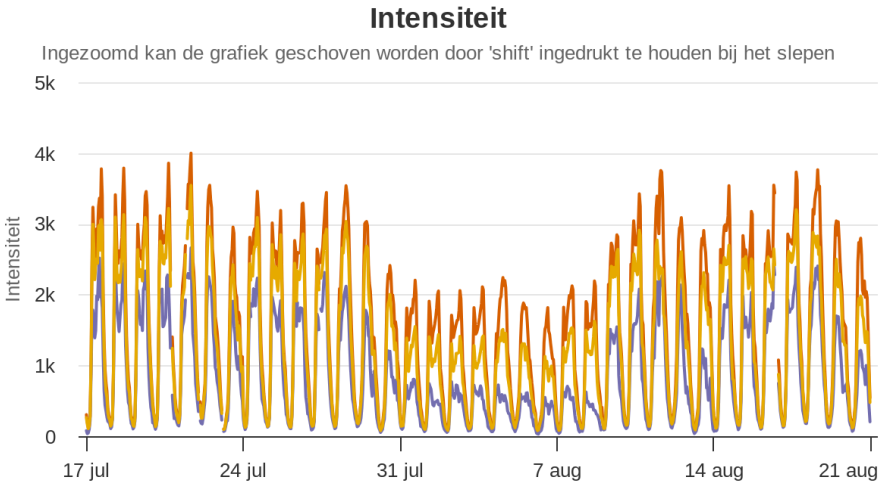

Figure 5.5*: Study area 4: Purple: before Afslag Arnhem-Centrum, Yellow: after Afslag Arnhem-Centrum, Orange: after Afslag Schaarsbergen*

The decrease in traffic intensity from 1700 vehicles per hour on the A50 from Knooppunt Waterberg can also be explained by the closure of the A12, since before the A12 closure, the flow from the A12 from Grijsoord to the A50 to Apeldoorn was 2200 vehicles per hour. This even means that 500 extra vehicles per hour use the A50 instead of the A12 to Grijsoord, probably as a detour route via the A50, A1 and A30. The traffic intensity on the entrance at Arnhem-Centrum increased with 200 vehicles per hour and at Schaarsbergen with 300, both indicating an increase in shortcut traffic.

Shortcuts

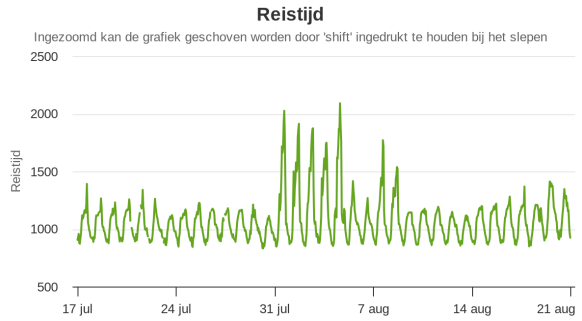

***Figure 5.6.1**: Amsterdamseweg to Westervoort*

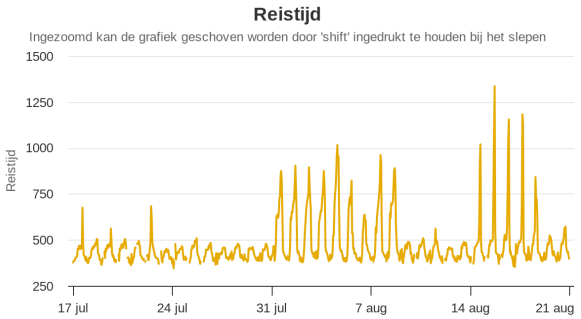

***Figure 5.6.2:** Schelmseweg to Arnhem-Noord*

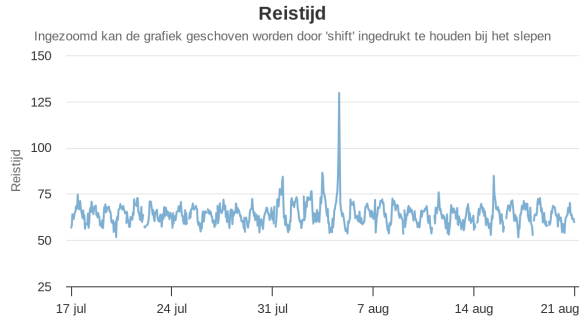

***Figure 5.6.3**: N311 to Afslag Schaarsbergen*

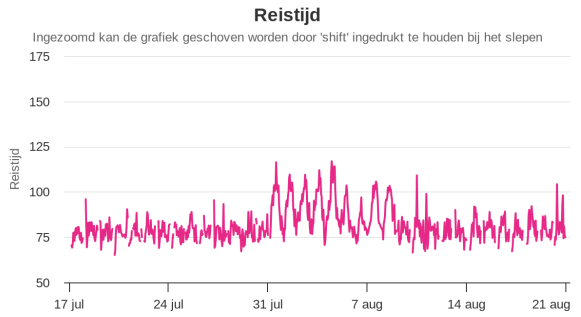

***Figure 5.6.4**: N225 from Afslag Renkum*

The intensities on the highway already indicate that there is cut-through traffic in Arnhem due to the road closure, and this can be seen as well in the travel time graphs for different expected shortcut routes in Arnhem. There is no traffic intensity data available about these routes, which means that only an indication of an increase of traffic can be shown. It can be seen that on the Amsterdamseweg, as shown in figure 5.6.1, the travel time increased significantly (54% increase), which means it probably increased in traffic drastically during the A12 closure. The same goes for the Schelmseweg to Arnhem-Noord (80% increase), shown in figure 5.6.2, which is connected to the Amsterdamseweg.

Travel time on the N311 seems to not have changed drastically (35% increase), but the presence of extra traffic can surely be derived from figure 5.6.3. This is traffic to Afslag Schaarsbergen, which makes it likely that this is cut-through traffic. From Afslag Renkum to Arnhem, a small increase in travel time can be seen, with one exceptional peak in figure 5.6.4. This peak might have another underlying cause, but the first days after the A12 closure also show a slight increase of around 20%. After the first days, the travel time seems to be normal again, which might indicate that road users were more aware of the road closure and anticipated, although it could also mean that the traffic intensity did not decrease but only the travel time did.

Detour routes

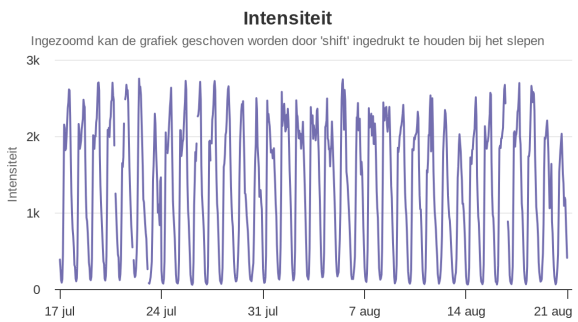

***Figure 5.7.1**: Traffic intensity N325 to Velperbroek*

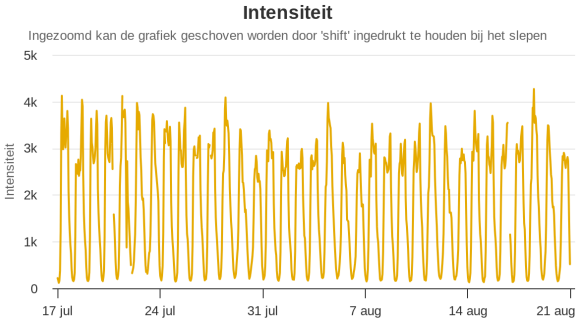

***Figure 5.7.2:** Traffic intensity A50 to Arnhem*

There are two detour routes advised by the road operator: one is via the A30 starting from Knooppunt Maalderbroek, then taking the A1 eastwards, and finally taking the A50 back to Arnhem. The other one is via the A50 to Nijmegen, then taking the A15 and the A325, which later changes into the N325 to Knooppunt Velperbroek.

The graphs show the traffic intensity on the last part of the detour route. On the N325, it can be seen that the peaks in traffic intensity are not higher during the A12 closure, but the peaks last longer indicating that over a whole day, the traffic volume is higher. This means that there probably was more traffic that uses the N325 as a detour route. On the A50 to Arnhem, traffic seems to have decreased slightly during the road constructions, but a direct cause for that cannot be traced.

Overview

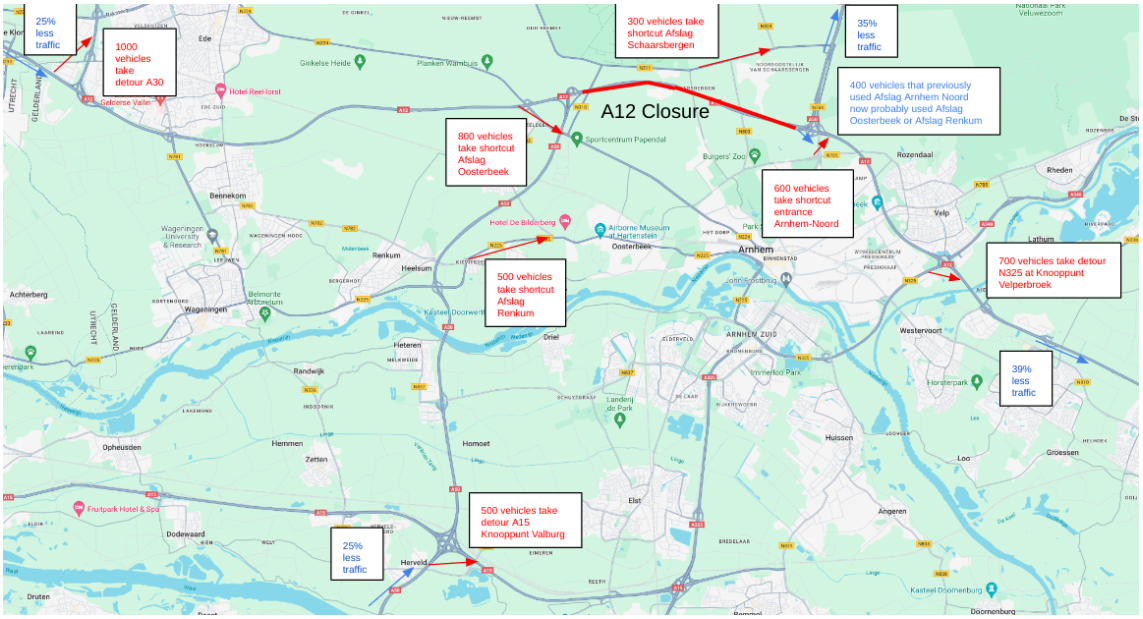

***Figure 5.8:** Overview of traffic change during A12 closure*

With the results discussed above, it is possible to make the overview shown in figure 5.8, which shows what happened at various highway junctions and exits. Overall, traffic from the A12 and A50 to Grijsoord seems to have decreased with 25% in the peak hours, but this is not only traffic that would have used the A12 between Grijsoord and Waterberg, as there is a traffic flow between the A12 to Utrecht and the A50 to Nijmegen of 1500 vehicles per hour

during peak hours in both directions. This would mean that the decrease in traffic from both the A12 and A50 in peak hours is 1000 of the 2500 vehicles per hour that would have driven between Grijsoord and Waterberg, which would mean a 40% decrease. The same applies to the A50, with also a decrease of 1000 of the 2500 vehicles per hour. This decrease can also be seen on the A12 to Germany (39%) and the A50 to Apeldoorn (35%). During the peak hours, 1000 vehicles per hour took the detour via the A30 and 500 vehicles per hour the detour via the A15/N325. Approximately 800 vehicles per hour took a shortcut from Afslag Oosterbeek and 500 vehicles per hour took a shortcut via Afslag Renkum. Not all these vehicles actually took a shortcut: since Afslag Arnhem-Noord was closed as well, drivers with a final destination in Arnhem, had to use one of the other two highway exits. The number of road users on the Arnhem-Noord exit before the road closure is approximately 400, as can be seen in figure 5.9. From the overview can be seen that 1500 vehicles per hour took an advised detour route, and 900 vehicles per hour (800 Oosterbeek + 500 Renkum - 400 Arnhem Noord) took a shortcut through Arnhem.

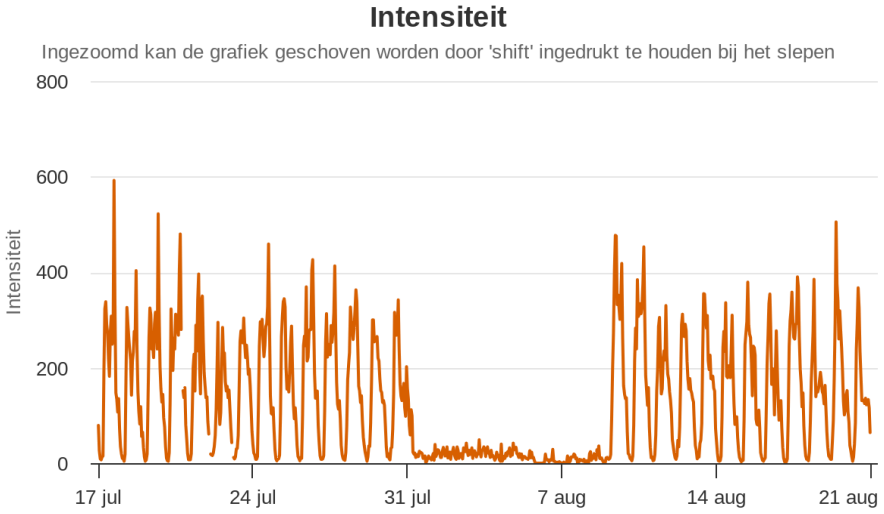

Figure 5.9: *Traffic intensity Afslag Arnhem-Noord*

These results are in line with the expectations of Alex Smienk, who stated that less traffic was observed in the area and expected that more commuters stayed home, switched mode or changed departure time. However, he also stated that there was quite some cut-through traffic, probably because the vacation season started in some regions, and vacation traffic seemed surprised by the closure. Freight traffic seemed to be aware of the road closure, yet some congestion occurred due to local traffic on roads through Arnhem.

The cut-through traffic he mentioned is also reflected in the travel time data and traffic intensity data, especially on the access roads to Arnhem. Due to the increase of cut-through traffic, some measures were taken, which were mainly focused on facilitating this traffic instead of preventing it. Traffic lights have been adjusted and traffic controllers have been deployed. Furthermore, a lot of work has been done with yellow detour signs and information on digital road signs.

Something that stands out in traffic intensity data for the A12 closure, is that from the first day, travelers seemed to already change their behavior to what they maintained for the rest of the time of the road closure. There hardly seems to be any surprise effect which smooths out later. This might indicate that travelers were informed well of the road constructions.

5.1.2. Prinsenbrug Haarlem

The analysis in Haarlem has been done on four routes mentioned in chapter 4. The decrease in traffic on the access roads to Haarlem, and especially the N200 over the Prinsenbrug, is also examined. The graphs in figures 5.10.1 until 5.10.8 show the travel time from both the east to west direction and the west to east direction.

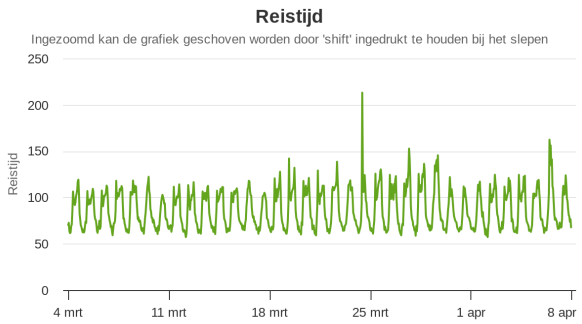

***Figure 5.10.1**: Buitenrustbrug: east to west*

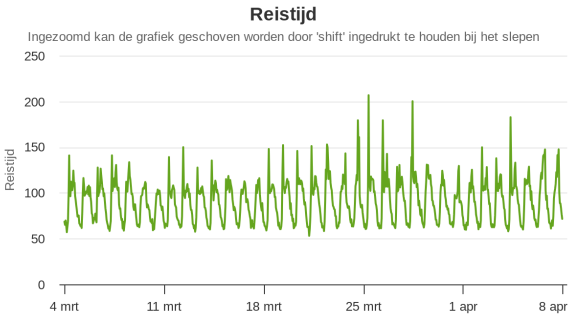

***Figure 5.10.2:** Buitenrustbrug: west to east*

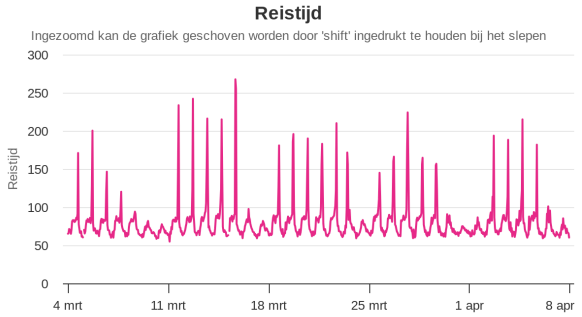

***Figure 5.10.3**: Schoterbrug: east to west*

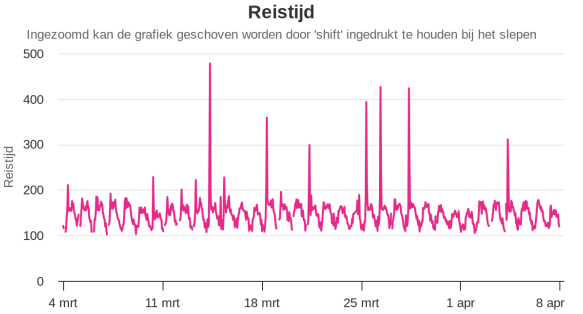

***Figure 5.10.4**: Schoterbrug: west to east*

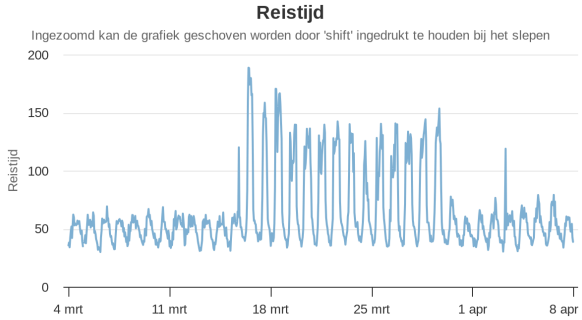

***Figure 5.10.5**: Catharijnebrug: east to west*

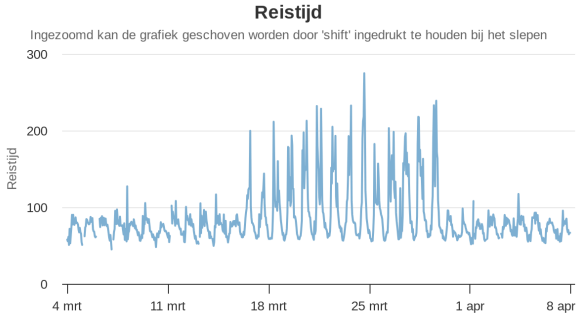

***Figure 5.10.6**: Catharijnebrug: west to east*

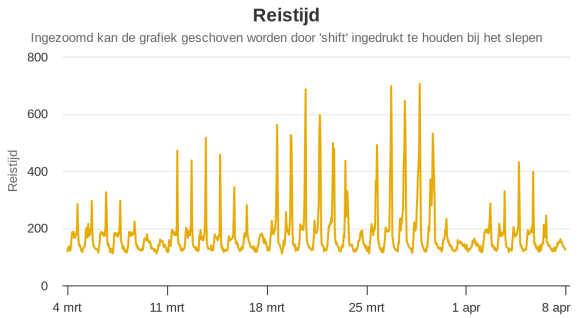

***Figure 5.10.7**: Waarderbrug: east to west*

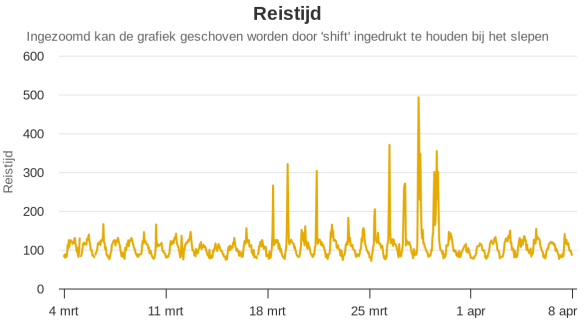

***Figure 5.10.8**: Waarderbrug: west to east*

On the N205 over the Buitenrustbrug, an increase in travel time can be seen during the closure of the Prinsenbrug. The travel time from east to west increased from approximately 110 to 140 seconds, an increase of 27%, and from west to east it increased from 140 to 150-200 seconds, an increase of approximately 22%. After the road constructions, the travel times seem to have returned to the situation before the road closure. For the Schoterbrug, from west to east direction, there were a few large peaks during the bridge closure, but overall, there was little change in travel time. From east to west direction, the travel times were already high, mainly during afternoon peak hours. Figure 5.11, where graphs are created from exported travel time data from Dexter, gives a better overview of the change in average travel time per day and shows that there was a very small increase (approximately 10%) in travel times during the closure of the Prinsenbrug. It seems that there were already congestions during peak moments, which could mean that more traffic volume did not lead to a lot more travel time since the road capacity is already reached, or that traffic avoided the Schoterbrug due to the long travel times.

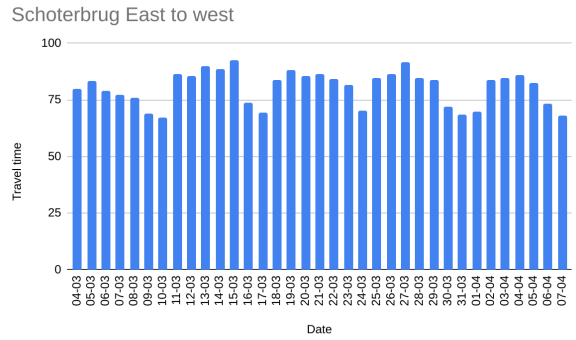

***Figure 5.11.1**: Schoterbrug: average travel time east to west*

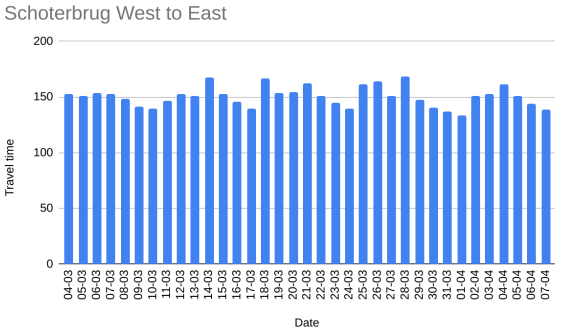

***Figure 5.11.2**: Schoterbrug: average travel time west to east*

The Catharijnebrug shows a large increase in travel times during the whole day, from 60 to approximately 150 seconds (150% increase) from east to west and from 100 to approximately 220 seconds (120% increase) from west to east, which cannot be explained other than by the presence of cut-through traffic. There seems to be a significantly higher traffic volume during the closure of the Prinsenbrug. The same applies to the Waarderbrug, which also shows an increase in travel time during the constructions, from 400 seconds to approximately 700 seconds (75% increase) from east to west and 150 to approximately 300 seconds. The increase in travel time of the week before can maybe be explained by the higher travel times on the Schoterbrug in the same week. It is difficult to say if these shortcuts were used more frequently than the N205 and the Schoterbrug, because the capacity on the other two roads is significantly higher than the capacity on the two small bridges. An estimation of the increase of traffic intensity is done later, which could show how much the detour routes and shortcut routes were used during the bridge closure

Maurice Leenen also mentioned that cut-through traffic was observed on the Catharijnebrug, where, after reports from stakeholders, even traffic controllers were needed to clear the driveway of the police station. According to him, there were more congestions around various bridges during peak hours, including the Schoterbrug and Waarderbrug, but this was the logical consequence of closing such an important bridge as the Prinsenbrug. It was inevitable, and that is also the reason that the campaign focused on working at home or traveling differently.

Traffic intensity

Graphs in figure 5.12.1 and 5.12.2 show the average number of vehicles per hour for every day in the period from the 4th of March until the 7th of April, instead of the traffic intensity for every hour in this period. These graphs can show if the traffic intensity changed during the closure of the Prinsenbrug. The blue line in figure 5.12.1 is the access road for the N200, and shows negative peaks during the weekends. The red line is the Amsterdamsevaart, where smaller negative peaks can be seen during the weekend.

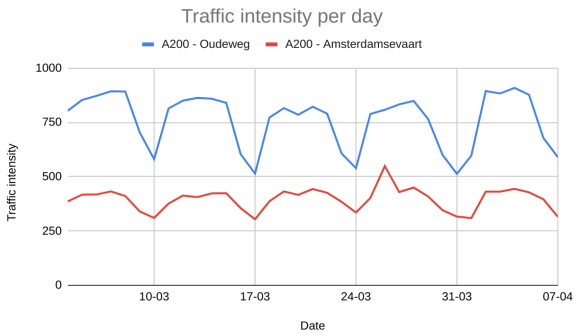

Figure 5.12.1: *Average traffic intensity per day on A200*

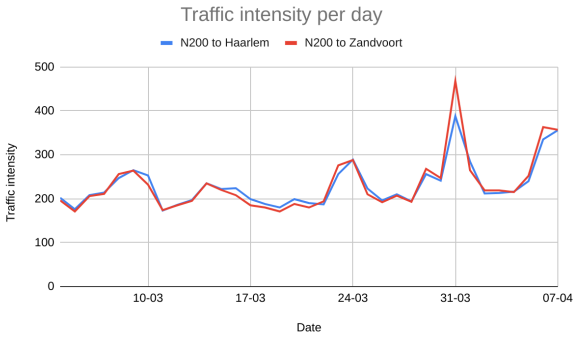

Figure 5.12.2: *Average traffic intensity per day on N200*

On the A200 to the Oudeweg, the road that leads to the Prinsenbrug, the traffic intensity decreased with dozens of vehicles per hour, or approximately 10%, which could mean that a part of the road users decided to stay home or travel by a different mode. On the A200 to the Amsterdamsevaart, no significant change was seen, which could mean that this route was not used by drivers as a detour route for the closed Prinsenbrug, or that some drivers decided to stay home or use another travel mode and others did use the Amsterdamsevaart as a detour route. The last possibility seems to make more sense, since travel time on this detour route increased during the Prinsenbrug closure.

On the N200 from both Haarlem to Zandvoort, shown by the red line in figure 5.12.2, and Zandvoort to Haarlem, shown by the blue line, a lower traffic intensity can be seen during the closure of the Prinsenbrug, with a few dozen vehicles per hour less in both directions. In this graph, there are positive peaks during the weekend, which can be explained by day trippers from and to Zandvoort, for the racing circuit or the beach.

To make an estimation of the traffic intensity increase due to the Prinsenbrug closure on the detour routes, the Bureau of Public Roads (BPR) function is used (Maerivoet & De Moor, 2005). This gives a method to derive the increase in traffic intensity from the increase in travel time. The function is as follows:

$$T = T_f(1 + \alpha(\frac{V}{C})^{\beta}), \text{ where}$$

- T is the travel time under current traffic conditions
- T_f is the free-flow travel time
- V is the traffic volume
- C is the capacity of the road
- α and β are parameters (ideally determined empirically) depending on the road characteristics

The travel times and free-flow travel times can be found in the graphs above, while the capacity of the road is constant (since the road itself does not change). Since it is not possible to empirically determine α and β, since there is no information available about the traffic intensity, an assumption is made. Table 5.1 gives the result of the increase in traffic intensity during peak hours according to the calculations in appendix VI, while the increase in the amount of vehicles per hour is based on this increase and on an assumption about traffic flows over these bridges.

Table 5.1: *Traffic intensity increase on alternative bridges*

	Buitenrustbrug	Schoterbrug	Catharijnebrug	Waarderbrug
Increase in traffic intensity in %	12.5%	3.9%	40.6%	15.7%
Increase traffic intensity in vehicles per hour	+250	+250	+270	

It is important to emphasize that these numbers are estimates, based on many assumptions for different parameters and traffic flow volumes. If these parameters or volumes deviate in practice, the numbers shown in the table could deviate as well.

5.1.3. Van Muijlwijkstraat Arnhem

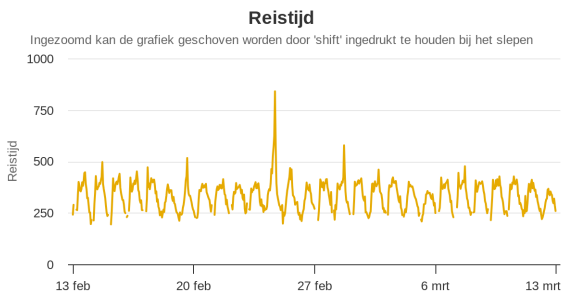

Figure 5.13.1: *Travel time Velperweg*

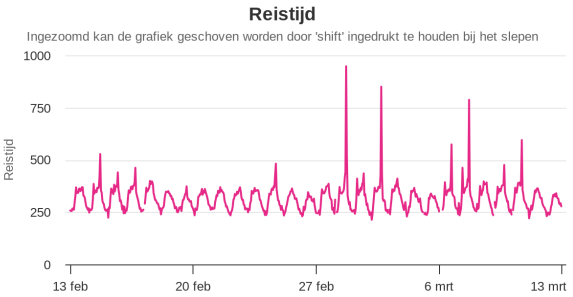

Figure 5.13.2: *Travel time IJssellaan*

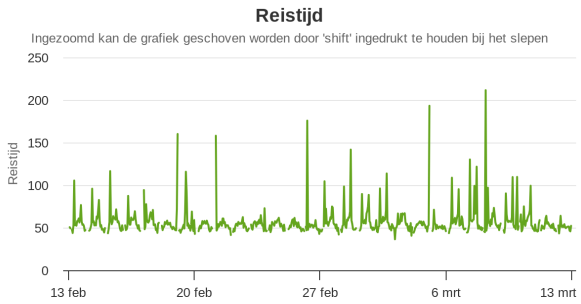

Figure 5.13.3: *Travel time Huijgenslaan*

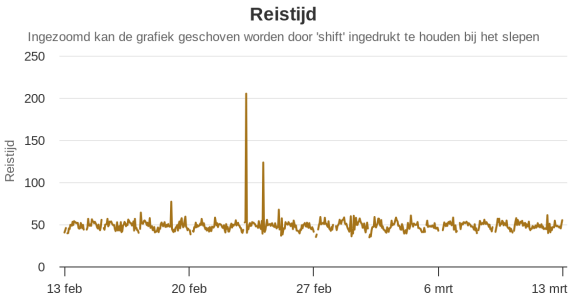

Figure 5.13.4: *Travel time Wichard van Pontlaan*

The travel time data on the Velperweg in figure 5.13.1 shows a peak in travel time on the first day of the road construction on Friday the 24th of February. The peak on Saturday is also higher than the peak of a regular Saturday. In the next week, there is a larger peak on Tuesday, a typical rushday, after which no significant travel time peaks can be seen. This

might indicate that travelers needed a few days to adapt to the road constructions. On the IJssellaan and Johan de Wittlaan, shown in figure 5.13.2, there is a small peak on Friday the 24th, while a larger increase in travel time can be seen in the week after the constructions began. These peaks are most significant at 17:00 on Tuesday and Thursday, both typical rush days.

The Wichard van Pontlaan, in figure 5.13.4, shows a few peaks in travel time at the start of the road constructions, but these peaks occur before the morning rush, which might indicate that there is a different event that causes the peaks. During the weeks after the start of the road constructions, there seems to be no change in travel time. The Huijgenslaan, shown in figure 5.13.3 has some peaks before the start of the road constructions, indicating that the road is already subject to congestions, but a peak cannot be found on the day of the start of the road constructions. Nevertheless, in the weeks after, the peaks in travel time are higher and more frequent. This might indicate that traffic volume increased on the Van Huijgenslaan, and therefore, traffic intensity increased on the alternative route to the Apeldoornseweg.

The results coincide with the observation from Edwin Leenders, since he mentioned that in the start of the road constructions, there was a lot of searching traffic, and after a week, road users adjusted their behavior. He also mentioned that there was cut-through traffic in the Steenstraat, and other roads through the neighborhoods. There have been complaints about this, which led to placing another sign with route advice, but there were no drastic traffic measures. The graph in figure 5.15 shows that there are indeed significantly higher travel times during the day with respect to the travel time during free-flow hours, but these were also seen before the constructions on the Van Muijlwijkstraat started.

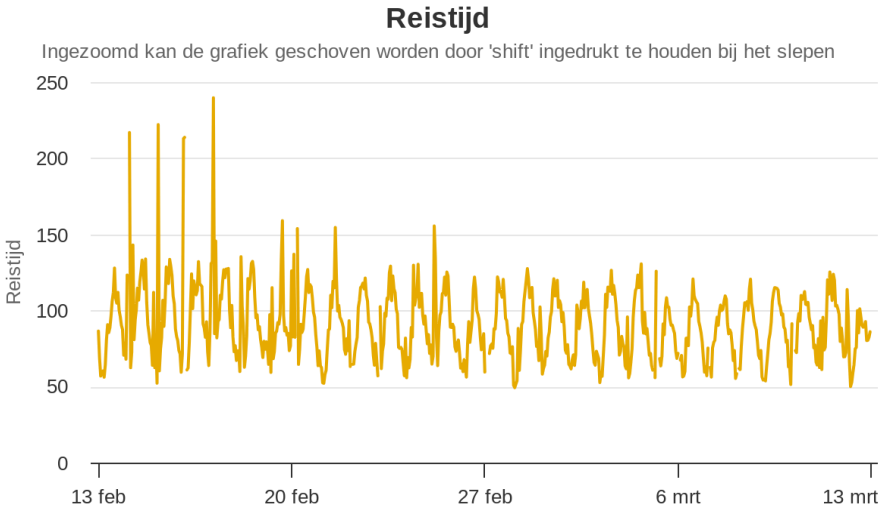

Figure 5.15: *Travel time Steenstraat*

The travel time around the Van Muijlwijkstraat does not seem to increase clearly or significantly, except for a few peaks. Therefore, a calculation for traffic intensities does not make a lot of sense in this case. The reason for the absence of a clear increase in travel time could be caused by the long duration and not complete closure, and makes it hard to draw conclusions. However, something that can be seen is the presence of search traffic, road users who seem unaware of the constructions and did not change their travel behavior in advance.

5.1.4. N271 Mook

The traffic intensity on the locations of the N271 near Mook mentioned in chapter 4 are shown in graphs, while the locations of the measuring points and the read traffic intensity values of the graphs are shown in Appendix VII.

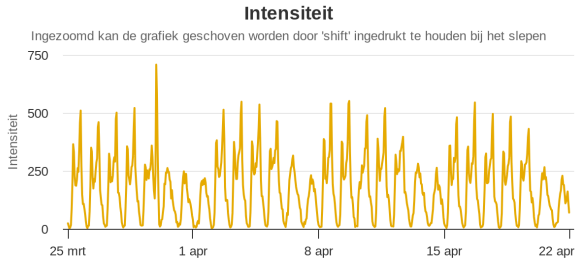

Figure 5.16.1: *Traffic intensity A73 exit*

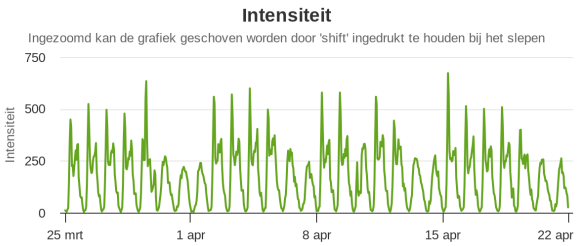

Figure 5.16.2: *Traffic intensity A73 entrance*

The entrance and exit of the A73 to Nijmegen saw an increase in traffic intensity. On the exit of the A73, during peak hours, an increase of 50 vehicles per hour was seen, while on the entrance of the A73, an increase of 70 vehicles per hour was seen. The increase in traffic intensity can be explained by two of the detour routes: it could have to do with through traffic on the N271, which was advised to take the A73 parallel to the N271, or with traffic from Groesbeek to Malden or the other way around. Using this information, it is possible to conclude that 50-70 vehicles per hour in each direction took a detour route via the A73.

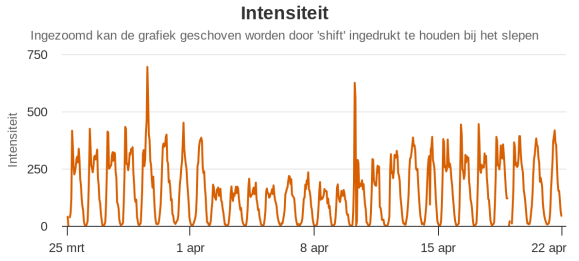

Figure 5.17.1: *N271 Generaal Gavinstaat - Groesbeekseweg*

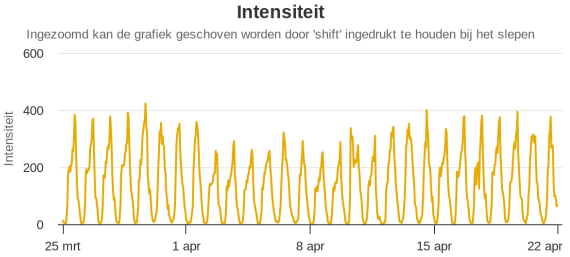

Figure 5.17.2: *N271 Pastoorsdijk - Generaal Gavinstraat*

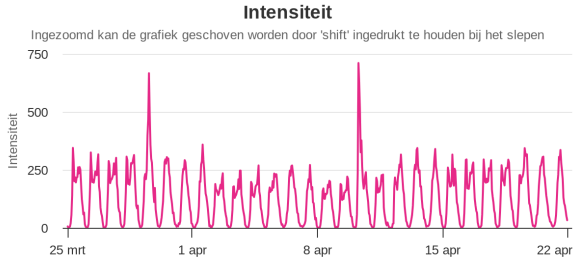

Figure 5.17.3: *N271 Zwarteweg - Pastoorsdijk*

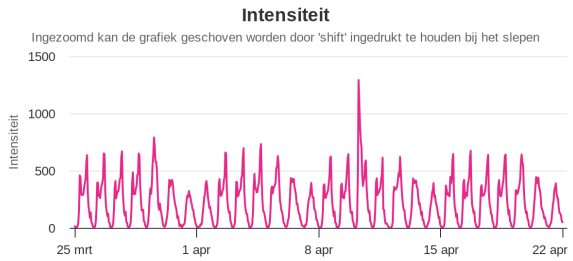

Figure 5.17.4: *N271 Gennip - Zwarteweg*

Figure 5.17.5: *N271 Driesbergstraat - Veldweg*

Between Gennip and Zwarteweg, except from an unexplainable peak on the 10th of April, no change in traffic intensity was observed, or through traffic decreased but the A73 to Groesbeek detour route increased by the same amount. After the crossing with the Zwarteweg, a decrease can be seen of 70 vehicles per hour on the N271 with respect to before the road closure was observed, indicating that 70 vehicles per hour followed one of the advised detour routes. After the crossing with the Generaal Gavinstraat, a decrease of 100 vehicles per hour on N271 was observed, indicating that 100 vehicles per hour used a shortcut over the Generaal Gavinstraat. It is assumed that 80 vehicles per hour took a shortcut via the Kerkstraat and the Driesbergstraat, looking at the intensities on the N271 after the roundabout and the just after the Driesbergstraat as shown in figure 5.17.5. The remaining 120 vehicles per hour on the N271 are seen as local traffic with a destination before the roundabout.

It can be concluded that from Gennep to Malden and from Gennep to Groesbeek, 150 vehicles per hour took a shortcut during peak hours. If traffic on every advised detour route increased with the same amount of vehicle, approximately 35 vehicles per hour took the advised detour from Malden to Groesbeek, 35 took the advised detour from Gennep to Groesbeek and 35 took the advised detour from Gennep to Malden. No decrease in traffic is observed, although there is no clear evidence to say that there was no decrease. An overview is shown in figure 5.18.

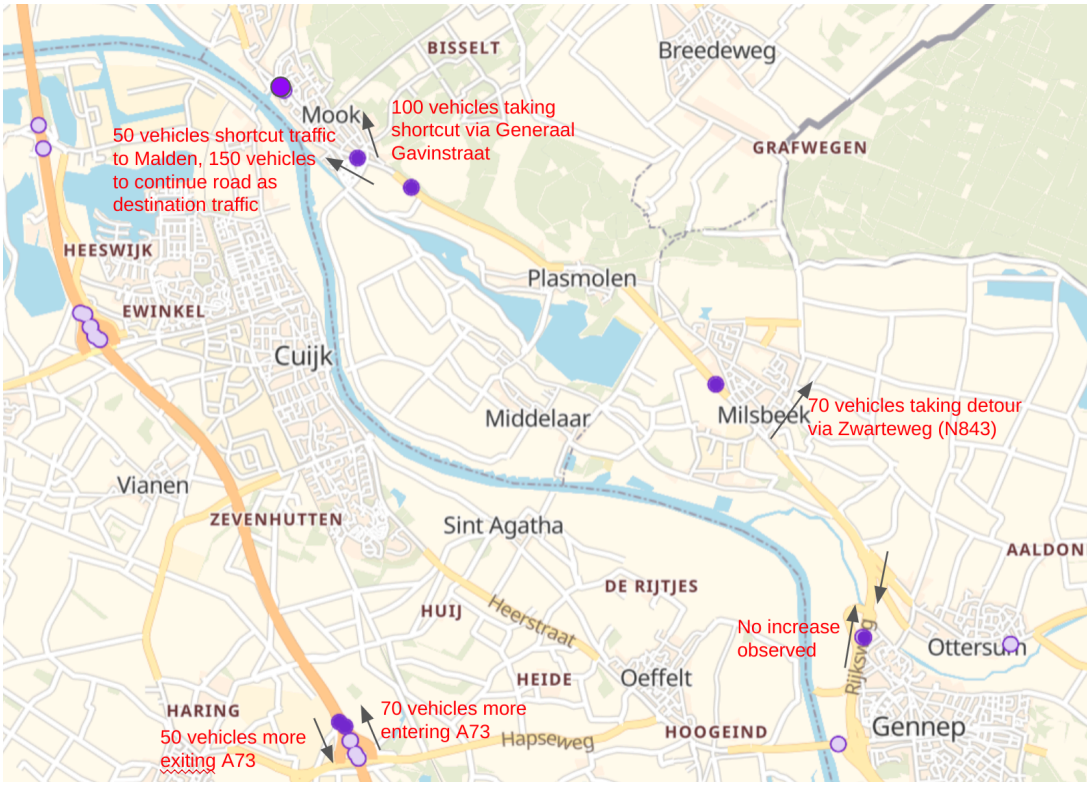

***Figure 5.18**: Overview of traffic change during roundabout closure N271*

It is not possible to see if there was an increase in travel time on shortcut routes, since there is no travel time data available on these roads. On the advised detour routes like the Zwarteweg and the A73, there is no clear increase in travel time during the constructions, as can been seen in figures 5.19.1 and 5.19.2.

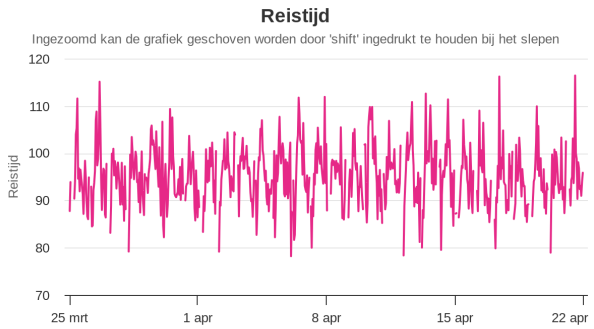

Figure 5.19.1: *Travel time Zwarteweg*

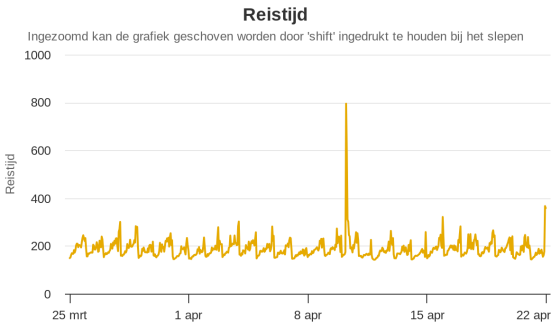

Figure 5.19.2: *Travel time A73*

5.2. Informed versus Uninformed Road User

5.2.1. Information source

The road users can be informed of a road closure by multiple means of communication, for example announcement boards, local newspapers, mouth-to-mouth or, as TripService does, social media or online advertising and navigation. When road users are informed before the departure of the trip, they can be influenced to make decisions in switching transport mode, changing departure time or choosing a different route. These actions could help relieve traffic at the location of a road closure. Therefore, it is important that the information reaches as many road users as possible.

As shown in figure 5.20.1, the survey done by TripService in the Van Muijlwijkstraat project shows that a majority of the respondents was informed, while another group of respondents was unaware of the road closure and learned of the road closure when they arrived or saw the signs along the road. From the informed respondents, almost half of the respondents learned it from announcement boards along the road, a quarter learned it from newspapers or other print media, another 22% learned it from social media and online advertisements and a small part learned it from their navigation. This is different from the A12 Grijsoord-Waterberg project, where a higher percentage of respondents was informed and where more than half of these respondents (57%) were informed through social media and online advertising, as can be seen in figure 5.20.2.

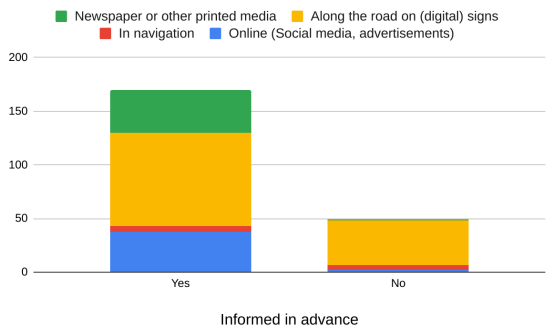

Figure 5.20.1: *Van Muijlwijkstraat*

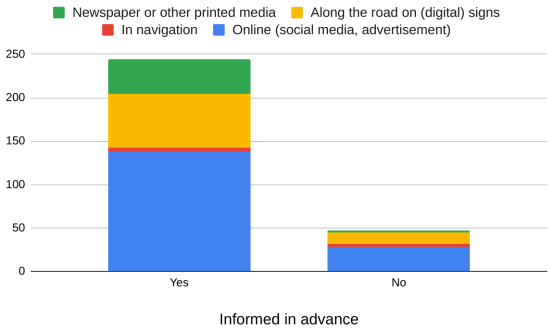

Figure 5.20.2: *Regio Arnhem-Nijmegen*

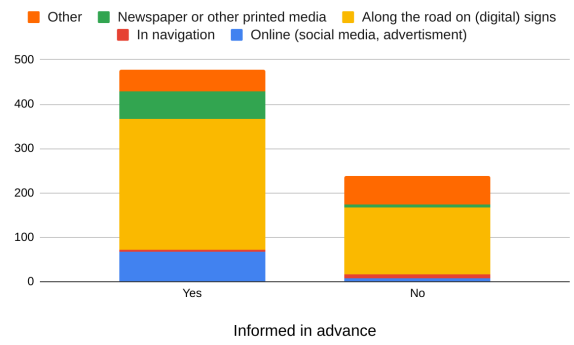

Figure 5.20.3: *Churchillweg Wageningen*

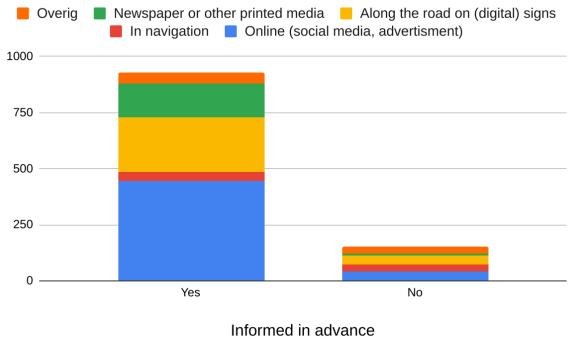

Figure 5.20.4: *A27 Merwedebrug*

Two other projects, one by Hoornstra on the Churchillweg in Wageningen, comparable to the Van Muijlwijkstraat, and one by Rijkswaterstaat on the A27 at the Merwedebrug, show the same pattern. By looking at these results, it can be concluded that a higher percentage of potential road users are informed in projects concerning national roads and that from the informed road users, half are informed by social media and online advertisements, while for projects on secondary roads, this is approximately a quarter of the informed road users.

A reason for these percentages might be the fact that the A12 Grijsoord-Waterberg campaign had over 4 million views and 10,299 clicks, while Van Muijlwijkstraat advertisement campaign only had 262 thousand views and 1560 clicks, as shown in Appendix II. Nevertheless, there are more potential road users on the A12 highway than on the Van Muijlwijkstraat, which means that more of them should be informed. The campaign for the closure of the Prinsenbrug had more views and clicks than the Van Muijlwijkstraat, namely 913 views and 1220 clicks, which means that more people might be informed by the advertisement campaign from TripService in the Prinsenbrug project. This, however, cannot be supported by survey results.

Both Alex Smienk and Edwin Leenders found it hard to estimate the reach of the advertisement campaign. They also mentioned that they or the road operators did tests to see if they would receive such a message when driving through the project area. They did not always receive the message on one of the advertisement platforms. While it might be the case that not all people passing through the project area receive a message due to the advertisement algorithm, the online advertisement has an important role in informing potential road users. As shown in Appendix VIII, less frequent travelers are informed at a higher rate by online means than more frequent travelers, who are informed at a higher rate by signs along the road. It can be said that online traffic management helps in getting less frequent travelers informed almost just as well as more frequent travelers are.

5.2.2. Follow-up behavior

The information provided by online advertisement or by a different source gives the commuter the option to change route, switch travel mode or departure time, or to stay at home. It is also possible that the commuter decides to not take action, since the road constructions would have minimal influence on his or her trip or the alternative options would be less appealing than the original route. In the surveys, the respondents were asked what action they took due to the road constructions.

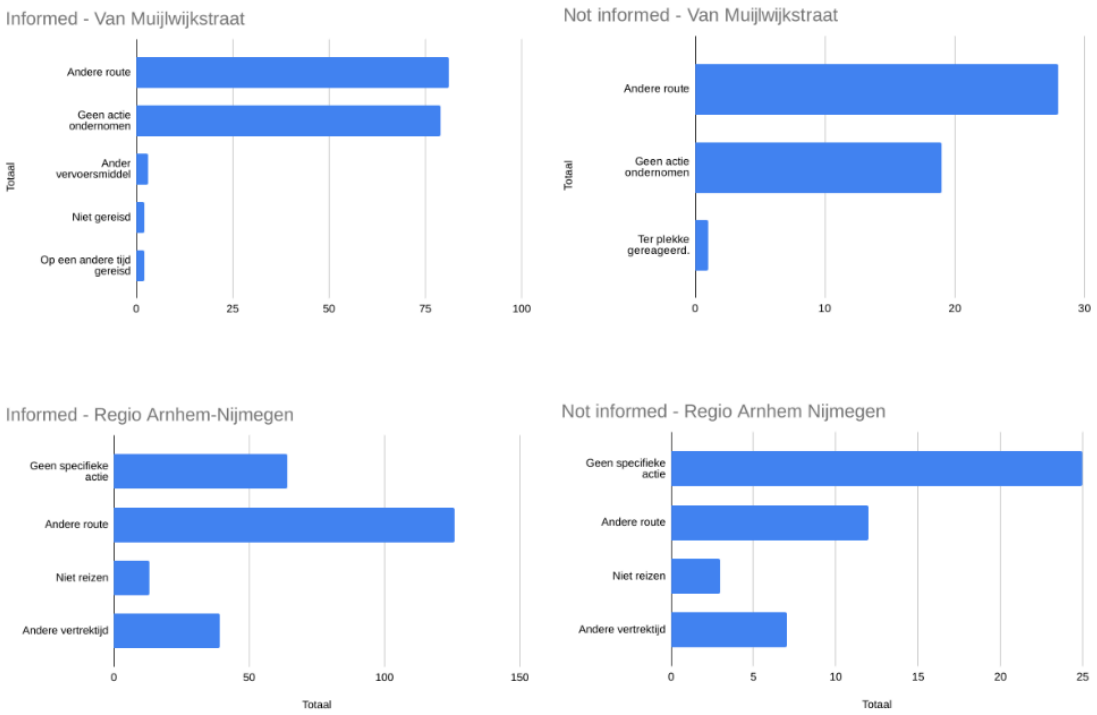

Figure 5.21: *Follow-up behavior in of informed and uninformed road users in the Van Muijlwijkstraat and Regio Arnhem-Nijmegen*

For the Van Muijlwijkstraat project, it can be seen in figure 5.21 that most respondents do not take action or take a different route. A few people stay at home, depart at a different time or switch travel mode, and those people were informed beforehand. It needs to be said that in this particular project, the advice was not to stay home or travel differently, but to avoid the Van Muijlwijkstraat, which most of the time was still (partly) accessible.

For the Regio Arnhem-Nijmegen project, it can be seen that most informed respondents changed their behavior in traffic. Most chose to change their route, while some others stayed home or departed later. Most of the uninformed road users did not take a specific action, and a few chose to change their route or departure time. Since the Regio Arnhem-Nijmegen project included more road constructions than only the A12 Grijsoord-Waterberg, the comparison of the survey results with traffic data results is not completely reliable. Nevertheless, the survey results and traffic data results have been compared in Appendix IX, where it is stated that the survey answers are representative for what happened during the A12 closure. Since there is no survey data available about the Prinsenbrug closure, a comparison cannot be made.

A difference in follow-up action between people informed by online advertisements or people informed by other means has also been investigated. The results in figure 5.22 show that the percentage of people not taking action and people taking action is approximately equal in each project for both groups. A small difference can be seen in what the follow-up action was, namely that more people informed by other means stayed home or departed on a different time, while people informed by online advertisement were more likely to take a different route. This could be explained by the fact that the online advertisement or click-through page possibly gives more information about alternative routes, or the fact that people reading online advertisements are more likely to open an online route planner, since

they are already online. However, this explanation is speculative and a conclusive answer about this difference cannot be given. It can be said however that for online advertisement and other means the same percentage of road users followed up the information in the Van Muijlwijkstraat, while for the A12 Grijsoord Waterberg project, the follow-up percentage for online means was slightly higher, indicating more people did a follow-up action when informed online.

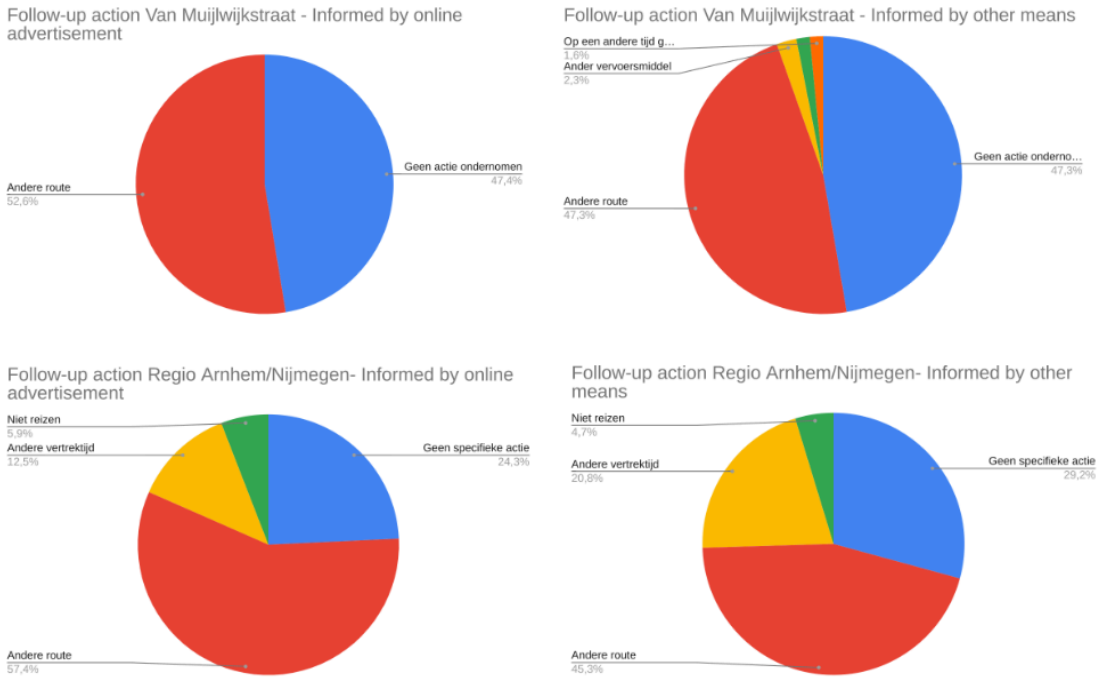

Figure 5.22: *Follow-action when informed by online advertisement or by other means, for Van Muijlwijkstraat and Regio Arnhem/Nijmegen*

5.3. Communication Review

5.3.1. Communication to road user

In the surveys of the Van Muijlwijkstraat and Regio Arnhem-Nijmegen projects, the responders were able to give a rating about the communication of the road operator to them. In this analysis, the average rating for communication is calculated for people informed by online advertisement and people informed by other means. The average age is also calculated for people informed by online advertisement and informed by other means. The results are shown in table 5.2.

Table 5.2*: Average rating and age when informed by online or other means*

	Regio Arnhem-Nijmegen		Van Muijlwijkstraat	
	Average rating	Average age	Average rating	Average age
Informed by online means	6,5	55	5,7	48
Informed by other means	6,4	54	5,3	50
	A27 Merwedebrug		Churchillweg Wageningen	
	Average rating	Average age	Average rating	Average age
Informed by online means	5,9	47	4,8	42
Informed by other means	5,7	50	4,1	40

In the Regio Arnhem-Nijmegen and A27 Merwedebrug project, it can be seen that the average rating of communication from people informed by online advertisement and informed by other means is approximately equal. For the Van Muijlwijkstraat and Churchillweg projects, two projects concerning secondary roads instead of national roads, the average rating is considerably higher for people informed by online advertisement than for people informed by other means. From these results, it can be said that for regional road projects, people rate communication higher when done via online means than when done via other means, while for projects on national roads, there is no big difference in rating.

Furthermore, the average age of people informed by online means and people informed by other means hardly differs. People informed by online means are not per se younger, people of higher ages are also reached using advertisements on for example Facebook and Google Ads. The platform on which they can be reached, however, might differ per age group.

In the Prinsenbrug project, behavior and complaints were monitored via BouwApp. On the BouwApp there were no complaints. According to Maurice Leenen, the sentiment was good, but there is no report to back it up. There seemed to be a reduction in questions in the BouwApp, because people were better prepared. There were small location-based questions, and less general questions, such as the duration of the project. Maurice Leenen would explain that by the use of Online Traffic Management. As a result, less communication was needed during the execution itself.

5.3.2. Nuisance for local residents

Although nuisance for local residents is not directly related to Online Traffic Management, it might be useful to see if there are complaints that can be solved by OTM. In the surveys, there is no specific information available about nuisance for local residents. The survey in Arnhem includes a rating for hindrance, from which the average can be distinguished in local residents and others using postal codes. The postal codes for neighborhoods around the Van Muijlwijkstraat are 6811 (city center), 6821 (Sint Marten), 6822 (Klarendal), 6824 (Velperweg) and 6828 (Spijkerkwartier). The locations and results are shown in appendix X.

Local residents give a 6.4, while the rest of the respondents give a 6.3, which means there is no significant difference. The graph in Appendix X shows how the local residents and other road users experience a change in travel time and traffic safety. It can be seen that local residents experience a larger increase in travel time than other road users, while for traffic safety, the change is similar for both. It can be said that local residents are impacted more significantly as road users than road users that do not live near the project area.

For the Van Muijlwijkstraat project, the BouwApp was not used, but the website from the municipality of Arnhem and the website from NTP could be used for complaints by residents. Alex Smienk mentioned that resident letters were also sent. The municipality received a few emails about ambiguities about the constructions, and as mentioned earlier, there were complaints about cut-through traffic through a neighboring area, especially the Steenstraat. Alex Smienk does not know if there were complaints in the A12 Grijsoord-Waterberg project, since the traffic management team had no sight of that.

5.3.3. Contractor review

In terms of informing the commuter, Maurice Leenen thinks Online Traffic Management is effective for certain target groups. Often young adults are reached, as well as young people who are more concerned with social media, and adults can be reached well through Google Ads (websites and mobile apps). However, there is always a target group that cannot not be reached with OTM but that has to be considered. They come to information moments and think this is important. There are also people who don't use navigation but look at road signs a lot. OTM is an addition to other information sources, but a very effective one in target audience reach, engagement and interaction, cost efficiency, measurability of results and impact.

Edwin Leenders from NTP emphasizes that the results are difficult to measure, since it is hard to find out how many people exactly used the information and what their follow-up behavior was. On another project in Grave, no notification was received by NTP and the road authority when they tested by driving in the project area, so NTP is not sure how it really caught on. Nevertheless, he mentioned that it is important to use more and more resources, including digital sources. NTP also uses its own BouwApp, which has more interaction in it, since people can ask questions there. Something like that could also be implemented in a dashboard for OTM, since now there is one-way communication. NTP's construction app is a bit like a "call center," where AI first tries to answer (smaller) questions, after which the questions are passed on if necessary. This might add value in the future.

Alex Smienk also especially emphasizes the complementary role of Online Traffic management. Newspapers, for example, are being used less and less often, although from the project's point of view, all residents who cannot be reached through social media or advertisements have to be kept informed. However, in terms of cost, it would be cheaper to take away all the yellow signs and fully deploy OTM to have a wide reach. At large closures, such as bridge closures, yellow signs can be seen up to a great distance from the bridge, where deployment of OTM might be cheaper and work better.

6. Performance of Online Traffic Management

Before evaluating the performance of Online Traffic Management, it is important to identify the indicators. Online traffic management can be assessed through various perspectives or for many different priorities. In this chapter, an assessment framework will be set up, after which some key performance indicators will be evaluated. Furthermore, some improvements will be proposed.

6.1. Assessment Framework

In the proposal for this research, an example of an assessment framework was made to give an impression of what subjects could be included. This framework is shown in figure 6.1. There were three main subjects, traffic network performance, communication to road users and experience from stakeholders perspective, and these were divided into a few sub-subjects. The results in chapter 5 show how some of these subjects scored, but there is no coherent result. The assessment framework is an attempt to find this coherent result, and also be used for future projects.

Figure 6.1: *Assessment framework from research proposal*

In the expert interviews, the contractors were asked for their priorities in choosing for Online Traffic Management. Alex Smienk is especially interested in reach, and also what gets through to the road users, as well as the follow-up behavior. For him, the costs are important, as is which service provider the campaign is connected to (like Waze of Flitsmeister). If this is made clear, more and more municipalities and governments would take the step to deploy OTM. In addition, it would be nice to know what kind of applications are possible. Edwin Leenders from NTP would want to know whether road users benefited from the advance notice, whether it was clear, and whether traffic is behaving as the contractor would like it to.

TripService wants key performance indicators to show what the effect is of using Online Traffic Management in roadwork projects. For example the vehicle decrease due to Online Traffic Management alone or the amount of non-frequent travelers that were informed by

online means. The aim is to create the framework in such a way that these specific key performance indicators can be read from it. In the previous chapter, some patterns could be seen, like search traffic and the adaptation time of traffic. Although there might be useful information for the performance of Online Traffic Management shown with these patterns, they are sometimes difficult to measure, and some are therefore excluded from the framework.

With this information, and knowing the information available and measurable, the assessment framework can be set up. Important indicators for the performance of online traffic management will be described, namely campaign reach, follow-up behavior and traffic change and communication clarity and benefits. These indicators are important for both the road operator and contractor, while TripService also values these. Furthermore, for all of these indicators, there is (somewhat) data available, which makes it possible to concretise performance in numbers. The framework will consist of tables, giving the indicator, description and data source.

6.1.1. Campaign reach

Campaign reach can be subdivided into several parts. In the current advertisement results overview made by TripService, the total number of views and clicks per advertisement platform is provided. This alone does not satisfy the wishes of the contractor or road users, since they want to know how many people actually received this information and used it. Although this might be difficult to estimate, the survey data gives some insights, like the percentage of informed road users that got the information via online advertisements. The views and clicks themselves also give information, for example about the engagement of the advertisements

Non-frequent travelers are a unique group that are not likely to be informed before the constructions start from signs along the road, but they can be informed by amongst others Online Traffic Management. From the results, it can be seen that a higher percentage of people traveling less than 1 time per week was informed by OTM in a municipality than people traveling more frequently. At last, the platforms on which the advertisements have been placed, should be given, to present the variety of platforms on which people can be informed about the road constructions. This enlarges the potential target audience.

It is not possible to measure what percentage of through-traffic or residents in an area received a notification, since it is hard to estimate what the size is of this potential group. It is, however, possible to show for example what the reach was with local residents or through traffic specifically and what the reach was with people interested in location in and around the project area specifically. This is something that could be included in future reports about the deployment of Online Traffic Management. The assessment framework for the campaign reach is shown in table 7.1, with the description and location of the available data.

Table 6.1: Campaign reach assessment framework

Total Views	Total Clicks (and engagement)	Percentage Informed by OTM	Percentage Non-Frequent Road Users Informed by OTM	Advertisement platforms
Amount of views, total on all platforms	Amount of clicks on the advertisement Total on all platforms	Percentage of informed road users that got the information from OTM campaign	Percentage of informed road users traveling less than 1 day per week that were informed by OTM	The list of platforms that were used for OTM
From advertisement platforms	From advertisement platforms	From surveys	From surveys	From advertisement platforms

6.1.2. Follow-up behavior and traffic change

The follow-up behavior is the reaction of road users after being informed or after not being informed. The analysis about follow-up behavior concluded that there is almost no difference in follow-up behavior between people informed by online advertisements or people informed by other means. The analysis did show that people that were informed beforehand, were more likely to change their route, stay home, switch travel mode or change departure time. This was also seen in the traffic intensity data, where a decrease in traffic intensity during peak hours shows to what extent people stay home, switch mode or depart earlier or later. The traffic intensity data on other routes can show what percentage of traffic chooses the advised detour route and what percentage takes a shortcut. The travel time data on the routes could show problems in the traffic network. Table 7.2 shows that the main source in this assessment framework is traffic data

Table 6.2: Follow-up behavior and traffic change assessment framework

Decrease in traffic intensity during peak hours	Percentage of traffic choosing detour route	Percentage of traffic choosing shortcut route	Travel time increase on detour route	Travel time increase on shortcut route
Decrease on access roads due to people staying home, switching travel mode or changing departure time	Percentage of traffic that chooses to drive on one of the designated detour routes	Percentage of traffic that chooses to drive on via a shortcut not designed as detour route	Increase of travel time on the detour routes due to the increase in traffic intensity	Increase of travel time on the shortcut routes due to the increase in traffic intensity
Traffic intensity data	Traffic intensity data	Traffic intensity data	Travel time data	Travel time data

6.1.3. Communication clarity and benefits

The travel experience of the road users is asked in the surveys. The answers could give valuable information about the communication experience from people who were informed via online means and people who were informed via other means. From the previous chapter, there is not much more measurable information available, meaning these are the only two indicators in the communication clarity and benefits framework, shown in table 6.3.

Table 6.3: Communication clarity and benefits framework

Average rating communication via online advertising	Average rating communication via other means
The average of the rating for communication given by people informed by online advertisement	The average of the rating for communication given by people informed by other means
Survey data	Survey data

6.2. Key Performance Indicators

6.2.1. Framework results

The frameworks can partly be filled in using the results in the previous chapter. Not all information is available, since for the Prinsenbrug, no survey data is available, and for the Van Muijlwijkstraat, there is no traffic intensity data available. Nevertheless, the data that is available gives enough information about differences between the use of online traffic management in a municipality on secondary roads, use of traffic management on primary roads and no use of traffic management on secondary roads.

Table 6.4: Framework results campaign reach

Project	Total Views	Total Clicks (and engage-ment)	Percentage Informed by OTM	Percentage Non-Frequent Road Users Informed by OTM	Advertise-ment platforms
Prinsenbrug Haarlem	913,000	1,220 (CTR: 0.13%)	No information	No information	Waze, Spotify, Facebook, Google Ads
Van Muijlwijk-straat Arnhem	262,000	1,561 (CTR: 0.60%)	22%	26%	Waze, Facebook, Google Ads
A12 Grijsoord Waterberg	4,062,000	10,229 (CTR: 0.25%)	57%	64%	Waze, Facebook, Google Ads

What stands out in the framework results in table 6.4 is that the total number of views is much higher for the A12 project, while there are not more platforms used for the advertisements. The engagement is a little lower than for the Van Muijlwijkstraat, but higher than for the Prinsenbrug. The percentage informed is double as much for the A12 compared to the Van Muijlwijkstraat, which might have something to do with the amount of views. When the campaign on the Van Muijlwijkstraat would have gotten more (unique) views, the percentage informed by OTM should get higher, with probably more people getting informed in total. However, it depends on the size of the target group whether more people can be reached at all. For both campaigns, the percentage of non-frequent travelers informed by online means is higher than the average percentage of people being informed by online means.

Table 6.5: *Framework results follow-up behavior and traffic change*

	Decrease in traffic intensity during peak hours	Percentage of traffic choosing detour route	Percentage of traffic choosing shortcut route	Travel time increase on detour route	Travel time increase on shortcut route
Prinsenbrug Haarlem	10%	Estimation: 500 vehicles -> 65%	Estimation: 270 vehicles -> 35%	0%-25%	75%-150%
Van Muijlwijk-straat Arnhem	No information	No information	No information	Small increase	No information
A12 Grijsoord Waterberg	40%	1500 vehicles -> 62.5%	900 vehicles -> 37.5%	0%	20%-80%
N271 Mook	Not observed	Estimation: 70 vehicles -> 32%	Estimation: 150 vehicles -> 68%	No clear increase	No information

The notable things that can be seen in the framework results in table 6.5 are first of all the decreases in traffic intensity during peak hours. For the A12 Grijsoord - Waterberg this decrease is significant, with 40%. In Haarlem, a decrease in intensity can be seen, but it is not as significant as for the highway. A reason that more people chose not to travel on the A12 during peak hours might be that the traffic disruption there was worse, with larger travel times and more congestion than for the Prinsenbrug project, encouraging more people to switch travel mode, change departure time or stay at home.

Since there was no decrease in traffic intensity during peak hours observed in Mook, it can be assumed that Online Traffic Management has an impact on traffic intensity decrease. The percentage of traffic using the advised detours is also significantly higher for the A12 closure and the Prinsenbrug closure than for the N271 closure in Mook, again indicating that travelers were better informed. The travel time increase is very dependent on the project area and the capacity of the available detour routes. In Haarlem, there were only limited options to cross the Spaarne, causing significant travel time increases over the routes over the bridges, while Arnhem had more shortcut options and there were roads with higher capacities on detour routes on the A12 closure between Grijsoord and Waterberg.
In the analysis of results, a lot of assumptions are made, for example for the traffic intensities on the Prinsenbrug in Haarlem and the increase on bridges elsewhere in Haarlem, while also for the project in Mook, various assumptions have been made. This has to be taken into account for the conclusions made above.

Table 6.6: *Framework results communication clarity and benefits*

	Average rating communication via online advertising	Average rating communication via other means	Difference in rating
Van Muijlwijkstraat Arnhem	5.7	5.3	+0.4
A12 Grijsoord Waterberg	6.4	6.4	+0.1

For the average rating of communication about the roadworks, shown in table 6.6, the averages for the A12 Grijsoord - Waterberg closure are overall higher than the averages for the Van Muijlwijkstraat. Since the content of the message or the context of the road closure has much influence on this rating, only the difference in rating between online means and other means is considered. This shows to what extent people appreciate online traffic management with respect to other forms of communication, like newspapers, (digital) signs and resident letters. It can be seen that for the Van Muijlwijkstraat, people appreciate the online traffic management more than the other communication means, while on the A12 Grijsoord - Waterberg project, the difference in appreciation is less significant.

6.2.2. Experts' opinion

When asked if Online Traffic Management is more or less valuable for projects in municipalities compared to projects on national roads, Maurice Leenen says that on the secondary road network, people are harder to reach, and Online Traffic Management could be a great way to help there. On the main road network, Rijkswaterstaat has lots of campaigns and channels through which people can be reached, and lots of signs on the motorway. It is also easier to advertise via Waze and Flitsmeister on national roads. On secondary roads, this is more difficult because you have to deal with pedestrians, bicycles, boat traffic, but that does not mean that it is less efficient. It might even have a greater impact, because people who live in or move around the area get a personalized ad about a closure they are likely to encounter. There are many similarities, but within a municipality you can probably make more of an impact.

Edwin Leenders also thinks that OTM could perform better in municipalities, as it requires more communication, with many more types of road users and local residents. On highways, pre-announcing is easier and bigger. In municipalities, there is often a pre-announcement sign, and a week later the fences are put up. There can also be cut-through traffic through neighborhoods, which can be prevented by informing more road users. Alex Smienk would not necessarily see a difference in it. In his opinion, the most important thing in the consideration for Online Traffic Management remains the amount of inconvenience expected. A complete road closure is then preconditional, and it would have to involve a major road (a trunk road or area bypass road), which would cause a good reason to deploy OTM.

When asked what the advantages of using Online Traffic Management are compared to the situation where it is not used, Maurice Leenen thinks road users can be managed much better and traffic management can be taken to the next level. It reaches more people than the yellow signs along the road, especially if several projects are going on at the same time, which can lead to a huge sea of signs. This creates an unclear situation to many people. The personalisation and targeting in ads and social media can inform people better, like with geofencing, so there is definitely an added value in Online Traffic Management. Edwin Leenders adds that it is possible to attract a wider audience with other road users as well. Transporters don't get a residents' letter and sometimes only pass through the area a few times a week or a month, and they can be better informed by this. There could certainly be added value in that. However, in practice, it might become difficult to inform the complete audience.

6.3. Improvements in Online Traffic Management

If asked for possible improvements in Online Traffic Management, Edwin Leenders proposes to make it more measurable. They themselves sometimes drive over the roads, but don't get a notification. They also get questions from the client as to whether the campaign is actually running. It would help to make it a bit more visible or demonstrable. At the end of a project, a report is sent with the number of clicks and views, but that often does not say everything. Preferably, all through traffic is informed. The client often tests whether everything around the work is arranged and when they look for a notification through social media or online ads, they often see nothing. It does remain difficult to prove this.

He also wants more insight into road users' reactions to information about the works. This could be done, for example, by a comprehensive dashboard showing the clicks, views and reaction of road users. This is also nice for the contractor, as there will be an overview of how traffic is actually behaving, and whether this is in line with the contractor's expectation, so that measures can be taken if necessary. A real-time dashboard with information on range and passenger behavior would be ideal, and more can be done with it than a report afterwards. A roadwork traffic dashboard is already provided by TripService, where clients can choose several routes to observe during the period of the road constructions. The dashboard shows the delays on those routes, giving an indication of where congestions occur. The dashboard gives no information about informing the road users.

Maurice Leenen says that it is very project-dependent. There was no need for a dashboard in the Prinsenbrug project because traffic could only use surrounding bridges anyway. With traffic phasing, where people could still be sent through when you would rather divert them, it might be more interesting. That hasn't been applied now, so he can't say much about it now, but is curious. According to him it could be of much added value and something TripService could capitalize on a lot. It can be shown well to a client or road authority what the traffic is doing and what the added value of TripService is. It is difficult to show how many people are sent by TripService, and if this can be clarified, it would be a hot item in the market. Then, inconvenience reduction can be shaped through operations very nicely with this. For Alex Smienk, it is often unclear what information gets through or not, it sometimes seems that random road users in an area get information instead of all road users. More information on coverage could help a lot.

7. Recommendation and Discussion

The frameworks that were established in chapter 6 show the most important indicators in the performance of Online Traffic Management that are measurable and available for this research and for TripService. The indicators are a combination of the goals as stated in the research proposal and subjects important for the experts that were interviewed. The results from chapter 5 have been used to test the framework and find differences or similarities in the situations where Online Traffic Management is used on a secondary road in a municipality, like the Van Muijlwijkstraat and the Prinsenbrug, where Online Traffic Management is used on a primary road operated by Rijkswaterstaat, like the A12 between Grijsoord and Waterberg, and on a secondary road where Online Traffic Management is not used, like the N271 in Mook.

The results show that in terms of campaign reach, the campaign on the primary road gets more views, and while showing less engagement, is the information source for half of the road users. This is a difference with the campaign on the secondary road in a municipality, where the amount of views is lower, and so is its share as an information source, with only a quarter informed by OTM. It can be recommended to look into improving the campaign reach in municipalities, for example by increasing the amount of views. There seems to be a higher potential as an information source in these projects. Another recommendation could be to put an additional focus on less frequent travelers as a target group, since this is a group that is more often informed by Online Traffic Management, and is less likely to get information from physical pre-announcements.

In the follow-up behavior and traffic change assessment framework, it can be seen in particular that the deployment of Online Traffic Management has an effect on following detour routes by road users. Although it cannot be clearly proven that Online Traffic Management is responsible for this, significantly more people drive according to recommended diversion routes when OTM is deployed, while without deployment most people drive along shortcuts. This is something that can be explained by the fact that more people were informed in advance, possibly by Online Traffic Management. Nevertheless, the impact remains highly dependent on the project area and project context.

The communication clarity and benefits framework now only contains the ratings given in the surveys conducted by TripService. The results show that in the project in the municipality, there is more appreciation for communication via online means than for other means, while for the project on the primary road, the difference in appreciation is minimal. The framework now consists of basically one indicator, since it is the only measurable and available information about the clarity and benefits of communication. It is recommended to include additional questions about communication appreciation in the surveys to gain more information for this framework, or find other ways to gain this information.

Implementing data about the information campaign into the roadwork traffic dashboard was proposed by Edwin Leenders. This could be looked into, since it would help the road operator or contractor see how many road users are informed, and when more research is done on the follow-up behavior, the expected decrease or percentage of traffic taking a detour can be estimated and displayed in the dashboard.

It is important to mention that the results from this study are results mainly based on one specific project, and cannot be seen as general findings about Online Traffic Management. There are certain patterns and trends that can be observed, and results may end up being in line with future findings about Online Traffic Management, but it is important that care is taken with these concrete outcomes. The main goal of this research is establishing the assessment framework, by examining what the most important indicators are and what information is available about this research. This assessment framework could be used in the future to evaluate certain key performance indicators. The framework is tested with the data that was available, and the trends can be presented as indications of how the situation of Online Traffic Management on highways and secondary roads and the situation without Online Traffic Management impact the indicators.

After testing the framework, it can be concluded that not all data is available, especially on secondary roads in municipalities. There is mainly a lack of traffic data, mainly traffic intensity data. This data is of significant importance to find out how the total traffic volume decreased and how advised detour routes and shortcut routes increased in traffic intensity. For the Prinsenbrug project in Haarlem, many assumptions were made, like road characteristics and volume of traffic flows. When the traffic intensity data is available on these secondary roads, these assumptions are not needed and the results are more reliable. Other assumptions, like exactly how many vehicles did take a specific detour, are also unnecessary when this traffic intensity data is available.

A lot of information about how people were informed and what their travel experience was, comes from surveys. These surveys are done after the advertisement campaign and roadworks, and include a standard set of questions. The use of these surveys in this research can be justified by the high number of respondents, which is 229 answers for the Van Muijlwijkstraat and 300 for Regio Arnhem/Nijmegen. Nevertheless, it could be the case that certain groups whose behavior is different from the actual happenings, did respond to the survey in larger numbers, or these groups did not respond to the survey, resulting in missing information from the surveys. There has not been an analysis to see if the group of respondents is representative for all road users on the Van Muijlwijkstraat. Next to that, it can be recommended to review the questions in the survey and try to make them more related to the specific project, and maybe add questions where respondents can answer that detour or shortcut they took, giving various logical options. This helps a lot in estimating how many road users took a specific detour or shortcut.

When considering these discussion points, TripService can use the assessment framework to test the performance of Online Traffic Management in future projects. With the results of the framework for multiple projects, it could be possible to state some key performance indicators, by for example combining the percentage of people informed by online traffic management with the decrease in traffic intensity, showing the influence of OTM in the traffic intensity decrease.

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Appendix

Appendix I: Overview Cases

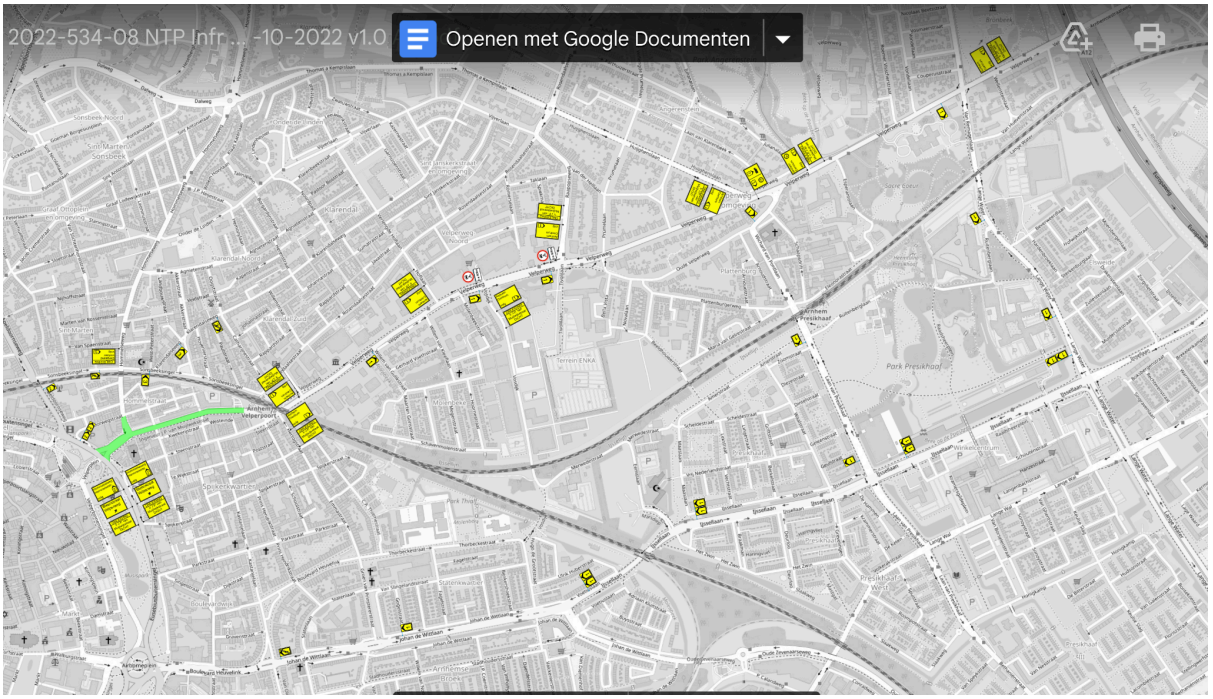

Figure 9.1.1: *Diversion plan Van Muijlwijkstraat*

Figure 9.1.2*: Overview of roadworks in Regio Arnhem/Nijmegen*

Appendix II: Advertisement Results

Van Muijlwijkstraat:

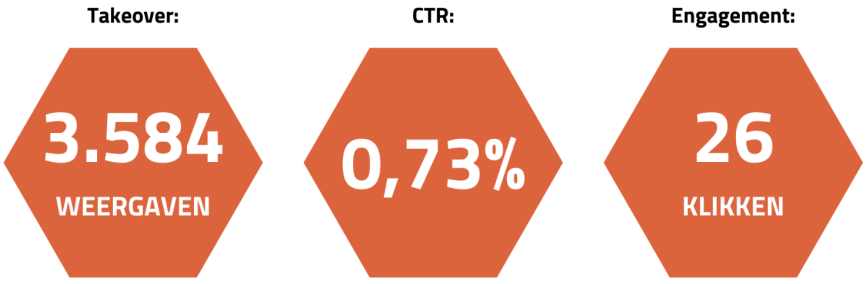

Figure 9.2.1: *Waze advertisement results Van Muijlwijkstraat*

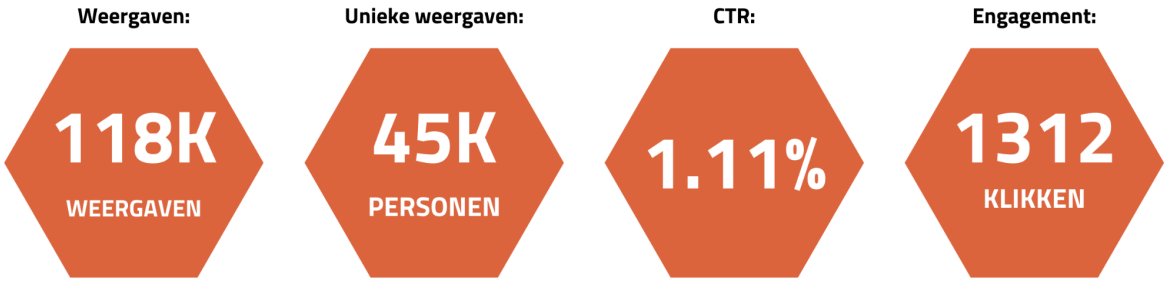

Figure 9.2.2: *Facebook advertisement results Van Muijlwijkstraat*

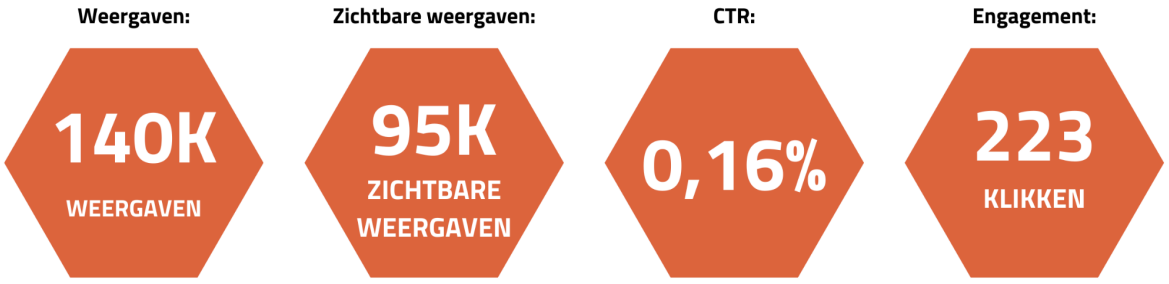

Figure 9.2.3: *Google Ads advertisement results Van Muijlwijkstraat*

Prinsenbrug

Figure 9.2.4: *Waze advertisement results Prinsenbrug*

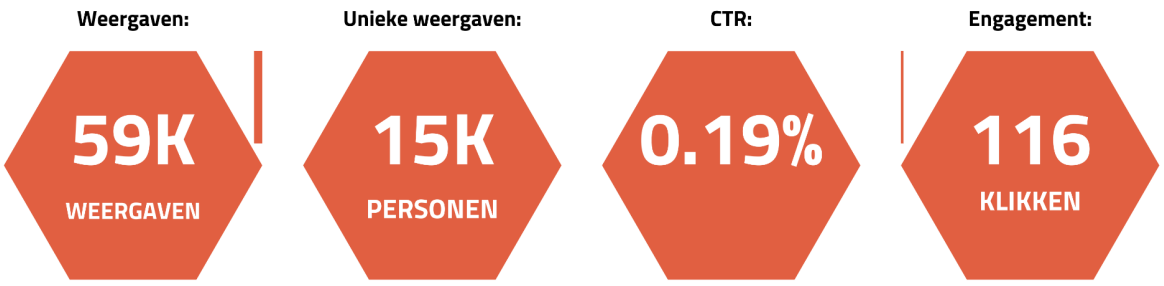

Figure 9.2.5: *Spotify advertisement results Prinsenbrug*

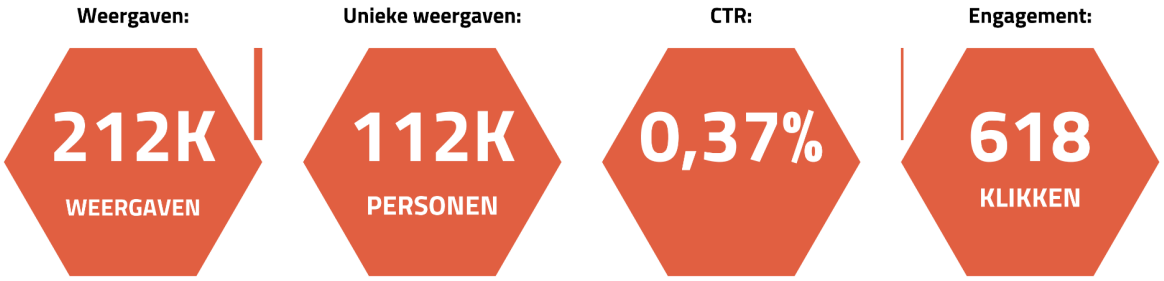

Figure 9.2.6: *Facebook advertisement results Prinsenbrug*

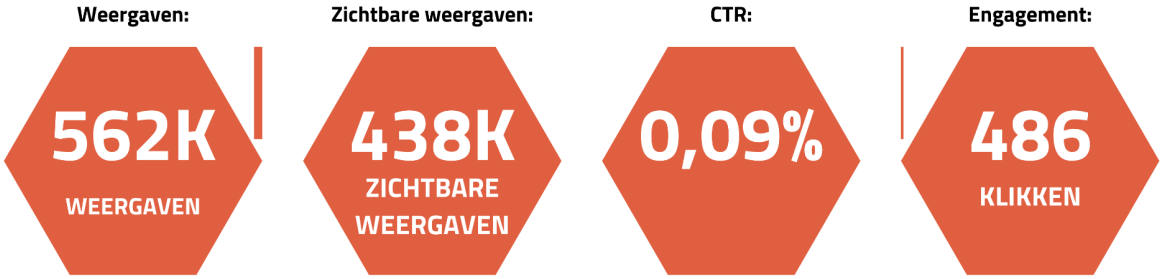

Figure 9.2.7: *Google Ads advertisement results Prinsenbrug*

A12 Grijsoord-Waterberg

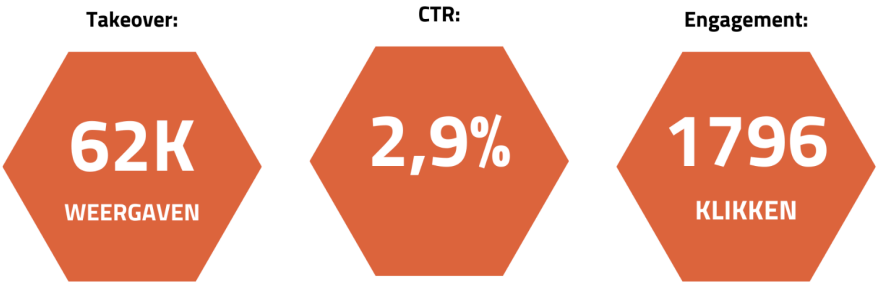

Figure 9.2.8: *Waze advertisement results A12 Grijsoord-Waterberg*

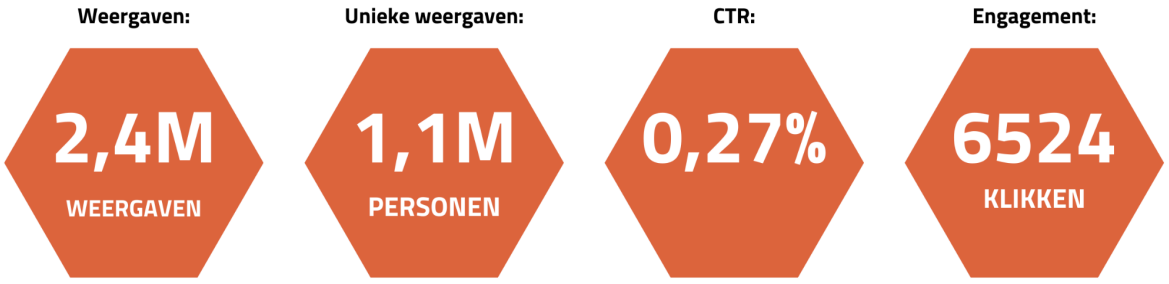

Figure 9.2.9: *Facebook advertisement results Prinsenbrug*

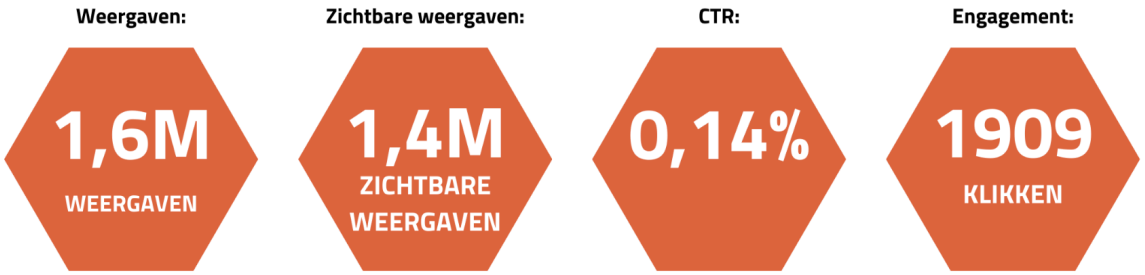

Figure 9.2.10: *Google Ads advertisement results Prinsenbrug*

Appendix III: Survey Questions

The survey done by TripService includes both open and multiple-choice questions. The multiple choice questions are *italicized,* and the options are shown beneath them. The survey questions are in Dutch.

Wat is uw geslacht

- Man
- Vrouw

Wat is uw leeftijd?

Wat zijn de vier cijfers van uw postcode?

Reist u weleens over de Muijlwijkstraat, zo ja hoe vaak?

- 4 of meer dagen per week
- 1 tot 3 dagen per week
- Minder dan 1 dag per week
- Nooit

Was u voor vertrek op de hoogte van de werkzaamheden aan de Van Muijlwijkstraat?

- Ja
- Nee

Waar heeft u de informatie over de werkzaamheden allemaal gezien?

- Online (Social media, advertenties)
- Krant of andere gedrukte media
- Langs de weg op (digitale) borden
- In de navigatie

Wat is meestal het doel van uw rit?

- Woon-werkverkeer
- Van en naar school of studie
- Bezoek aan vrienden of familie
- Winkelen of recreatie

Met welk vervoermiddel reist u over de Muijlwijkstraat ? (more options possible)

- Personenauto
- Bestelbus
- Vrachtauto
- Fiets
- Landbouwverkeer
- Anders…

Checkt u voor vertrek de actuele verkeersinformatie?

- Ja
- Nee
- Anders…

Welke actie heeft u ondernomen op basis van deze informatie?

- Geen actie ondernomen
- Andere route
- Ander vervoermiddel
- Op een andere tijd gereisd
- Op een andere dag gereisd
- Niet gereisd

- Anders…

Hoeveel hinder heeft u ervaren van de werkzaamheden in een schaal van 1 tot 10?

- Number on scale from 1 to 10

Als ik de huidige situatie rond de Muijlwijkstraat vergelijk met de situatie voor de werkzaamheden, dan ervaar ik…

- Veel minder hinder van verkeer
- Minder hinder van verkeer
- Geen verandering
- Meer hinder van verkeer
- Veel meer hinder van verkeer

Als ik de huidige reistijd rond de Van Muijlwijkstraat vergelijk met de situatie voor de werkzaamheden, dan ervaar ik…

- Een veel kortere reistijd
- Een kortere reistijd
- Geen verandering
- Een langere reistijd
- Een veel langere reistijd

Als ik de huidige veiligheid van voetgangers en fietsers rond de Muijlwijkstraat vergelijk met de situatie voor de werkzaamheden, dan ervaar ik…

- Een veel slechtere veiligheid
- Een slechtere veiligheid
- Geen verandering
- Een betere veiligheid
- Een veel betere veiligheid

Ik vind dat de wegbeheerder goed communiceert over werkzaamheden

- Number on scale from 1 to 10

Ik vind het een goed initiatief dat de wegbeheerder mijn mening als weggebruiker vraagt via deze enquête.

- Ja
- Nee

Heeft u nog andere tips of toevoegingen?

Mogen wij u vaker benaderen voor vragen over uw mobiliteit ervaringen? Zo ja, vul hieronder uw emailadres in.

Appendix IV: Expert Interviews

Algemeen:

- Waarom hebben jullie Online Traffic Management ingeschakeld? Hoe zijn jullie daarop gekomen?
  ***Maurice Leenen**: Normaliter wordt bij projecten TSNed (Traffic Service Nederland) ingezet, waar Dura Vermeer een 25% marktaandeel in heeft. Zij bieden ook deze service aan. Dura Vermeer is bij TripService tegengekomen via een verkeersexpositie in Houten, en dat triggerde Maurice om hier ook naar te kijken. Maurice heeft de omgevingsmanager van het project bij de Prinsenbrug voorgesteld om online traffic management te gebruiken. TSNed haalt data ook van TripService, en Dura Vermeer heeft OTM bij dit project als een soort pilot gebruikt. Eerst zijn er bij beide partijen offertes opgevraagd, en de gemeente Haarlem wilde graag OTM proberen, daarvoor is ook budget vrijgemaakt.*
  ***Edwin Leenders:** Meegenomen in het EMVI plan, waar de gemeente Arnhem wel enthousiast van werd. Het centrum van Arnhem is vrij druk, en daarom wilde de gemeente de weggebruiker goed informeren, waardoor het verkeersinfarct beperkt zou worden.*
  ***Alex Smienk:** Om het bereik zo groot mogelijk te krijgen. De omleidingsroutes waren grootschalige omleidingsroutes, en de verwachting was dat het in Arnhem ook erg druk zou worden door lokale omleidingen en sluipverkeer. Juist dat wilden ze voorkomen, en daarom wilden ze zo veel mogelijk mensen bereiken via social media en advertenties, en ook via andere service providers.*
  - Wat wilden jullie bereiken met online traffic management?
    ***Maurice Leenen:** Dura Vermeer stuurde erg op voorbereiding en omgeving, ervoor zorgen dat mensen van tevoren op de hoogte zijn van de werkzaamheden, om op de dagen zelf dat de brug dicht was, mensen minder hinder ondervinden en tijd hebben om hun gedrag aan te passen, voorafgaand aan de werkzaamheden. Tijdens de werkzaamheden aansturen op dat mensen niet een omleidingsroute konden volgen, maar moesten volgen, aangezien de brug dicht was en alleen andere routes mogelijk waren. Ze wilden overtuigen dat het chaos zou worden, dus dat rijden via de omleidingsroute het best werkt. Als er een gedeeltelijke afsluiting is zou je een omleiding kunnen adviseren, maar nu werd er ingestoken om vooraf te informeren. Ook om in te zetten op thuisblijven, ander vervoermiddel, het OV pakken, volg anders deze route.*
    ***Edwin Leenders:** Dat het verkeer op navigatie begeleid zou worden en het verkeer gestuurd kon worden. Zo zou het verkeer over andere routes heen kunnen rijden om de Van Muijlwijkstraat te ontlasten.*
  - Hebben jullie met hiermee bereikt wat jullie wilden bereiken?
    ***Maurice Leenen:** Ja, maar dat is niet gebaseerd op data. Gedrag werd gemonitord via BouwApp, van weggebruikers en mensen die hinder kunnen ondervinden. Er is niet gekozen om een dashboard of sentimentanalyse uit te voeren. Het gevoel was goed, maar er is geen rapport om het te onderbouwen. Er leek een mindering aan vragen in de BouwApp, omdat mensen beter voorbereid waren, het waren kleine locatiegerichte vragen, en minder algemene vragen, zoals de duur van het project. Dat zouden ze*

wijden aan Online Traffic Management. Er is hierdoor minder communicatie tijdens de uitvoering zelf nodig.
Edwin Leenders: *Het is lastig om dat te beantwoorden. Bij een ander project in Grave is geen melding binnengekomen bij NTP en de wegbeheerder toen ze hebben getest door in het projectgebied te rijden, dus NTP weet niet zo goed hoe het echt aanslaat. Moeilijk meetbaar.*
Alex Smienk: *Er was nog wel behoorlijk veel sluipverkeer, mede doordat in een aantal regio's de vakantieperiode startte, en die leken verrast door de afsluiting. Vrachtverkeer leek wel op de hoogte te zijn van de wegafsluiting, maar toch ontstonden er door lokaal verkeer op wegen door Arnhem een aantal opstoppingen. Alsnog is hij blij dat Online Traffic Management is ingeschakeld, al blijft het altijd lastig om het effect te achterhalen van de gele borden langs de weg of juist online middelen om reizigers te informeren.*

- Hebben jullie eerdere ervaringen met Online Traffic Management? Hoe waren deze ervaringen?
  Maurice Leenen: *Er is eerder gebruik gemaakt van het sturen van verkeer door social media en advertenties, bijvoorbeeld via Waze, en bij knooppunt Nieuwermeer wordt Ask&Go gebruikt. Daar worden kaartaanpassingen en campagnes mee gedaan. In het verleden is TSNed ook gebruikt voor dit soort doeleinden en data. Regionaal is er misschien ooit gebruikgemaakt van TripService OTM, en binnen team verkeer landelijke projecten is dit de eerste keer.*
  Edwin Leenders: *In Grave was het echt een afsluiting, en daarbij was er ook een aankondiging om doorgaand verkeer van tevoren te informeren.*
  Alex Smienk: *Er is ook eerder OTM ingezet voor werkzaamheden en evenementen in dezelfde regio Arnhem/Nijmegen. Hetzelfde geldt voor de provincie Overijssel. De ervaringen zijn toch een beetje wisselend, omdat het lastig is om te zien hoeveel mensen er bereikt worden en wat het opvolggedrag is, al blijft dat wel ingewikkeld. Het blijft altijd een afweging om het nou wel te gebruiken, omdat het kwantitatief lastig te onderbouwen is. Er wordt nu vaak gekeken wat de impact van het project is op het verkeer, en als de impact zo groot is dat er ernstige hinder ontstaat, wordt ook OTM ingeschakeld.*
  - Is OTM meer of minder van waarde bij projecten in gemeenten ten opzichte van projecten op nationale wegen (snelwegen, autowegen)?
    Maurice Leenen: *Ja, er is wel een filtering in te maken. Op het onderliggend wegennet zijn mensen moeilijker te bereiken. Op het hoofdwegennetwerk heeft Rijkswaterstaat heel veel campagnes en kanalen waarmee mensen bereikt kunnen worden, en veel borden op de snelweg. Via Waze en Flitsmeister valt ook makkelijker te adverteren. In het onderliggende netwerk is dat lastiger omdat je te maken hebt met voetgangers, fietsen, vaarverkeer, maar dat betekent niet dat het minder efficiënt kan zijn. Het heeft misschien zelfs een grotere impact, omdat mensen die in het gebied wonen of zich er verplaatsen, een gepersonaliseerde advertentie krijgen over een afsluiting waar ze waarschijnlijk mee te maken krijgen. Er zijn veel overeenkomsten, maar binnen een gemeente kun je waarschijnlijk meer impact maken.*
    Edwin Leenders: *OTM kan in gemeenten beter tot zijn recht komen, er is namelijk meer communicatie nodig, met veel meer soorten weggebruikers en*

omwonenden. Op snelwegen is vooraankondigen makkelijker en groter. In gemeenten staat vaker een vooraankondigingsbord, en een week later worden de hekken neergezet. Er kan dan ook sluipverkeer door de wijken heen komen.
Alex Smienk: *Hij zou er niet per se een verschil in zien, het belangrijkste in de afweging blijft de hoeveelheid hinder die wordt verwacht. Een complete wegafsluiting is dan randvoorwaardelijk, en het zou dan ook een belangrijke weg moeten betreffen (een stroomweg of gebiedsontsluitingsweg), en dan heb je wel een goed verhaal waarvoor je OTM inzet.*

- Wat zijn volgens jullie de voordelen van het gebruik van Online Traffic Management ten opzichte van de situatie waarin het niet gebruikt wordt?
  Maurice Leenen: *Weggebruikers kunnen veel beter aangestuurd worden, het management kan naar een hoger niveau getild worden. Het bereikt meer mensen dan de gele borden langs de weg, zeker als er meerdere projecten tegelijkertijd bezig zijn, wat kan leiden tot een enorme borden zee. Dat is voor veel mensen niet duidelijk. Die personalisatie en targeting in advertenties en social media kun je mensen beter sturen, zoals met geofencing, dus er zit zeker een meerwaarde in Online Traffic Management.*
  Edwin Leenders: *Je trekt een breder publiek met ook andere weggebruikers. Transporteurs krijgen geen bewonersbrief en komen soms maar een paar keer per week of per maand door het gebied heen, en die kunnen hierdoor wel beter geïnformeerd worden. Daar kan zeker wel een meerwaarde in zitten. De realisatie is lastig. In MELVIN (wegafsluiting platform) staan namelijk ook waar op de weg gewerkt wordt.*

- Zouden jullie verbeterpunten zien in Online Traffic Management en zo ja, wat zijn die verbeterpunten?
  Maurice Leenen: *Dat is heel projectafhankelijk. Er was geen behoefte aan een dashboard bij dit project, omdat het verkeer toch alleen gebruik kon maken van omliggende bruggen. Bij een verkeersfasering, waar mensen nog steeds doorheen gestuurd zouden kunnen worden terwijl je ze liever zou omleiden, is het misschien interessanter. Dat is nu niet toegepast, dus ze kunnen er nu niet veel over zeggen, maar zijn wel benieuwd. Het zou van veel meerwaarde kunnen zijn. Daar zou TripService zou hier wel veel op in kunnen spelen. Je zou hier goed mee kunnen inspelen op een opdrachtgever of wegbeheerder om te laten zien wat het verkeer doet en wat de toegevoegde waarde is van TripService. Het is lastig om te laten zien hoeveel mensen door TripService gestuurd worden, en als daar helderheid in kan komen, heb je goud in handen op de markt. Je kunt dan hinderbeperking door werkzaamheden heel mooi vormgeven hiermee.*
  Edwin Leenders: *Meetbaar maken. Zelf rijden ze soms ook wel over de wegen heen, maar krijgen ze geen melding. Ook krijgen ze dan van de opdrachtgever dan de vraag of de campagne wel daadwerkelijk bezig is. Het zou helpen om het wat zichtbaarder of aantoonbaarder te maken. Op het eind van een project wordt wel een rapport gestuurd met hoeveelheid clicks en weergaven, maar dat zegt vaak niet alles. Liefst wordt wel al het doorgaande verkeer geïnformeerd. De opdrachtgever test vaak wel of alles rond de werkzaamheden geregeld is en wanneer ze zoeken naar een melding via social media of online advertenties, zien ze vaak niks. Het blijft wel lastig om dit aan te tonen.*

Alex Smienk: *Voor hemzelf is het vaak onduidelijk welke informatie wel of niet doorkomt, het lijkt soms dat er willekeurige weggebruikers in een gebied informatie krijgen in plaats van alle weggebruikers. Meer informatie over bereik zou veel kunnen helpen.*

- Zijn er mogelijke toevoegingen die OTM zouden verbeteren?
  Edwin Leenders: *Meer inzicht in de reactie van de weggebruiker op de informatie over de werkzaamheden. Dit zou bijvoorbeeld kunnen door een uitgebreid dashboard met de clicks, weergaven en reactie van weggebruikers. Voor de aannemer is het ook fijn, omdat er dan een beeld is van hoe het verkeer zich daadwerkelijk gedraagt, en of dit in lijn is met de verwachting van de aannemer, zodat er eventueel maatregelen kunnen worden genomen. Een real-time dashboard met informatie over bereik en reizigersgedrag zou ideaal zijn, en er kan meer mee gedaan worden dan een rapport achteraf.*

- Met welke partij wordt het meeste rekening gehouden bij keuzes over de wegafsluiting (weggebruikers/omwonenden/wegwerkers/gemeente)?
  Maurice Leenen: *De gemeente Haarlem wilde het project gefaseerd uitvoeren, omdat het een belangrijke verkeersader is, zodat de weg nog steeds bereikbaar was. Dat is door Dura Vermeer uitgewerkt, hoe het er dan uit komt te zien en hoe het gerealiseerd kon worden. Dit kwam uit op een aantal van acht faseringen, die niet helemaal wenselijk waren voor de doorstroming en de verkeersveiligheid, omdat bij elke fasering er meer complexiteit ontstaat. Elke keer ga je veranderen, niet alleen intern, die kunnen zich makkelijk aanpassen, maar de weggebruiker hierin meenemen is moeilijker. Voor het is het ingewikkelder om 8 faseringen te volgen met verschillende data. Daarom is besloten om pijnlijk maar kort te sluiten. Dat levert meer hinder op, maar dan zijn de werkzaamheden ook eerder voorbij. Daarin is verkeersdoorstroming en veiligheid voor zowel wegwerkers als verkeersdeelnemers beter. De afweging tussen omwonenden en weggebruikers is lastig. Er zijn vooral bedrijven rond de Spaarneweg. Bewoners en ondernemersverenigingen zijn hierin meegenomen en er was veel participatie vanuit de gemeente Haarlem. Het is onoverkomelijk dat mensen die er wonen hinder ondervinden van de afsluiting. Dan zou je heel graag verkeer over gelijkwaardige wegen willen leiden, maar dat is vaak niet haalbaar. Er zijn maar weinig bruggen over de rivier.*
  Edwin Leenders: *In het verkeer stonden bussen op 1, ze mochten geen vertraging hebben. Voetgangers en fietsers stonden op 2 en auto's op 3. Dat is hoe de gemeente Arnhem de informatievoorziening prioriteert. Tussen veiligheid, bewoners, weggebruikers is het altijd een beetje maatwerk. Als er vanuit een partij klachten komen, kan de situatie wat worden aangepast.*
  Alex Smienk: *Er is gekozen voor een volledige wegafsluiting om het werk goed te kunnen uitvoeren, dus vooral vanuit het perspectief van de aannemer en voor de veiligheid van de wegwerkers. Dat was wel een belangrijk uitgangspunt. Daarnaast is ook met de gemeente Arnhem en grote attracties in Arnhem rekening gehouden door zoveel mogelijk grootschalig om te leiden, met het oog op omwonenden en lokale belangen.*

- Als er een beoordelingskader zou komen voor Online Traffic Management, wat zouden jullie daarin dan terug willen zien? En welke Key Performance Indicators zijn bij jullie van belang bij het kiezen voor OTM?
  Edwin Leenders: *Of de weggebruikers iets aan de vooraankondiging gehad hebben, of het duidelijk was, en of het verkeer zich gedraagt zoals de aannemer dat graag zou willen.*
  Alex Smienk: *Vooral bereik, en ook wat er doorkomt bij de weggebruikers, het opvolggedrag, daarnaast zijn voor hemzelf de kosten belangrijk, net als bij welke serviceprovider het is aangesloten (heeft ook weer met bereik te maken). Als je dat overzichtelijk kunt maken, zouden steeds meer gemeenten en overheden de stap gaan maken om OTM in te zetten. Daarnaast zou het fijn zijn om te weten wat voor toepassingen mogelijk zijn, zoals sluipverkeer voorkomen, omleidingsroutes volgen, vooraankondigingen van afsluitingen, evenementen, spreiding van verkeer, en dergelijke toepassingen.*

Verkeer:

- Was het verkeer naar jullie idee op de hoogte van de werkzaamheden?
  Maurice Leenen: *Ja, toch wel lastig te onderbouwen, maar ze zijn toch ervan overtuigd dat het heeft geholpen. Het is lastig om te zien hoeveel verkeer gebruik maakt van de borden en hoeveel verkeer vooraf op de hoogte was, helemaal bij zo'n project waarbij de hele weg dicht zit. Je zag wel dat er minder zoekverkeer plaatsvond en dat er in de communicatie minder vragen binnenkwamen, dus het lijkt erop dat er meer mensen op de hoogte waren. Er is intern een samenvatting gemaakt met advertentie resultaten, kosten en ook een geschat effect, onderbouwd door verschillende bronnen opgesteld door hunzelf. Dit is op basis van bronnen en niet op eigen onderzoek.*
  Edwin Leenders: *Je ziet bij grote werkzaamheden dat er sowieso veel zoekend verkeer is. Het is lastig om erachter te komen of er meer of minder zoekend verkeer was zonder inzet van OTM, het is de eerste week altijd wel chaos.*
  - Was er minder verkeersvolume in het projectgebied?
    Maurice Leenen*: Dat is moeilijk te beantwoorden, je hebt een gevoel en trends in de communicatie, maar er is niet goed een uitspraak over te doen. Er is geen nulmeting gedaan.*
    Edwin Leenders: *Het wordt na een week wel wat rustiger, maar dat komt doordat reizigers na een week wel hun gedrag aanpassen.*
    Alex Smienk*: Ja, er is minder verkeer gezien in de regio. Het is lastig om te onderbouwen dat meer mensen zijn thuisgebleven, anders hebben gereisd of op een andere tijd zijn gaan reizen, maar dat is wel wat ze verwachten dat er gebeurd is. Daar is in ieder geval wel op ingezet.*
  - Deed het verkeer wat jullie verwachten dat het deed?
    Maurice Leenen: *Ja, tot op zekere hoogte. Vaak zijn er grote afsluitingen waarbij je gaat monitoren. In verkeerskunde wordt vaak gezegd dat je 10 tot 14 dagen nodig hebt om het gedrag van weggebruikers aan te passen, maar dit project duurt precies 14 dagen. Daarin volgde het grootste deel van het verkeer de omleiding, al was er ook sluipverkeer, daarom is binnen een week de verkeerstekening aangepast, omdat 1 verkeerstak heel dominant was. Bij de brug zelf is meer ruimte gecreëerd, omdat het pontje boven verwachting vaak werd gebruikt. Er is een aantal aanpassingen gedaan om de*

voetgangers meer ruimte te geven op een bepaalde plek. De volgende twee punten zijn aangepast n.a.v. meldingen vanuit onze stakeholders (zoals gemeente, politie etc.):

- *Aan de westkant van de Prinsenbrug liep verkeer te sluipen op de Koudehorn richting de Catharijnebrug ten hoogte van politiebureau Haarlem. Door de dominantie (sluip)verkeersstroom is er een verkeersregelaar ingezet bij de uitrit van het politiebureau. Hierdoor kon de politie weer vrij uitrukken naar meldingen;*
- *Aan de oostkant van de Prinsenbrug werd verkeer op de N200 Oudeweg net vóór de brug omgeleid via de Gedempte Oostersingelgracht. Hier probeerde verkeer te sluipen door één straat eerder de weg in te slaan (de voormalige Oudeweg die dood loopt). De situatie is hier verduidelijkt zodat geen verkeer meer ging sluipen via een doodlopende straat.*

- Hebben jullie specifieke omleidingen aangegeven en werden deze gevolgd?
  - Welke wegen waren dit?
    Alex Smienk: *Er waren twee grootschalige omleidingen aangegeven: eentje over de A30/A1/A50 en eentje over de A50/A15/N325.*
  - Wat was de motivatie achter het aanwijzen van deze wegen?
    Maurice Leenen*: Enerzijds de richtlijn, die aangeeft hoe je verkeer kan/moet omleiden. Dit gebeurde, alleen de Schoterbrug was niet gelijkwaardig, maar het is de dichtstbijzijnde brug en zou toch wel gebruikt worden, en dus is deze ook gebruikt. Voetgangers hebben een pont kunnen gebruiken, en een andere brug is voor fietsers gebruikt.*
    Edwin Leenders: *De weg had de grootste capaciteit, dus het was logisch om het verkeer hier overheen te laten rijden. Het ontlast ook de wijken, aangezien verkeer hier dan niet doorheen rijdt, tenzij er sluipverkeer is.*
    Alex Smienk*: Dat waren alternatieven die al vastlagen. Het verkeer moet toch ergens heen, en deze routes lagen klaar in het calamiteitenscenario, wat gebruikt wordt bij incidenten op de weg. Deze zijn dus ook ingezet voor de werkzaamheden.*
  - Zagen jullie tegenstrijdige informatie tussen de fysiek aangegeven omleidingsroutes en de routes gegeven door de navigatie?
    Maurice Leenen: *Daar is geen check op gedaan. Vanuit TSNed werden wel controles gedaan of de omleidingen aangegeven werden zoals ze getekend waren, maar dus geen check op wat voor route navigatie aangeeft en welke door de borden wordt gegeven.*
    Edwin Leenders: *Nee, er is hier ook goed naar gekeken met Traffic Service.*
    Alex Smienk: *Het is niet gecontroleerd, maar waarschijnlijk wel het geval geweest. De navigatiesystemen geven wel de kortste routes aan. Het is algemeen bekend dat dat bijdraagt aan een toename van verkeer op de sluiproutes.*

- Waren er sluiproutes waar veelvuldig gebruik van werd gemaakt?
  Edwin Leenders: *Ja, met name de Steenstraat, hier werd het erg druk.*
  Alex Smienk: *Vooral binnen Arnhem, al zaten er misschien ook een aantal provinciale wegen bij. Dit waren met name belangrijke toevoerwegen naar Arnhem,*

zoals de N224. Daarnaast waren er een aantal trekpleisters zoals Burgers Zoo en Luchtmuseum, maar ook het ziekenhuis, die minder goed bereikbaar waren.

- Waren hierover klachten van omwonenden?
  Edwin Leenders: *Er kwam veel autoverkeer door de wijk door sluipverkeer op de Steenstraat, daar zijn wel klachten over geweest.*
  Alex Smienk: *Van omwonenden is verder niet veel gehoord door Alex.*
- Zijn er maatregelen genomen om dit tegen te gaan?
  Edwin Leenders: *Er werd een extra bord neergezet met een adviesroute. Geen wegaanpassingen of andere ingrijpendere maatregelen.*
  Alex Smienk: *Verkeerslichten zijn aangepast zodat een aantal stromen van de omleidingsroute beter worden gefaciliteerd, om te voorkomen dat daar files komen te staan. Daarnaast is er veel met gele borden gewerkt om verkeer af te vangen op de omleidingsroutes. Bermdrips zijn volop ingezet, net als verkeersregelaars op een aantal locaties waar het heel druk werd, om te voorkomen dat er onveilige situaties ontstonden.*

- Waren er opstoppingen of files in de buurt van de wegafzetting die misschien verband hadden met de wegafsluiting?
  Maurice Leenen*: Ja, er is geen nulmeting gedaan om te kijken waar verkeer eerst rijdt, maar op spitsmomenten zie je dat het volloopt rond de brug, maar dat is een logisch effect van het vierkant sluiten van de brug, vooral dus rondom spitsuren*
  Edwin Leenders: *Met name de eerste week, daarna paste het verkeer zich aan. Verder viel het mee.*
  - Hebben jullie hier iets aan gedaan?
    Maurice Leenen: *Er valt op zo'n moment weinig aan te doen*
  - Had dit voorkomen kunnen worden door dat aan te geven in de campagne?
    Maurice Leenen*: Vermoedelijk niet, er werd ingezet op dat het grote hinder zou worden, dus men werd aangeraden om thuis te werken, op een ander moment te reizen of met een ander vervoermiddel te gaan. Dat is vaak het zwaarste wat je kan communiceren naar omwonenden en forenzen.*
    Edwin Leenders: *Nee, het gaat toch altijd wel gebeuren dat er opstoppingen en files komen als een weg wordt dichtgegooid.*

Communicatie:

- Zijn er vanuit omwonenden klachten binnengekomen over de communicatie van de wegafsluiting?
  Maurice Leenen*: Over de communicatie niet*
  Edwin Leenders: *Er is geen bouwapp gebruikt, maar de website van de gemeente en de website van NTP konden wel gebruikt worden voor communicatie (en bewonersbrieven zijn gestuurd)*
  Alex Smienk: *Vooral binnen Arnhem, al zaten er misschien ook een aantal provinciale wegen bij. Dit waren met name belangrijke toevoerwegen naar Arnhem, zoals de N224. Daarnaast waren er een aantal trekpleisters zoals Burgers Zoo en Luchtmuseum, maar ook het ziekenhuis, die minder goed bereikbaar waren.*
  - Waar gingen deze klachten specifiek over?
    Edwin Leenders: *Er zijn wel een aantal mailtjes binnengekomen over onduidelijkheden over de afsluiting.*

    - Wat is er gedaan met de klachten?
      Edwin Leenders: *Er is niks aangepast.*

- Op welke doelgroepen hebben jullie ingezet?
  Maurice Leenen: *Doorgaand verkeer over de Prinsenbrug, omwonenden, recreatieve bezoekers Zandvoort (paasraces tijdens het weekend), en recreatieve bezoekers Haarlem Centrum, reizigers naar station Haarlem (vanwege de aansluiting op de Kiss&Ride*
  Edwin Leenders: *Vooral doorgaand verkeer, geen fietsers en voetgangers, ook omwonenden (in een digitaal vangnet, geofences)*
    - Waarom deze doelgroepen?
      Edwin Leenders: *Ze wilden vooral doorgaand verkeer in de stad bereiken.*
      Alex Smienk: *Het vrachtverkeer, omdat deze groep vaak dezelfde route neemt, en de A12 naar Duitsland is een veel genomen route door vrachtverkeer. Ook is geprobeerd het vakantieverkeer goed te bereiken. Dat is wel lastiger, maar wel geprobeerd via social traffic management. Er is ook geprobeerd het spitsverkeer wat in die periode actief was te beperken. Daarnaast is ook op de website van Burgers Zoo aangegeven dat er werkzaamheden zijn op de A12, zodat bezoekers daarvan op de hoogte waren.*
    - Was dit een goede keuze en waarom wel/niet?
      Edwin Leenders: *Lastig te beantwoorden. Het is niet mogelijk om iedereen te bereiken. Het bereik was waarschijnlijk wel voldoende.*
    - Welke doelgroepen had je achteraf gezien nog willen bereiken? Of was een groter bereik beter geweest?
      Maurice Leenen: *Er is ruim gekozen voor doelgroepen. Er is ook gekeken om vaarverkeer mee te nemen, maar het was niet echt een recreatief vaarseizoen. Dat had op een ander moment nog wel een toevoeging kunnen zijn.*
      Alex Smienk: *Wellicht had er iets meer kunnen worden ingezet op reizen met de trein voor dagjesmensen.*

- Denken jullie dat advertenties of berichten op sociale media effectiever zijn dan andere middelen (bijeenkomsten, brieven, etcetera) ?
  Maurice Leenen: *Effectiever voor bepaalde doelgroepen, vaak bereik je jong volwassenen en jongeren beter met social media, en volwassenen kun je goed bereiken via google apps (websites), maar je houdt altijd een doelgroep die je niet bereikt maar waar je wel rekening mee moet houden. Die komen dan wel naar informatiemomenten en vinden dit belangrijk. Er zijn ook mensen die geen navigatie gebruiken maar wel veel naar wegbewijzeringsborden kijken. OTM is een toevoeging, maar wel een hele effectieve op de genoemde doelgroepen.*
  Edwin Leenders: *Het is een goede aanvulling. Mensen hebben nu veel meer digitale middelen. Er kunnen meer mensen bereikt worden met OTM.*
  Alex Smienk: *Het is vooral aanvullend op elkaar. Er wordt steeds minder vaak bijvoorbeeld de krant ingezet, al moet je vanuit het project wel blijven informeren naar alle bewoners die niet kunnen worden bereikt via social media of advertenties.*

- Wat is de toegevoegde waarde van deze informatiebronnen? (doelgroepbereik, betrokkenheid en interactie, kosten efficiëntie, meetbaarheid van resultaten, impact)
  Maurice Leenen: *Op al deze gebieden is OTM een toegevoegde waarde, en daarin is het ook efficiënt.*
  Edwin Leenders: *Mensen die het interesseert zullen waarschijnlijk wel doorklikken. Er zit nog niet veel interactie in, het is vooral eenzijdig informeren.*
  Alex Smienk: *Qua kosten zou het goedkoper zijn om alle gele borden weg te halen en volop in te zetten op OTM om zo een groot bereik te hebben. Bij grote afsluitingen zoals bruggen zie je tot op grote afstand tot de brug gele borden staan, waar de inzet van OTM wellicht goedkoper zou zijn en beter kunnen werken.*
- Zouden er andere middelen kunnen zijn die een aanzienlijke impact hebben op het op de hoogte brengen van weggebruikers?
  Maurice Leenen: *Je kunt het zo gek maken als je wilt, maar er zit natuurlijk ook wel een prijskaartje aan. Volgens Rijkswaterstaat is bewezen dat tekstwagens effectiever zijn, bepaalde kleuren markering zouden kunnen, een fietsrace omleiding, maar dat zijn fysieke maatregelen die veel kosten en waarvan de effectiviteit niet bewezen is.*
  Edwin Leenders: *Het is wel belangrijk om steeds meer middelen in te zetten. NTP gebruikt ook een eigen bouwapp, daarin zit meer interactie. Hier kunnen mensen ook vragen stellen. Zoiets zou ook geïmplementeerd kunnen worden in een dashboard voor OTM. De bouwapp van NTP lijkt een beetje op een "callcenter", waar eerst AI probeert om (kleinere) vragen te beantwoorden, en de vragen daarna eventueel worden doorgezet. Dat zou in de toekomst misschien wel van meerwaarde kunnen zijn.*

- Was de inhoud van de informatievoorziening voldoende?
  Maurice Leenen*: Er is veel tijd gestopt in het zo kort en bondig mogelijk maken van de informatievoorziening, met een link voor meer informatie over het project, om het zo helder mogelijk te communiceren.*
  Edwin Leenders: *De informatievoorziening was wel voldoende zoals die was.*
  Alex Smienk: *Nee, het was zo wel prima.*
  - Had meer informatie ervoor gezorgd dat meer mensen anders zouden reizen?
    Edwin Leenders; *NTP heeft niet echt gekeken naar het overhalen om thuis te blijven of anders te reizen, dat was niet helemaal aan de orde.*

Projectspecifiek:

- Context
  - Wat gebeurde er tijdens de werkzaamheden?
    Maurice Leenen: *Prinsenbrug 2 weken gesloten vanwege onderhoud. Er is ook een vooraankondiging geweest vanaf 14 dagen van tevoren.*
    Edwin Leenders: *Een EMVI plan gemaakt met fasering, OTM werd daarin meegenomen (alle faseringen), werd goed beoordeeld.*
    Alex Smienk: *Vanuit het regionale verkeersmanagement team is er met name gekozen om de vooraankondigingen ook regionaal te doen, gezien de*

hoeveelheid grote werkzaamheden en evenementen in de omgeving. Dit was 4 weken voor de werkzaamheden en 2 weken voor de werkzaamheden. In de vooraankondiging werd doorverwezen naar de werkzaamheden die gepland waren. Voor de A12 zelf is ook 2 weken van tevoren een vooraankondiging geweest over de afsluiting voor doorgaand verkeer. 4 weken van tevoren is er al een vooraankondiging geweest voor omwonenden.

- Wat was de aangepaste verkeerssituatie?
  Maurice Leenen: *Omleidingsroutes, fysiek aangegeven langs de weg, over andere bruggen over de Spaarne in Haarlem. De omleidingen gaan volgens de richtlijnen met gele borden. Omleidingen waren via de N205, omdat omleiden over gelijkwaardige wegen moet. Ook werd over de Schoterbrug omgeleid, aangezien er daar veel sluipverkeer overheen werd verwacht. Er zijn maar een paar plekken waar je in Haarlem over de Spaarne kunt.*
  Edwin Leenders: *Er zijn wat auto's vanaf gegaan, van de ring naar het station. Er was in het ontwerp al rekening mee gehouden dat dit gebeurde, en dat alleen bussen hier nog konden rijden. Deze is er ook al snel vanaf gehaald. Het ging overigens niet om een volledige afsluiting van verkeer, maar wel om een aangepaste verkeerssituatie. (zie mail)*
  Alex Smienk: *De projecten in Arnhem en Nijmegen waren complete wegafsluitingen, soms in 1 richting en soms in beide richtingen.*

- Structuur
  - Welke verschillende partijen waren bij het project betrokken?
    Maurice Leenen: *Voor de Prinsenbrug zijn bij de werkzaamheden zelf veel dingen binnenshuis gedaan, maar er waren ook een aantal onderaannemers. De gemeente Haarlem was opdrachtgever, opdrachtnemer was Dura Vermeer Infraregio Noordwest, aanstuurder van de onderaannemers. TSNed is ingeschakeld voor de wegafsluiting.*
    Edwin Leenders: *Verkeersmateriaal is gedaan door STN, dat is de huisaannemer van Arnhem. De gemeente Arnhem heeft een doorstromingsmanager, wegbeheer, evenementenmanagement die allemaal bezig zijn met dit soort projecten. Verder geen externe bureaus.*
    Alex Smienk: *Voor de A12 was Rijkswaterstaat de opdrachtgever, die ook traffic management en online traffic management heeft ingezet. In de regio is dat vanuit de regio perspectief gedaan, afstemming ging met de omgevingsmanager van het project. Alex Smienk was voorzitter van het regionale verkeersmanagement team, waar de afspraken over afsluitingen/omleidingen en vooraankondigingen zijn gemaakt.*

Appendix V: Traffic Intensity Decrease A12 Grijsoord-Waterberg

Figure 9.5.1 shows the measuring points and detour and shortcut routes for study area 1. Table 9.5.1 shows the traffic intensities, the decrease on the measuring points and the increase on the shortcut or detour that follows from the intensities on the measuring points.

***Figure 9.5.1**: Traffic intensity measuring points and detours/shortcuts study area 1*

***Table 9.5.1:** Traffic intensities on measuring points study area 2*

	Before road closure	During road closure	Decrease on Highway	Increase on detour/shortcut
Before Knooppunt Maanderbroek	4000	3000	25%	
A30 detour	*-0*	*-1000*		+1000
Knooppunt Maanderbroek - Afslag Oosterbeek	4000	2000	50%	
Amsterdamseweg shortcut	*-0*	*-500*		+500
Afslag Oosterbeek-Knooppunt Grijsoord	4000	1500	62.5%	
A50 to Nijmegen	*-1500*	*-1500*		+0
Knooppunt Grijsoord-Knooppunt Waterberg	2500	0	100%	

Figure 9.5.2 shows the measuring points and detour and shortcut routes for study area 1. Table 9.5.2 shows the traffic intensities, the decrease on the measuring points and the increase on the shortcut or detour that follows from the intensities on the measuring points.

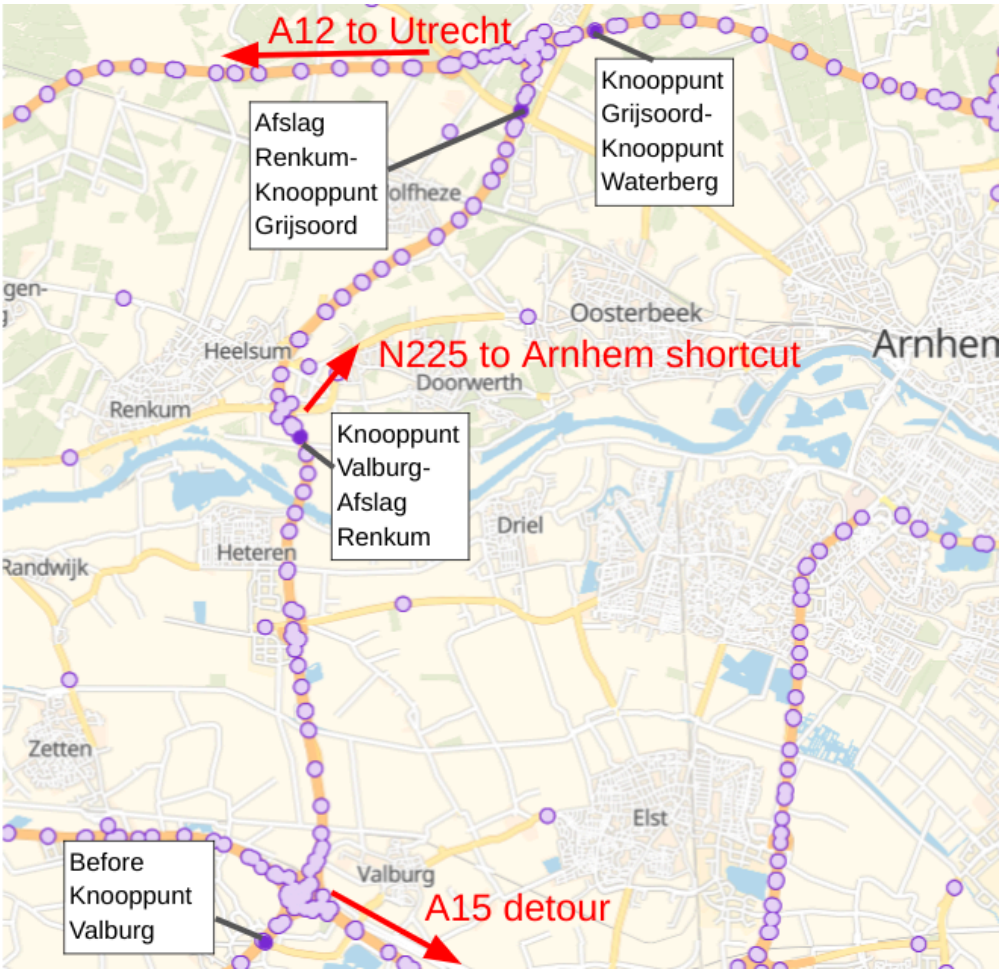

***Figure 9.5.2**: Traffic intensity measuring points and detours/shortcuts study area 2*

***Table 9.5.2:** Traffic intensities on measuring points study area 2*

	Before road closure	During road closure	Decrease on Highway	Decrease on detour/shortcut
Before Knooppunt Valburg	4000	3000	25%	
A15 detour	*-500*	*-1000*		*500*
Knooppunt Valburg-Afslag Renkum	3500	2000	43%	
N225 to Arnhem shortcut	*-0*	*-500*		*500*
Afslag Renkum-Knooppunt Grijsoord	3500	1500	57%	
A12 to Utrecht	*-1000*	*-1500*		*500*
Knooppunt Grijsoord-Knooppunt Waterberg	2500	0	100%	

Figure 9.5.3 shows the measuring points and detour and shortcut routes for study area 1. Table 9.5.3 shows the traffic intensities, the decrease on the measuring points and the increase on the shortcut or detour that follows from the intensities on the measuring points.

***Figure 9.5.3**: Traffic intensity measuring points and detours/shortcuts study area 3*

***Table 9.5.3:** Traffic intensities on measuring points study area 3*

	Before road closure	During road closure	Decrease on Highway	Increase on detour/shortcut
A12/A50	3400	1000	70%	
Entrance Arnhem-Noord	*+600*	*+1200*		*600*
A12 Knooppunt Waterberg-Knooppunt Velperbroek	4000	2200	45%	
N325 connection	*-1200*	*-500*		*700*
After Knooppunt Velperbroek	2800	1700	39%	

Figure 9.5.4 shows the measuring points and detour and shortcut routes for study area 1. Table 9.5.4 shows the traffic intensities, the decrease on the measuring points and the increase on the shortcut or detour that follows from the intensities on the measuring points.

***Figure 9.5.4**: Traffic intensity measuring points and detours/shortcuts study area 4*

***Table 9.5.4:** Traffic intensities on measuring points study area 4*

	Before road closure	During road closure	Decrease on Highway	Increase on detour/shortcut
A50	2500	800	68%	
Entrance Arnhem-Centrum	*+500*	*+700*		*200*
Afslag Arnhem-Centrum - Afslag Schaarsbergen	3000	1500	50%	
Entrance Schaarsbergen	*+400*	*+700*		*300*
After Afslag Schaarsbergen	3400	2200	35%	

Appendix VI: Traffic Intensity Calculation Prinsenbrug

BPR Function: $T = T_f(1 + \alpha(\frac{V}{C})^{\beta})$, where

- T is the travel time under current traffic conditions
- T_f is the free-flow travel time
- V is the traffic volume
- C is the capacity of the road
- α and β are parameters (ideally determined empirically) depending on the road characteristics

Assumptions:

- For Buitenrustbrug: α=0.15 and β=4
- For Waarderbrug and Catharijnebrug: α=0.35 and β=5

The α and β values are usually determined empirically, by calibrating using traffic intensity data and travel time data on various moments. Since the traffic intensities are not known on these locations, these assumptions are made. For the Buitenrustbrug, the typical values for 2-lane roads in both directions are used, while for roads with a smaller capacity, both values increase due to the road characteristics (Saric et al., 2018).

Buitenrustbrug:

On the Buitenrustbrug, the travel times during peak hours increase from 110 seconds to 140 seconds, so $T_0 = 110$ and $T_1 = 140$. The free flow travel time, the lowest travel time measured, is 60 seconds.

BPR Function: $T = T_f(1 + \alpha(\frac{V}{C})^{\beta})$

The function can be used for the situation before the bridge closure (T_0) and during the bridge closure (T_0).

$T_0 = T_f(1 + \alpha(\frac{V_0}{C})^{\beta})$

$T_1 = T_f(1 + \alpha(\frac{V_1}{C})^{\beta})$

These can be filled in with the data and assumptions known:

$110 = T_f(1 + 0.15(\frac{V_0}{C})^{4})$

$140 = T_f(1 + 0.15(\frac{V_1}{C})^{4})$

These can be rewritten as:

$(\frac{V_0}{C})^{4} = \frac{\frac{110}{T_f}-1}{0.15}$

$(\frac{V_1}{C})^{4} = \frac{\frac{140}{T_f}-1}{0.15}$

Therefore the relations between the two formulas is as follows:

$(\frac{V_1}{C})^{4} = k * (\frac{V_0}{C})^{4}$, where $k = (\frac{V_1}{V_0})^{4}$, meaning $\frac{\frac{140}{T_f}-1}{0.15} = k * \frac{\frac{110}{T_f}-1}{0.15}$

Simplifying, and filling in T_f:

$140 - T_f = 110k - kT_f$
$140 - 60 = 110k - 60k$
$80 = 50k$
$k = (\frac{V_1}{V_0})^4 = 1.6$
$(\frac{V_1}{V_0}) = 1.125$
Therefore, the increase is 12.5%

Schoterbrug:
The travel time results from the Schoterbrug are unfit to use for the formula, since the travel time data does not increase. However, it is more than likely that the traffic intensity increased due to the Prinsenbrug closure, since it is designated as a detour route, both physically and online. The easiest assumption is that the increase in vehicles is more or less equal to the increase of the vehicles on the Buitenrustbrug, since both were designated as detours.

Catharijnebrug:
On the Catharijnebrug, the travel times during peak hours increase from 60 seconds to 150 seconds, so $T_0 = 60$ and $T_1 = 150$. The free flow travel time, the lowest travel time measured, is 40 seconds.

BPR Function: $T = T_f(1 + \alpha(\frac{V}{C})^\beta)$

The function can be used for the situation before the bridge closure (T_0) and during the bridge closure (T_0).

$T_0 = T_f(1 + \alpha(\frac{V_0}{C})^\beta)$
$T_1 = T_f(1 + \alpha(\frac{V_1}{C})^\beta)$
These can be filled in with the data and assumptions known:
$60 = T_f(1 + 0.35(\frac{V_0}{C})^5)$
$150 = T_f(1 + 0.35(\frac{V_1}{C})^5)$
These can be rewritten as:
$(\frac{V_0}{C})^5 = \frac{\frac{60}{T_f}-1}{0.35}$
$(\frac{V_1}{C})^5 = \frac{\frac{150}{T_f}-1}{0.35}$
Therefore the relations between the two formulas is as follows:
$(\frac{V_1}{C})^5 = k * (\frac{V_0}{C})^5$, where $k = (\frac{V_1}{V_0})^5$, meaning $\frac{\frac{150}{T_f}-1}{0.35} = k * \frac{\frac{60}{T_f}-1}{0.35}$
Simplifying, and filling in T_f:
$150 - T_f = 60k - kT_f$
$150 - 40 = 60k - 40k$
$110 = 20k$

$k = (\frac{V_1}{V_0})^5 = 5.5$

$(\frac{V_1}{V_0}) = 1.406$

Therefore, the increase is 40.6%

Waarderbrug:

On the Waarderbrug, the travel times during peak hours increase from 400 seconds to 700 seconds, so $T_0 = 400$ and $T_1 = 700$. The free flow travel time, the lowest travel time measured, is 120 seconds.

BPR Function: $T = T_f(1 + \alpha(\frac{V}{C})^\beta)$

The function can be used for the situation before the bridge closure (T_0) and during the bridge closure (T_0).

$T_0 = T_f(1 + \alpha(\frac{V_0}{C})^\beta)$

$T_1 = T_f(1 + \alpha(\frac{V_1}{C})^\beta)$

These can be filled in with the data and assumptions known:

$400 = T_f(1 + 0.35(\frac{V_0}{C})^5)$

$700 = T_f(1 + 0.35(\frac{V_1}{C})^5)$

These can be rewritten as:

$(\frac{V_0}{C})^5 = \frac{\frac{400}{T_f}-1}{0.35}$

$(\frac{V_1}{C})^5 = \frac{\frac{700}{T_f}-1}{0.35}$

Therefore the relations between the two formulas is as follows:

$(\frac{V_1}{C})^5 = k * (\frac{V_0}{C})^5$, where $k = (\frac{V_1}{V_0})^5$, meaning $\frac{\frac{700}{T_f}-1}{0.35} = k * \frac{\frac{400}{T_f}-1}{0.35}$

Simplifying, and filling in T_f:

$700 - T_f = 400k - kT_f$

$700 - 120 = 400k - 120k$

$580 = 280k$

$k = (\frac{V_1}{V_0})^5 = 2.1$

$(\frac{V_1}{V_0}) = 1.157$

Therefore, the increase is 15.7%

Intensities

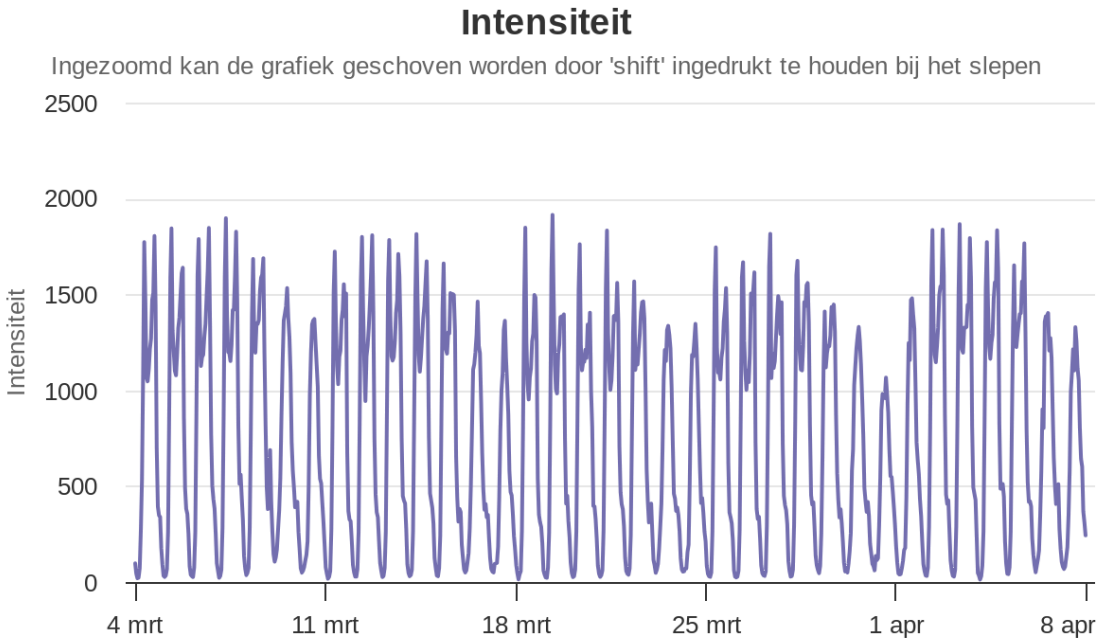

Figure 9.6.1: *Traffic intensity N200 to Haarlem*

The intensity during peak hours on the N200 is around 1800 vehicles per hour, as can be seen in figure 9.6.1. Traffic can cross the Spaarne over the Prinsenbrug or the Schoterbrug, but it is also possible that the destination of some traffic is before the bridges, since there are a lot of businesses located there. We assume that 1400 vehicles per hour cross one of the two bridges. Since the N200 seems to be a more important road than the Waarderweg, we assume that the intensity over the Prinsenbrug is 800 vehicles per hour and over the Schoterbrug is 600 vehicles per hour.

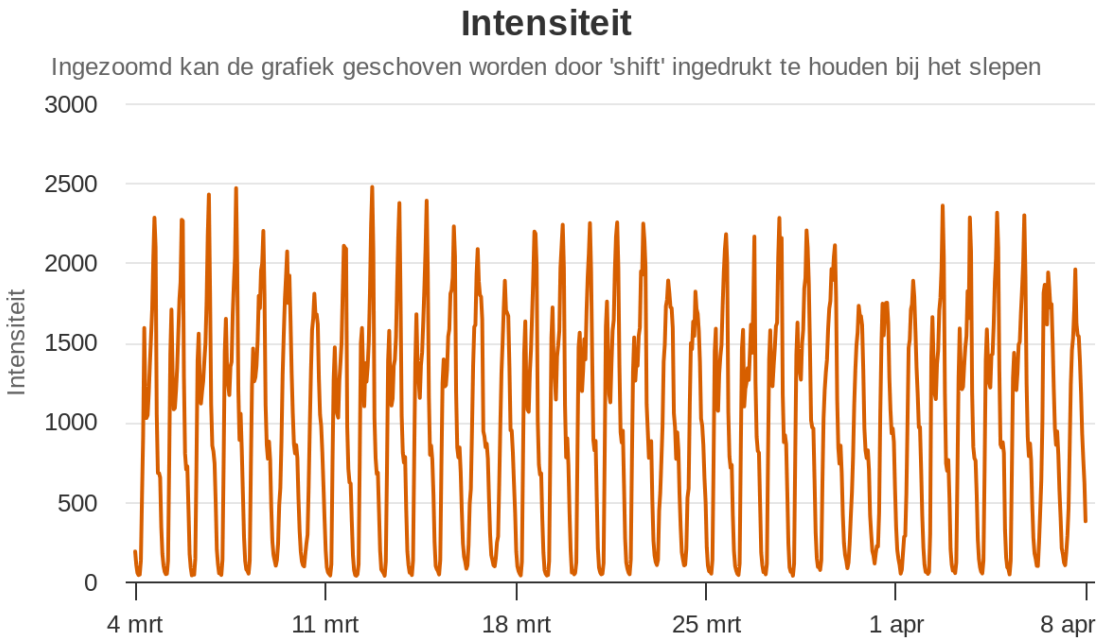

Figure 9.6.2: *Traffic intensity N205 to Haarlem*

The intensity during peak hours on the N205 is around 2500 vehicles per hour, as can be seen in figure 9.6.2. There are two significant intersections between the location where the intensity is measured and the Buitenrustbrug, namely with the Prins Bernhardlaan/Amerikaweg and Europaweg, where it is plausible that some traffic left the N205. Therefore, we assume that the intensity over the Buitenrustbrug is 2000 vehicles per hour.

Since traffic on the Prinsenbrug decreased by 10%, 780 vehicles per hour had to take a different route over the Spaarne. From the calculation, the intensity over the Buitenrustbrug increased by 12.5%, which would mean that the traffic intensity increased with 250 vehicles per hour over the Buitenrustbrug. Since it is not known what the increase on the Schoterbrug was, we assume that it is approximately the same as the other detour route, with the Buitenrustbrug, so 250 vehicles per hour. This means that the other 270 vehicles per hour probably took a shortcut over the Waarderbrug or the Catharijnebrug.

Appendix VII: Appendix V: Traffic Intensity Change N271 Mook

Figure 9.7 shows the measuring points and detour and shortcut routes for study area 1. Table 9.7 shows the traffic intensities on the measuring points, read from the graphs.

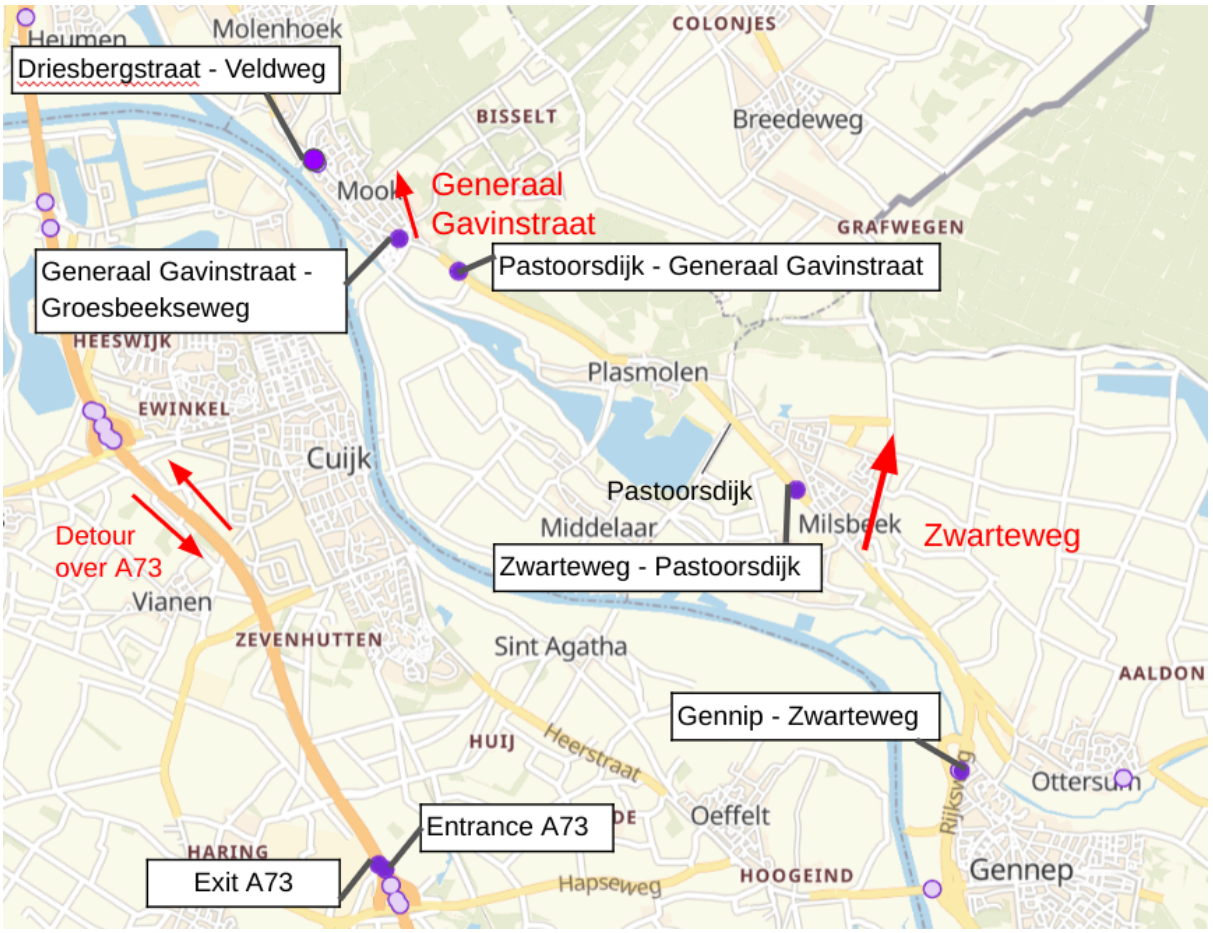

Figure 9.7: *Location of measuring points and detour and shortcut routes on N271 in Mook*

Table 9.7: *Traffic intensity before and during road closure N271 Mook*

	Before road closure	During road closure
Entrance A73	500	570
Exit A73	500	550
Gennip - Zwarteweg	650	650
Zwarteweg - Pastoorsdijk	320	250
Pastoorsdijk - Generaal Gavinstraat	400	300
Generaal Gavinstraat - Groesbeekseweg	400	200
Driesbergstraat - Veldweg	500	80

Appendix VIII: Information source and travel frequency

As shown in figure 9.8, the more people travel over the road, the higher percentage is that gets the information from signs along the road, while on the opposite, the less the people travel over the road, the lower the percentage the that gets the information from signs along the road, but the higher the percentage that gets the information from online advertisements. Approximately 27% percent of informed non-frequent road users in the Van Muijlwijkstraat case is informed by online advertisement, while in the Regio Arnhem/Nijmegen case, this is 64%. For frequent informed travelers, this percentage is 19% and 54% respectively, which indicates that the percentage of people being informed by online means is higher when they travel less frequently.

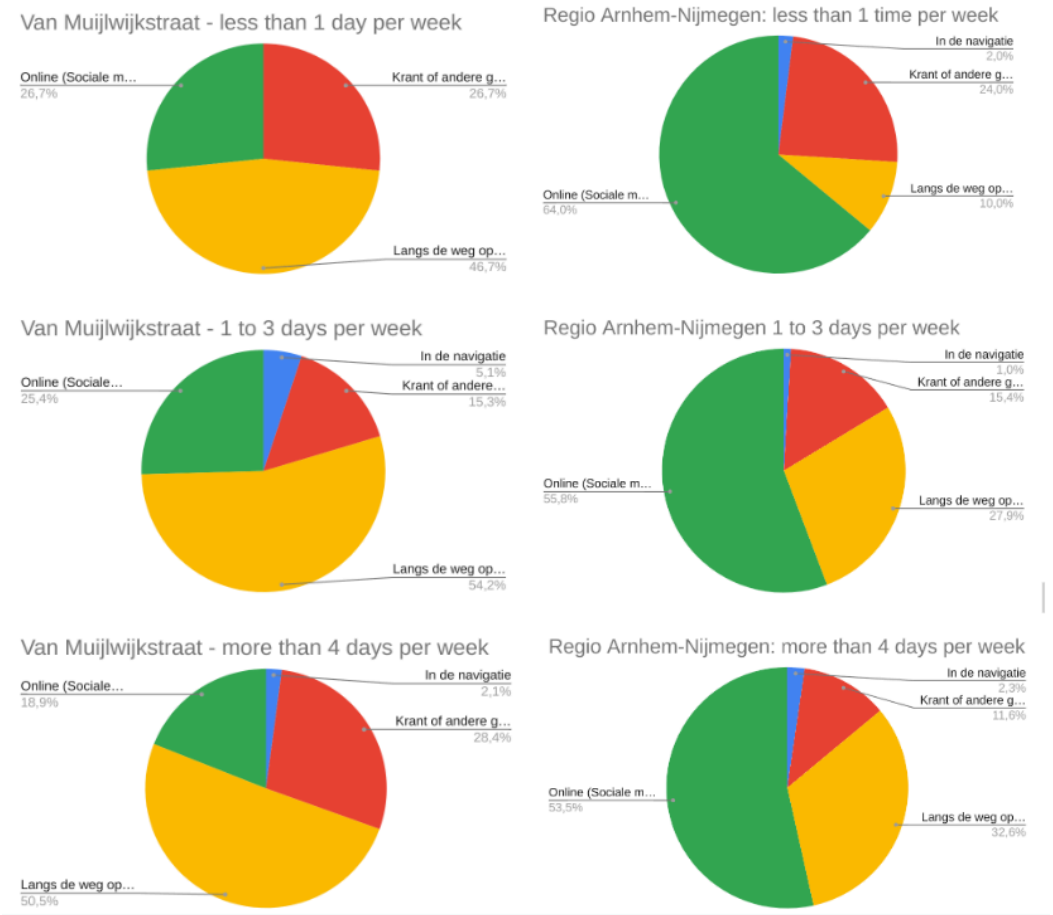

Figure 9.8.: *Information source and travel frequency, where green is online means, yellow is signs along the road, red is newspaper or other printed media and blue is in navigation*

As shown in table 9.8, people traveling less are slightly less informed. Although there is a difference in percentage informed of the road closure between people traveling less than one day and more than 4 days per week, it can be said that online traffic management helps to get less frequent travelers just as well informed as more frequent travelers.

***Table 9.8**: Information source and travel frequency Van Muijlwijkstraat*

Van Muijlwijkstraat			
Travel frequency	Informed	Not informed	Percentage informed
less than 1 day per week	16	7	70%
1 to 3 days per week	59	23	72%
more than 4 days per week	97	24	80%
Regio Arnhem-Nijmegen			
Travel frequency	Informed	Not informed	Percentage informed
less than 1 day per week	50	13	79%
1 to 3 days per week	104	19	85%
more than 4 days per week	86	22	80%

Appendix IX: Comparison Traffic Data and Survey Data Regio Arnhem/Nijmegen

Since the A12 was closed completely for one direction, choosing to take no specific action was not possible, while this might have been an option during other road constructions. We therefore consider respondents that did not take action as road users who did not potentially use the A12 between Grijsoord and Waterberg, and they are therefore excluded from the graph in figure 9.9.
The survey results and traffic data results show resemblance, with approximately a quarter choosing to stay home or change departure time equivalent to the 25% decrease in traffic intensity during peak hours on the A12 and A50, while most other respondents changed their route.

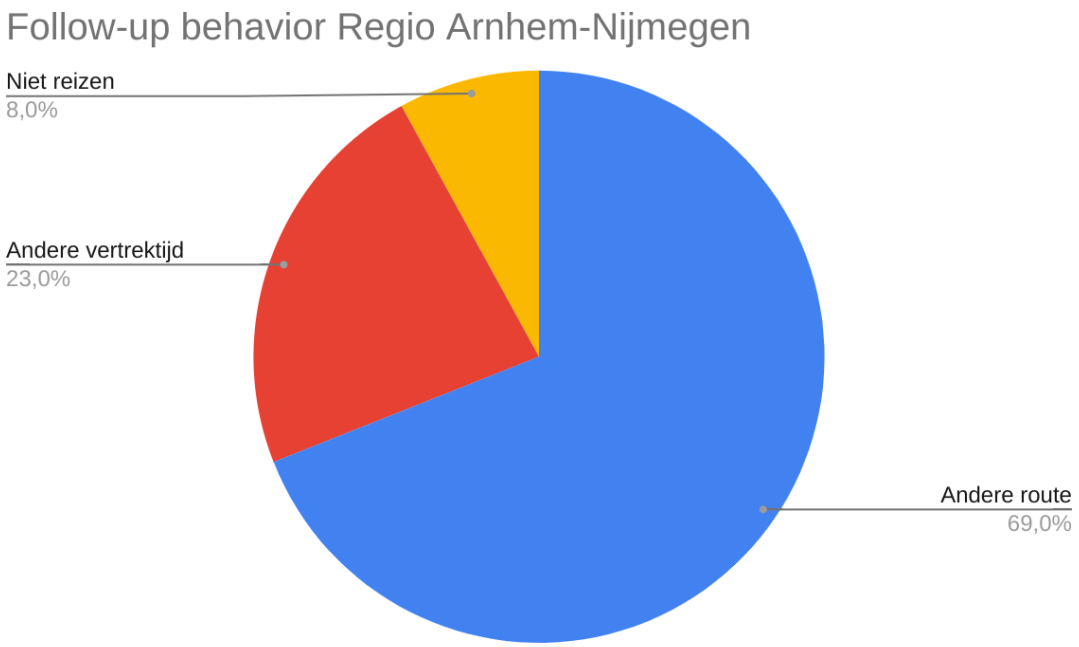

***Figure 9.9:** Follow-up behavior Regio Arnhem-Nijmegen, excluding respondens not taking a specific action*

Table 9.9: Traffic intensity data compared to diagram

	Intensity in veh/h	Percentage of total	Percentage in diagram
Decrease in overall traffic during peak hours	1500	38.5%	31%
Increase detour during peak hours	1500		
Increase shortcut during peak hours	900	61.5%	69%
Total	3900	100%	100%

Table 9.9 shows that the percentages in traffic intensity data and the diagram are moderately similar. It can be said that the survey answers are representative for what happened during the A12 closure.

Appendix X: Communication review

In figure 9.10, it can be seen that more local residents experience a longer travel time, while for other road users, more experience no change in travel time. The change in traffic safety is approximately equal for both groups.

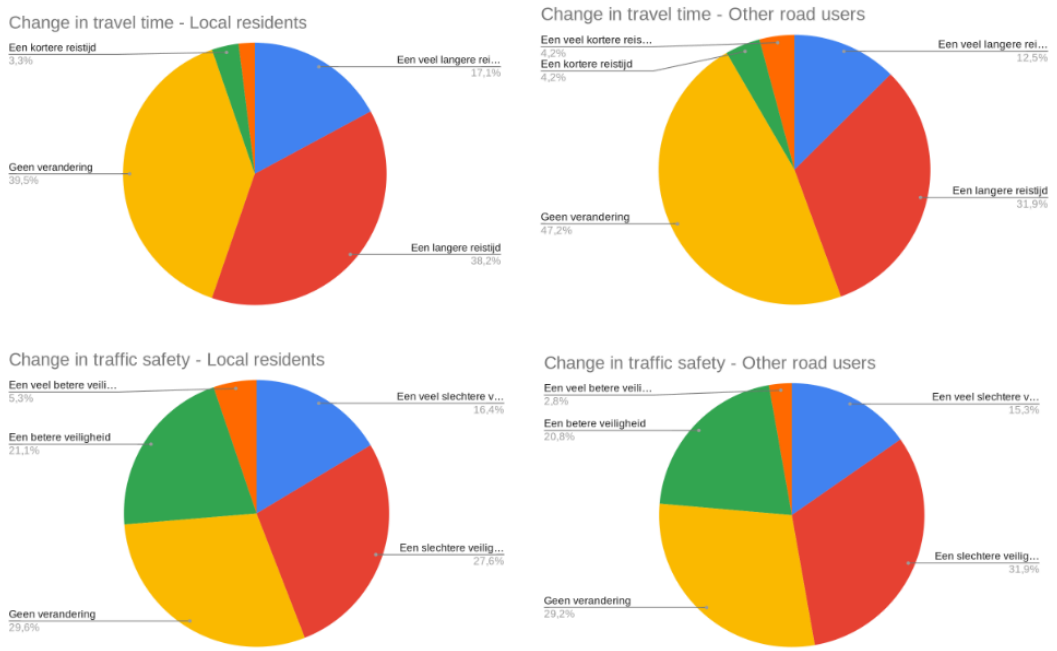

Figure 9.10: *Change in travel time and traffic safety for local residents and other road users*