# The effect of public transport strikes on road congestion

## A case study in the Netherlands

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Cover: Photo of people waiting for the bus (Van Lonkhuijsen, nd)

TU Delft

# Preface

The report that lies in front of you is my Bachelor of Science end thesis in Civil Engineering at Delft University of Technology. The topic of this thesis is ”The effect of public transport strikes on road congestion”. This thesis was written for the domain of Transport and Planning of the faculty of Civil Engineering and Geosciences.

Throughout my Bachelor several different topics are covered, however, I found the Transport and Planning domain the most interesting. In the summer of 2022, I experienced hindrance when the public transport sector had a strike. Due to the strikes, I could not travel for several days. When I saw the option of researching the effect of public transport strikes, I immediately chose this. That is why I have chosen to research the effect of public transport strikes on road congestion.

I would like to thank my daily supervisors, Yufei Yuan and Sina Nordhoff for providing me with relevant support and feedback throughout this project, as well as my fellow students that provided me with weekly feedback. Furthermore, I would like to thank Niels van Oort as an external supervisor for the sparring sessions which I found very useful.

*Hessel Rozema*
*Delft, June 2023*

# Abstract

During the summer holiday of 2022 6 strikes happened that affected the public transportation sector of the Netherlands. Previous research has shown that during such strikes the use of the road network increase which leads to more congestion. However, these researches solely focus on the effect of public transport strikes within cities, while these 6 strikes or of national and regional scale. This research aims to find the effect of national and regional public transport strikes on road congestion on the main roads. This thesis uses traffic data provided by the Nationaal Dataportaal Wegverkeer which gives the intensity and average speed every hour of road segments. In total 62 road segments are selected, a mix of locations where the chance of congestion is the highest and extra segments to cover the entire Netherlands

A percentage change method is used to measure the effect of the strikes during the strike and the days after the strike. This is done by comparing the traffic of an average day before the strike to the day of the strike, the same is done for the days after the strike, and finally by comparing the traffic on the day of the strike to exactly one week later. The significance of the results is calculated using a repeated one-way ANOVA test.

The results show an increase in intensity of 6.9% and a 1.9% decreasing speed throughout the day. During the morning rush hour, the intensity increased less, 3.4%, while the speed decreased the same, 1.9%. Especially the evening rush hour is susceptible to strikes, with an increase in intensity of 9.9% and a decreasing speed of 6.1%. There is a difference between national and regional strikes, whereas national strikes show an increase in intensity of 7.4% and regional strikes 6.7%. For speed, this is a decrease of 3.5% for national strikes and regional strikes of 1.4%. No clear relation could be found for the days after the strike, this could be due to overlap between strikes which then have an effect on each other.

With these results regulations about future strikes can be made to reduce the impact on the road network. National strikes have a bigger impact than regional strikes, additionally, the evening rush hour experiences more hindrance than other parts of the day. Therefore only allowing regional strikes or strikes that happen only during the morning period could reduce the total impact on the road network.

# Contents

# 1 Introduction

## 1.1. Problem description

In the Netherlands, a commonly used mode of transport is public transport. In 2019, almost 14% of all travel kilometers were done by public transport (Centraal Bureau voor de Statistiek, nd). In the 2 years after that, when the public transport sector was affected by the COVID-19 pandemic, this was still 8.2% (Centraal Bureau voor de Statistiek, nda, ndb). If the national public transport system were to be partially or fully shut down for a certain period, this could have an impact on the other transportation networks. These other networks now also have to deal with the people that usually travel by public transport, which leads to an increase in usage and could lead to congestion (Van Exel and Rietveld, 2009). Over the last few years a lot of strikes in the public transport sector happened, which led to a partially or fully shut down public transportation network. Given the importance of public transport in the Netherlands, it is crucial to understand the impact of public transport strikes on congestion on the main roads.

## 1.2. Research scope

This thesis focuses on the effect on the main roads (highways), therefore only strikes that affected the train will be taken into account. This is because people travel longer distances by train than other public transportation services and the main roads connect cities, thus longer distances (Centraal Bureau voor de Statistiek, nd). Due to the limited time available, this thesis also only focuses on strikes that happened in 2022. In this period 6 strikes happened in the months of August and September that affected the train, therefore only these strikes will be considered (NS, nd).

## 1.3. Research goals

The objective of this research is to analyze the effect of public transport strikes on congestion levels in the Netherlands. The main research question is phrased as: "What is the effect of public transport strikes on congestion on the main roads?". This question will be answered by the following sub-questions:

1. When and where were the public transport strikes and how long did they last?
2. What is the difference in congestion levels on the main road during a strike compared to a normal day before the strike?
3. To what extent has the strike impacted the road network the week after the strike?

The first sub-question will give information about the location, scale, and time of the strike. This will help to answer the main question by looking if there is a difference between each strike. The information needed to answer this question can be found in newspapers.

The second sub-question supports the main question by quantifying the effect of the strike compared to a normal day. To do this, data about a road network is necessary. Different kinds of data can be used as long as it is accurate, this thesis uses the average speed and intensity. The challenging part of this question is identifying a normal day, how this is done will be discussed in chapter 3.

Finally, the third sub-question helps to answer the main question by seeing if the effects measured will last longer than only the day of the strike. This will be done the same as sub-question 2, but then for the 7 days after the strike.

## 1.4. Societal relevance

This research addresses the impact of public transport strikes on congestion on the road network. It is important to know the quantity of the effect to take proper measures to minimize this effect during future strikes. When the impact on the road network is known, traffic management can be applied in order to make the highways as efficient as possible during these strike days. E.g. rerouting cars to reduce the traffic on the main roads or opening the rush-hour lane more often to optimize the traffic flow. Besides that regulations by the government can be made e.g. on how often strikes or where strikes may happen.

## 1.5. Report structure

In this thesis first a literature review is conducted, which can be seen in chapter 2. In chapter 3 this literature is used to define the methodology. After this, the method is defined in a case study in the Netherlands in chapter 4. After this, the results can be seen in chapter 5. The results will then be discussed in chapter 6, the conclusions and recommendations.

# 2 Literature review

In this chapter, a literature review is conducted to come up with hypotheses. First, in section 2.1, the existing literature about the impact of public transport strikes on the road network is reviewed. This existing literature is used to define the knowledge gap that is explained in section 2.2. With the existing literature and the knowledge gap hypotheses are made in section 2.3. In section 2.4 an overview is given of the conceptual model. Finally, this chapter is summarized in section 2.5.

## 2.1. Existing literature

In the last couple of decades, more and more research is conducted about the effect of public transport strikes. A study performed by Van Exel and Rietveld (2001) reviews 13 different researches and a survey that measured the effect of public transport strikes ranging from 1966 to 2000. The strikes studied in these 13 types of research range from scale, location and public transport affected. The study states that 10-20% of all the trips were canceled. Besides that, most travelers switched to the car which led to more road congestion. Finally, there was a long-term decrease in the public transport market, ranging from 0.3 to 2.5%.

In 2003 there was a 35 days lasting strike in Los Angeles that affected the busses, light rail and subway. Research conducted by Lo and Hall (2006) studied the effect of this strike on the highway. Despite transit ridership representing a minor portion of overall travel, it had a big impact on the highways. The research concluded that between 5:00 and 22:00, the traffic speeds decreases up to 20% and the average rush period increased up to 200%. The study states: "We believe that highways are especially susceptible to congestion during strikes because travelers have little opportunity to adjust and equilibrate their travel patterns, as is possible during ordinary periods of traffic growth" (Lo and Hall, 2006).

Research performed by Adler et al. (2017) looked at strikes from 2001 to 2011 and measured the effect on the road network in Rotterdam. During this period there were 13 strikes in Rotterdam, one regional bus strike and two national train strikes. This research came to the conclusion that the travel time increased by 0.017 minutes per car kilometer on the ring road and by 0.224 minutes per car kilometer in the city center and during rush hours this was even more.

A later study done in Athens, where there were 11 strikes between 2012 and 2013 affecting the metro and bus, showed an increase in traffic flow up to 30%. This increase in traffic flow resulted in a decrease in mean travel speed up to 27%, which then led to an increased travel time up to 25%. Besides changes in the traffic flow, speed and travel time the study also found that the strike coverage time, day of the week and site-specific characteristics have an impact (Spyropoulou, 2020).

As mentioned in the study from Van Exel and Rietveld (2001) people switched to the car when a strike happened, later studies confirmed this. Van Exel and Rietveld (2009) came to the conclusion that during a strike 24 % switched to driving a car and 14 % switched to being the passenger of a car. A later study measured even higher numbers, namely 52 % driving a car and 11 % being a passenger (Nguyen-Phuoc et al., 2018).

## 2.2. Literature gap

This thesis wants to contribute to the existing literature by studying the effect of a strike affecting the train on both national and regional scales. Existing literature mainly focuses on the effect of public transport strikes in cities e.g. (Spyropoulou, 2020; Lo and Hall, 2006; Adler et al., 2017) and therefore the effect on national en regional scale is unknown. However, there has been some research on the effect of a public transport strike on a national level. Two studies mentioned in Van Exel and Rietveld (2001) measure the effect of these national strikes, but these strikes only affected the busses. This thesis solely focuses on train strikes and is therefore different than other studies.

## 2.3. Hypotheses

From the literature review can be assumed that car usage during a strike will increase, average travel speed will decrease and travel time increases. However, in this thesis there is no data available for travel time, thus this variable can't be measured. Therefore the first hypotheses will be:

- During a strike car usage will increase.
- During a strike travel speed will decrease.

As mentioned in the research from Lo and Hall (2006) highways are highly susceptible to congestion during strikes. Especially during rush hours the effect of the strikes is more significant according to Lo and Hall (2006) and Adler et al. (2017), hence the third hypothesis is:

- During a strike the duration of rush hours increases and the effects mentioned in hypotheses 1 and 2 are stronger.

The research from Spyropoulou (2020) mentioned that duration and day of the week have an impact on the effect of the strike. The impact of multi-day strikes is expected to be larger than that of one-day strikes due to the greater difficulty in planning around multi-day strikes compared to doing so with one-day strikes. Besides that, people typically have to travel to work on weekdays even though the train network is down, whereas on weekends they have the option to stay at home. This leads to the following two hypotheses:

- A longer-lasting strike will have a bigger impact on the road network compared to a one-day strike.
- Strikes on weekdays will have a bigger impact than strikes on the weekend.

Finally, it is believed that in the days after a strike the effect on the road network will slowly get back to normal. The reason for this is that people reschedule their planned trips shortly after the strike, thus a small increase in car usage will be present. The last hypotheses can be formulated as:

- The effects measured the days after the strike will be slightly higher compared to a normal day but will slowly get back to normal.
- The effects measured exactly one week after the strike will be lower than during the strike.

## 2.4. Conceptual model

In this section an overview of the to-be-researched variables is given. The independent variables that are taken into account in this thesis are:

- Day of the week
- Duration of the strike
- Location of the strike
- Time of the day
- Days after the strike

**Day of the week:**
The day of the week is used to measure the effect of the weekdays versus the weekend days.

**Duration of the strike:**
Duration of the strike is essential to see if there is a difference between strikes that lasted 1 or multiple days

**Location of the strike:**
The location of the strike is to measure the difference in effect between a regional and a national strike.

**Time of the day:**
Time of the day should also be taken into account to see the difference throughout the day, e.g. a difference between rush hour and total effect of the day.

**Days after the strike:**
The days after the strike measures the effect for the 7 days after the strike.

The effect of these independent variables is measured on two dependent variables, intensity and average speed. An overview of the conceptual model is given in figure 2.1. In this figure the red lines represent the effect on the average speed and the black lines represent the effect on the intensity.

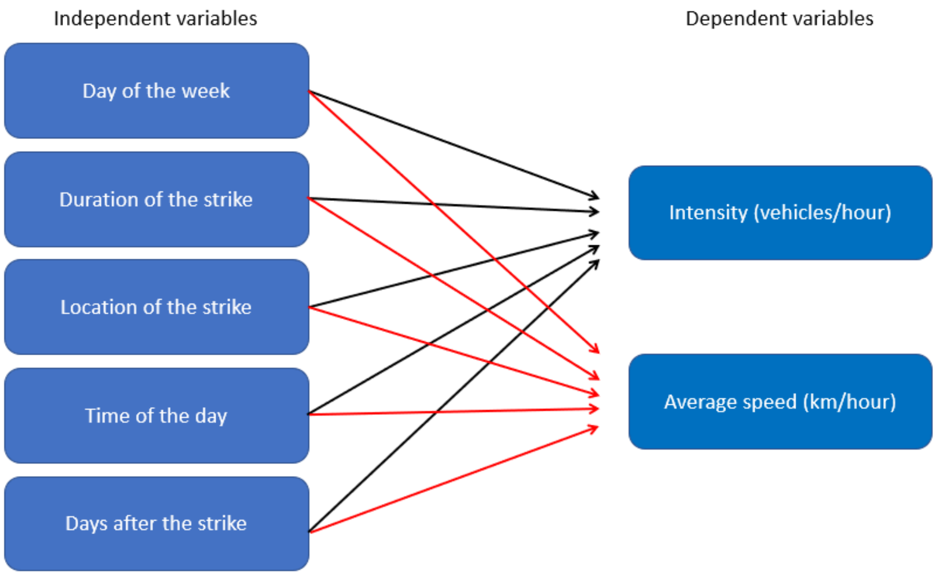


**Figure 2.1:** Conceptual model

## 2.5. Summary

In this chapter the existing literature is reviewed, which showed when strikes happen people are switching to the car. This causes extra use of the road network, which leads to a decrease in travel speed and an increase in flow and travel time. Especially the rush hours are more susceptible to strikes. Existing literature researches the effect of strikes within cities, however, the strikes in this research are of national and regional scale. Therefore the literature gap is defined to be the difference in the scale of the strikes. With the existing literature, 7 hypotheses were created, which can be seen in section 2.3. Finally, The variables to test these hypotheses are given in the conceptual model, which can be seen figure 2.1.

# 3 Methodology

In this chapter, the methodology is discussed. First, a data collection method is given in section 3.1. This section explains how all the data will be gathered for the strikes and road network. After this, the data analysis method is explained in section 3.2. In this section is first a method defined how to determine congestion using the fundamental diagram. Secondly, a description is given of what a normal day is. After that, this normal day is used to compare the traffic during and after a strike to a normal day, this is done by a linear function that gives the difference in percentage. Afterward, a statistical test, repeated one-way ANOVA, is performed to determine the significance of the effect. Finally, this chapter is summarized in section 3.4.

## 3.1. Data collection method

In this section the data collection method is explained. First, strike information is collected using newspapers, after which data from the road network is collected by selecting a variety of road segments.

### 3.1.1. Strike information

To understand the effect of different strikes, information about each strike is needed. This information can be found by searching newspapers for available knowledge about the strikes. As mentioned in the hypotheses different strikes could have a different effect on the road network. Hence, the required information for each strike is the duration, time and location.

- The duration of a strike is needed to determine if the strike was a multi-day strike or a single-day strike. If it was a multi-day strike, it should also be known how long the strike lasted and if this has any effect on the outcome.
- The time is essential to measure the effect of a weekday compared to a weekend day.
- The location of a strike is used to see if there is a difference in effect for a national or a regional strike. Besides that, the effect can be easily compared for each region.

### 3.1.2. Road network information

As mentioned in the introduction there are lots of different types of data that can be used as long as it says something about the road network. The data used in this thesis is the intensity and the average speed of a road segment because this data is made available by the Dutch "Nationaal Dataportaal Wegverkeer" (NDW, nd). NDW gives the intensity and average speed of different road segments per hour. Every strike has a unique dataset because each strike has a different time, duration, or location. Each dataset contains multiple road segments spread out over the whole area of the strike. More road segments are necessary for larger strikes to cover the whole area. The chosen road segments are the same for both national and regional strikes to ensure the same comparison of data. E.g. road segments are defined for the national strikes, when researching a regional strike in the north only the north road segments defined are used in this case. The road segments should be located at crucial locations in the road network where the chance of road congestion is high. This is because these locations are the bottlenecks of the road network. These crucial road segments are defined by the ANWB and can be found in Appendix-A. Besides the crucial locations, a good spread is also important. Therefore, if there are highways not included due to them missing a crucial location, they should be added to the dataset.

## 3.2. Data analysis method

In this section the data analysis method is explained. First, a concept to determine congestion is explained, after which the calculation of a normal day is given. Finally, the strike comparison method is given, which is a percentage change method. The significance of the results is calculated using a repeated one-way ANOVA test.

### 3.2.1. Defining congestion

The data used in this thesis are the average speed and intensity. The speed is measured in kilometers per hour and intensity in vehicles per hour, intensity can therefore be seen as flow. To measure congestion the fundamental diagram of traffic flow is used, see figure 4.2.

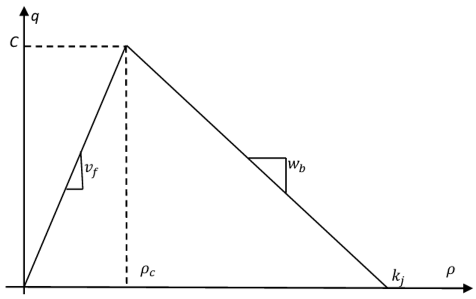


**Figure 3.1:** Fundamental diagram of traffic flow (Zheng and Su, 2016)

In this diagram, the x-axis represents the density and the y-axis the flow. The speed can be calculated by taking the slope from the origin to the point on the graph. On the left side of the diagram, the speed is constant and the flow and density increase, in this case there is no congestion. It is assumed that during this period all cars drive at the maximum speed described by the highway. Once the flow reaches its maximum it will continue to decrease towards the right side, the congestion side. The speed decreases and the density increases. Congestion can be measured by comparing traffic on a normal day to traffic on a strike day. It is important to compare the same timestamps, e.g. 12:00 to 12:00 because the traffic differs throughout the day and comparing different timestamps could give misleading results. Congestion is present when there is a decreasing speed while the flow increases or does not change much, because this leads to a higher density and thus the right side of the diagram.

### 3.2.2. Defining a Normal day

To measure the effect of the strikes a reference is needed, in this case traffic on a normal day. Not every day can be a normal day, therefore a method is needed to estimate the traffic on this normal day. In the case study from Athens, a normal day was estimated to be the average between 2 days that had no strikes. These days would typically be exactly one week earlier and one week later (Spyropoulou, 2020). Another study performed by Lo and Hall (2006) did a case study on Los Angeles. They measured the effect on 20 working days during the strike and had as normal days the average traffic from 20 consecutive working days before the strike. From these two studies can be seen that normal days are determined by multiple days around the strike day. Taking the average of multiple days will remove outliers in the data and this will lead to a more accurate average day.

In the Netherlands the traffic differs throughout the week, Tuesday and Thursday are the busiest days of the week (ANWB, 2023b). Creating one normal day for all strikes, no matter what day of the week it is will give misleading information. Tuesday and Thursday will then always have a larger impact than the other days of the week. Therefore for every day of the week, Monday to Sunday, an individual normal day needs to be determined. This is done by combining the methods mentioned in the previous research. A normal day is in this thesis defined as:

- The average traffic between 2 non-strike days exactly 1 and 2 weeks earlier than the strike.

This uses the principle used in Spyropoulou (2020) research to compare the same days to each other, e.g. Monday compared to another Monday. Besides that, it also uses the principle used in Lo and Hall (2006) of only using the previous days.

It is however important to note that during these 2 days, no big traffic disruptions may be present. Big disruptions are accidents or road maintenance that fully shuts down a road. If there are big disruptions, this day is not used to calculate the normal day and is replaced with a day a week earlier. This process repeats itself until there are 2 days selected that are the same day of the week on which no big disruptions happened. There are no days that don't have any disruptions at all, minor accidents can happen all the time. Therefore small disruptions may be present during the calculation of a normal day.
All strikes researched in this thesis happened during the summer holiday period. Comparing a non-holiday day with a holiday day could give misleading information due to the difference in traffic on the road network. Therefore to measure the effect of the strike during the holiday a normal day should be calculated by only using holiday period days.

### 3.2.3. Strike comparison

To measure the effect of each strike, data comparison is necessary. The day of the strike will be compared to a normal day identified by subsection 3.2.2, the same is done for the days after the strike. In the case of a multiple-day lasting strike, each day is compared to the defined normal day. A Monday will be compared to a Monday, a Tuesday to a Tuesday etc.

A numerical comparison is necessary to quantify the difference between each strike. This will be done by calculating the difference in percentage between the normal day and the strike day, the percentage change method. The difference is calculated for each road segment ($R$) so that the effect of each region can be measured separately. Besides that, the difference is also calculated for each time interval ($t$), in such a way that the effect on rush hours can be measured separately from non-rush hours.

The difference for the intensity ($I$) is calculated by the formula 3.1 and the difference in velocity ($V$) is measured by the formula 3.2. In these formulas, $SD$ means strike day and $ND$ means normal day.

$$\Delta I_{t,R} = \frac{I_{SD_{t,R}} - I_{ND_{t,R}}}{I_{ND_{t,R}}} * 100\% \tag{3.1}$$

$$\Delta V_{t,R} = \frac{V_{SD_{t,R}} - V_{ND_{t,R}}}{V_{ND_{t,R}}} * 100\% \tag{3.2}$$

The total effect of the strike can then be measured by summation see formulas 3.3 and 3.4. In these formulas, n are the time intervals and m are the road segments of the strike.

$$\Delta I = \sum_{t=1}^{n} \sum_{R=1}^{m} \Delta I_{t,R} \tag{3.3}$$

$$\Delta V = \sum_{t=1}^{n} \sum_{R=1}^{m} \Delta V_{t,R} \tag{3.4}$$

The effect on the rush hour can be measured by only selecting the time intervals in which there is rush hour. In the Netherlands, the morning rush hour is defined to be between 07:00 and 09:00 and the evening rush hour is between 16:00 and 19:00 (Boers, 2022).

Besides quantifying the effects it is also important to know if the effects are significant. If the results are significant ($p < 0.05$) the results are unlikely to be the cause of chance and therefore can be assumed to represent reality. This will be done by the repeated one-way ANOVA test (Ostertagova and Ostertag, 2013).

An one-way ANOVA test uses the means sums of squares $MS$ to come up with an F-statistic that tells the ratio of explained variance in the data to the unexplained variance. The full formula can be seen in formula 3.5.

$$F = \frac{MS_M}{MS_R} = \frac{SS_M/(k-1)}{SS_R/(N-k)} \tag{3.5}$$

Where,

- $SS_M = \sum n_k(\overline{x}_k - \overline{x}_{total})^2$ is the sum over all groups. It measures the squared difference between the mean of group $k$ and the mean of all samples times the group size $n_k$. This is the explained variance between each group.
- $SS_R = \sum(x_{ik} - \overline{x}_k)^2$ is the sum of the squared residuals. It measures the squared difference within each group. This is the unexplained variance within each group.
- $k$ is the number of groups.
- $N = \sum n_k * k$ is the total number of samples, the number of groups times the data per group.

This F-statistic can then be used to calculate the significance, this will automatically be done by SPSS. The groups that will be used to calculate the significance are summarized in table 3.1, all groups are tested on both the intensity and the speed.

**Table 3.1:** significance calculation per group

| Group name | variables |
|---|---|
| Strike number | 1, 2, 3, 4, 5, 6, 7, 8 |
| Strike location | North, Zuid-Holland, Noord-Holland, East & South, National |
| Strike duration | 1 day, 2 days |
| Time of day | 00:00-00:59, 01:00-01:59, 02:00-02:59, 03:00-03:59, etc. |
| Type of day | normal day, strike day |
| Week after strike | strike day, 7 days after strike |
| Normal day vs after strike | 1 day after the strike, , 2 days after strike, etc. |

## 3.3. Summary

To summarize this chapter the data collection method will collect the duration, location and time of a strike by searching newspapers. Besides that, the intensity and average speed are collected for different road segments using the NDW data. The data analysis method defined congestion as an increase in intensity and a decrease in speed, which is measured between a strike day and a normal day. This normal day is defined as the average traffic between 2 non-strike days exactly 1 and 2 weeks earlier than the strike. Finally, the strikes and normal days will be compared using a percentage change method, which significance will me measured using a repeated one-way ANOVA test.

# 4
# Case study - The Netherlands

In this chapter, the methodology is used on strikes in The Netherlands. First, in section 4.1 information about the strikes is given regarding the duration, location and time. After this, in section 4.2 the road segments are defined using information from the ANWB. Next, the days to calculate the normal days are given in section 4.3. Finally, this chapter is summarized in section 4.4.

## 4.1. Strike information

In 2022 The Netherlands had to endure 6 strikes that shut down the train network (NS, nd). An overview of these strikes can be seen in table 4.1. It is important to note that all strikes happened during the summer holiday period, therefore the outcome can differ from a non-holiday period.

**Table 4.1:** Overview of the strikes (NS, nd)

| Strike number | Day | Duration | Location |
|---|---|---|---|
| 1 | Wednesday 24 August 2022 | 1 day | Regional (North) |
| 2 | Friday 26 August 2022 | 1 day | Regional (Zuid-Holland) |
| 3 | Monday 29 August 2022 | 1 day | Regional (Noord-Holland) |
| 4 | Tuesday 30 August 2022 | 1 day | National |
| 5 | Wednesday 31 August 2022 | 1 day | Regional (South & East) |
| 6 | Friday 9 September 2022 | 1 day | National |

From the strikes mentioned in table 4.1 can be seen that none of the strikes lasted multiple days. However, strike 4 was nationwide, which leads to a 2-day strike for the region Noord-Holland by combining strikes 3 and 4. And for the region south & east by combining strikes 4 and 5. Therefore, 2 extra strikes will be considered to measure the effect of multiple-day lasting strikes.

**Table 4.2:** Multiple-day lasting strikes

| Strike number | Days | Duration | Location |
|---|---|---|---|
| 7 | Monday 29 - Tuesday 30 August 2022 | 2 days | Regional (Noord-Holland) |
| 8 | Tuesday 30 - Wednesday 31 August 2022 | 2 days | Regional (South & East) |

Figure 4.1 gives an overview of where these locations are in the Netherlands. In this figure can be seen that there is a non-region. This non-region is not affected by a regional strike, only by national strikes. National strikes affect the whole Netherlands and therefore the whole map is affected.


**Figure 4.1:** Overview which part of the Netherlands is which region (RTL Nieuws, 2022)

## 4.2. Road segments

The final road segments are selected by combining the crucial road segments and road segments that provide a spread throughout the research area. Crucial road segments are defined as road segments where the chance of congestion is the highest. This information is given by the ANWB (2023a) and can be found in Appendix-A. However, these locations will not cover the whole area and therefore extra locations are selected. An overview of all the locations is given in figure 4.2. In this figure, the black crosses mark the location of crucial road segments and the red crosses mark the location of the road segments used to cover the area. However, not all of these road segments have working sensors. The road segments with a purple circle around it do not have accurate data or no data at all and can therefore not be used.


**Figure 4.2:** Overview of road segments selected

73 locations are selected but when removing the locations where there is no data available only 62 remain. So in total 62 road segments are being used, at which the intensity and average speed is known in both directions. An overview of which road segments are used for which strike can be found in Appendix-B.

## 4.3. Normal day definition

The formula to determine a normal day states that it is the average traffic between 2 days one and two weeks earlier, however, no big disruptions may be present. During the period 2 weeks before the strikes, some big disruptions were present, such as the lockdown of the A50, A2 and A10/A4 (Rijkswaterstaat, 2023). Besides that, as mentioned in subsection 3.2.2 the strikes happened during the holiday period. Therefore to measure the effect of the strike during the holiday a normal day should be calculated by using two holiday days. This is why the two days to calculate a normal day are chosen to be between 8 July 2022 and 24 July 2022. During this period there was a holiday and no big disruptions happened, only minor disruptions such as a nightly shutdown of a highway (Rijkswaterstaat, 2023).

**Table 4.3:** Normal day dates

| Day | Reference 1 | Reference 2 |
|---|---|---|
| Monday | Monday 11 July 2022 | Monday 18 July 2022 |
| Tuesday | Tuesday 12 July 2022 | Tuesday 19 July 2022 |
| Wednesday | Wednesday 13 July 2022 | Wednesday 20 July 2022 |
| Thursday | Thursday 14 July 2022 | Thursday 21 July 2022 |
| Friday | Friday 1 July 2022 | Friday 8 July 2022 |
| Saturday | Saturday 16 July | Saturday 23 July 2022 |
| Sunday | Sunday 17 July 2022 | Sunday 24 July 2022 |

In the table can be seen that the normal day for Friday is calculated with 1 July 2022 instead of 15 July 2022. This is because farmers blocked parts of the highway which caused extra congestion and therefore can't be considered a normal day (NOS, 2023).
For some road segments there is only information of one reference day, due to a malfunctioning detector. For these road segments, the normal day is defined as only one day. E.g. if data for Monday 11 July is missing, but there is data for Monday 18 July, the normal day is defined as the traffic on Monday 18 July.

## 4.4. Summary

In this chapter first 8 strikes are defined differing in duration, location and time. After this, 62 road segments with accurate data are chosen to cover the whole research area of which the intensity and average speed are known. Finally, the days to calculate the normal days are defined to be during the period of 1 July 2022 to 24 July 2022.

# 5 Results

In this chapter the results will be discussed. In section 5.1 the results during the strike are given, this is done for the speed and the intensity. Section 5.2 gives the results the days after the strike, these are given for both the speed and intensity. Finally, section 5.3 summarizes the results and elaborates how the results contribute to congestion.

## 5.1. During a strike

In this section the results during a strike are discussed. This is first done for the speed and afterward for the intensity.

### 5.1.1. Speed

This subsection shows the results of the change in speed for days during a strike. An example of how the speed differs throughout the day is given in figure 5.1. In this figure, the average speed of all road segments of strike 4 is compared to the normal day that is associated with strike 4. This figure shows a decrease in speed during the day when a strike is present, especially during the rush hours the speed decreases.

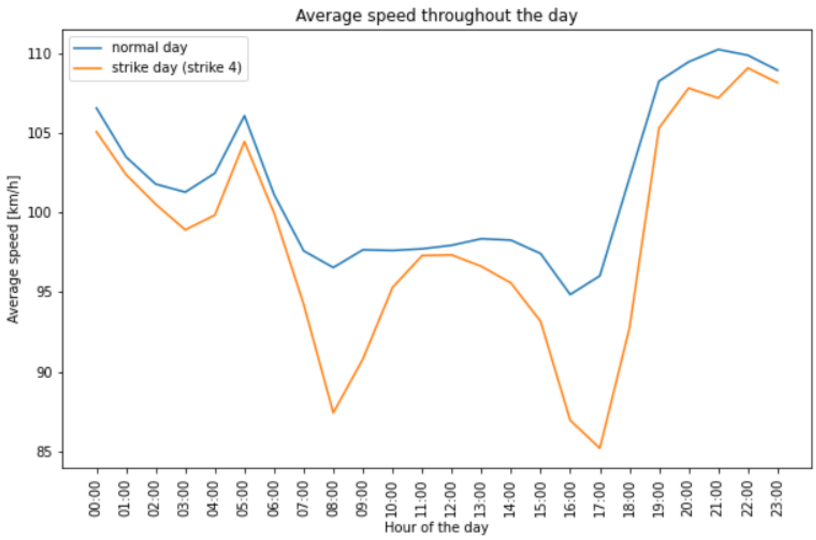


**Figure 5.1:** Average speed of strike 4 compared to a normal day

The difference in average speed is calculated using the percentage change method for the rush hours and the total effect, which can be seen in table 5.1. The total effect is the effect during the day, which is in this research defined as 06:00 till 22:00. The significance calculated using the repeated one-way ANOVA test for each of the independent variables can be seen in table 5.2.

**Table 5.1:** Speed change in percentage ($V$)

| | **Strike Number** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Period** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | average |
| morning rush hour (07:00-09:00) | 0.1 | -2.9 | -0.7 | -5.1 | -0.2 | -1.2 | -5.8 | 0.9 | -1.9 |
| evening rush hour (16:00-19:00) | 0.2 | -2.4 | -10.1 | -9.7 | -3.1 | -8.4 | -11.7 | -3.9 | -6.1 |
| total effect (06:00-22:00) | 0.1 | -0.3 | -3.1 | -4.2 | 0.1 | -2.7 | -4.5 | -0.9 | -1.9 |

**Table 5.2:** Significance test of dependent variable speed

| Group name | F-statistic | significance |
|---|---|---|
| Strike number | 34.131 | <0.001 |
| Strike location | 58.704 | <0.001 |
| Strike duration | 1.148 | 0.284 |
| Time of day | 289.491 | 0.000 |
| Type of day | 182.993 | <0.001 |

Table 5.1 shows that strike number 1 hardly experiences any effect of the strike, which can also be said for strikes number 2, 5 and 8 throughout the day. However, these strikes experience some change in average speed during rush hour. Strikes 3, 4, 6 and 7 all experience a decrease in speed during the day which is larger than 2.5%. The highest decrease in speed is measured during the evening rush hour of strike 7, measuring a decrease of 11.7%. On average the average speed decreases 1.9% during the morning rush hour, 6.1% during the evening rush hour and 1.9% throughout the day.
From table 5.2 can be seen that only the duration does not show any significance. There is however a significant difference between the strikes, locations, time during the day and between a normal day and a strike day.

### 5.1.2. Intensity

In this subsection the results of the change in intensity for days during a strike can be seen. figure 5.2 shows the intensity throughout the day compared to a normal day. In this figure, the average intensity of all road segments of strike 4 is compared to the normal day that is associated with strike 4. This figure shows an increase in intensity during the day (06:00-22:00) when a strike is present. Especially during the rush hours the intensity increases.

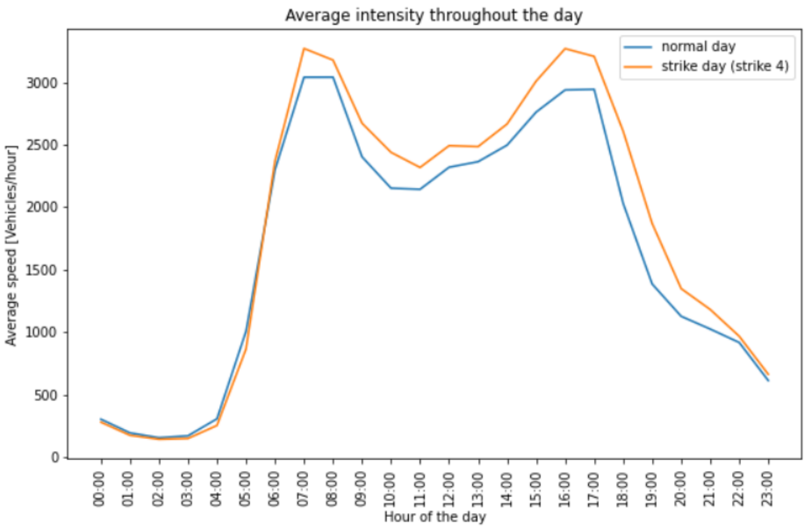


**Figure 5.2:** Intensity of strike 4 compared to a normal day

Table 5.3 shows the percentage change in average intensity for the rush hours and the total effect that is calculated using the percentage change method. The significance of the independent variables can be found in table 5.4, which is calculated using the repeated one-way ANOVA test.

**Table 5.3:** Intensity change in percentage ($I$)

| | Strike Number | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Period** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | average |
| morning rush hour (07:00-09:00) | -3.7 | -0.2 | 7.8 | 7.2 | 1.6 | 5.6 | 6.9 | 1.9 | 3.4 |
| evening rush hour (16:00-19:00) | 6.4 | 7.3 | 9.0 | 17.7 | 9.7 | 4.0 | 12.7 | 12.4 | 9.9 |
| total effect (06:00-22:00) | 5.4 | 2.8 | 6.6 | 12.6 | 6.6 | 2.2 | 10.5 | 8.2 | 6.9 |

**Table 5.4:** Significance test of dependent variable intensity

| Group name | F-statistic | significance |
|---|---|---|
| Strike number | 23.077 | <0.001 |
| Strike location | 40.324 | <0.001 |
| Strike duration | 1.716 | 0.190 |
| Time of day | 4289.970 | 0.000 |
| Type of day | 4.099 | 0.043 |

In table 5.3 can be seen that all strikes experience an increase in intensity for the evening rush hour and throughout the day. The intensity during the morning rush hour decreases for strike number 1 and 2, respectably 3.7% and 0.2%. The highest increase in intensity is measured during the evening rush hour of strike 4, 17.7%. The average intensity increases by 6.9% during the day. During the evening rush hour, this is even more, it then increases by 9.9%. During a strike, the intensity during the morning rush hour increases on average by 3.4%.
Table 5.4 shows the significance of each of the independent variables. Every variable is significant except for the duration of the strike.

## 5.2. After a strike

In this section the results for the speed and intensity change for the days after the strike are presented. The days after the strike are compared to the normal days associated with them and the strike day is compared to 7 days after the strike.

### 5.2.1. Speed

This subsection shows the change in speed the days after the strike. The change in speed the days after a strike compared to the normal days is given in table 5.5. This table is visualized in figure 5.3, where each line represents a strike.

**Table 5.5:** Speed change in percentage the days after the strike compared to normal days (06:00-22:00)

| **Days after strike** | **Strike Number** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | average |
| Day 1 | 1.1 | -4.2 | -5.4 * | -1.9 * | 2.4 ** | -1.0 | -3.0 * | 2.4 ** | -1.2 |
| Day 2 | -0.0 | -1.3 | -3.0 * | -1.7 ** | -1.6 ** | -0.7 | -5.5 ** | -1.6 ** | -1.9 |
| Day 3 | 0.1 | -4.8 * | -5.5 ** | 1.5 ** | 3.1 ** | -1.4 | 0.5 ** | 3.1 ** | -0.4 |
| Day 4 | -3.9 | -10.6 * | 0.5 ** | 0.4 ** | 3.0 ** | -3.2 | 2.0 ** | 3.0 ** | -1.1 |
| Day 5 | 0.7 * | -5.3 * | 2.0 ** | 0.4 ** | -0.7 ** | -2.1 | 1.5 ** | -0.7 ** | -0.5 |
| Day 6 | -0.1 * | -6.0 ** | 1.5 ** | -2.4 ** | 3.7 ** | -1.5 | -3.0 ** | 3.7 ** | -0.5 |
| Day 7 | -0.1 * | 0.8 ** | -3.0 ** | -4.2 ** | -0.0 | -1.3 | -6.0 ** | -0.0 | -1.7 |

* During this day a strike happened in another part of the country
** During this day there was overlap between days after the strike for different strikes


**Figure 5.3:** Change in speed the days after a strike

Table 5.5 shows that all strikes except for strike 6 have days after the strike that have overlap with another strike. This overlap could be the cause that there is no clear relationship between the days after the strike and the speed change, as can be seen in figure 5.3. Strike 6, which does not have any overlap shows a decrease in speed for all 7 days after the strike, which ranges from 0.7 to 3.2%. From table 5.5 and figure 5.3 can be seen that the average speed decreases the days after the strike is between 0.5% and 1.7%.

The speed exactly one week after the strike is also compared to the speed during the strike. The percentage change can be seen in figure 5.9.

**Table 5.6:** Speed change in percentage the days after the strike compared to the strike (06:00-22:00)

| **Days after strike** | **Strike Number** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | average |
| 1 week | -0.3 * | 3.7 | 1.5 | 3.4 | 2.0 | 4.7 | 1.1 | 2.0 | 2.3 |

* During this day a strike happened in another part of the country

From table 5.6 can be concluded that exactly one week after the strike the speed on average increases by 2.3%, ranging from a decrease of 0.3% to an increase of 4.7%. It is important to note that 7 days after strike 1, strike 5 was present. This could have an impact on the results of strike 1.

The significance of these variables are calculated by a repeated one-way ANOVA test, which can be seen in table 5.7.

**Table 5.7:** Significance test of dependent variable speed

| Group name | F-statistic | significance |
|---|---|---|
| Normal day vs after strike | 91.559 | <0.001 |
| Week after strike | 0.487 | 0.485 |

Table 5.7 shows that there is a significant difference between the normal days and the days after the strike. However, there is no significant difference between the speed during the strike and exactly one week later, therefore no assumptions can be made for this variable.

### 5.2.2. Intensity

Lastly, this subsection shows the change in intensity for the days after the strike. The change in intensity the days after the strike compared to the normal days is calculated and can be seen in table 5.8. This table is visualized in figure 5.4 to give an overview, where every line represents a strike.

**Table 5.8:** Intensity change in percentage the days after the strike (06:00-22:00)

| Days after strike | Strike Number | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | average |
| Day 1 | 0.4 | 10.0 | 14.5 * | 7.6 * | 2.4 ** | -0.0 | 9.0 * | 2.4 ** | 5.8 |
| Day 2 | -0.8 | 10.2 | 9.0 * | 4.0 ** | -1.6 ** | 2.7 | 8.3 ** | -1.6 ** | 3.8 |
| Day 3 | -2.2 | 7.0 * | 8.3 ** | 0.1 ** | 3.1 ** | -0.2 | 3.4 ** | 3.1 ** | 2.8 |
| Day 4 | -4.5 | 14.6 * | 3.4 ** | 5.9 ** | 3.0 ** | 0.7 | 12.2 ** | 3.0 ** | 4.8 |
| Day 5 | 0.9 * | 10.5 * | 12.2 ** | 4.1 ** | -0.7 ** | -1.6 | 6.0 ** | -0.7 ** | 3.8 |
| Day 6 | 13.6 * | 9.0 ** | 6.0 ** | 1.6 ** | 3.7 ** | -2.7 | 2.3 ** | 3.7 ** | 4.7 |
| Day 7 | 7.3 * | 0.8 ** | 2.3 ** | 6.1 ** | -0.0 | -1.0 | 3.8 ** | -0.0 | 2.4 |

* During this day a strike happened in another part of the country
** During this day there was overlap between days after the strike for different strikes

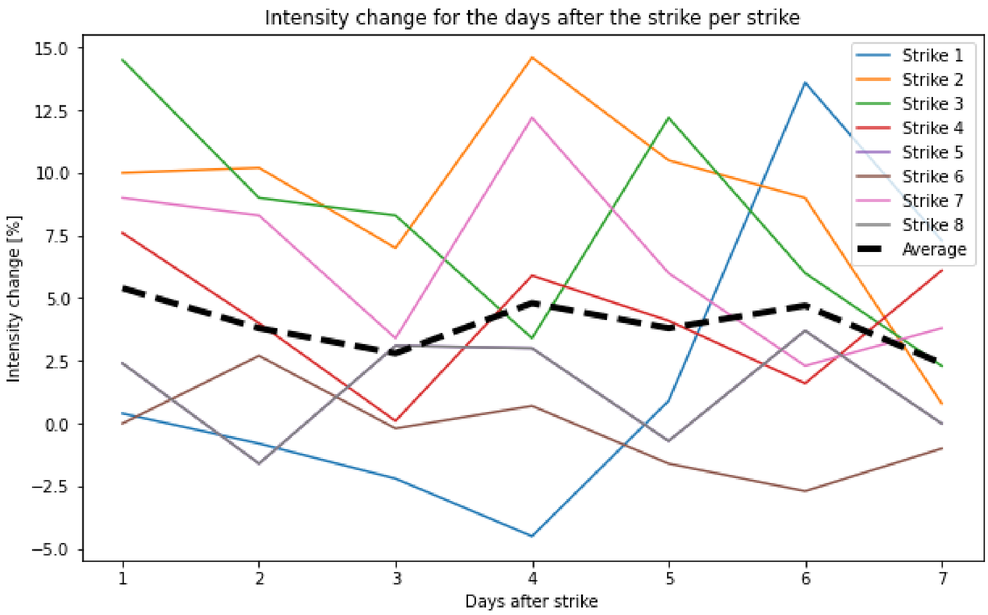


**Figure 5.4:** Change in intensity the days after a strike

The days after the strike have the same overlap as mentioned previously, which can also be seen in table 5.8. In this case, the overlap could be the cause that there is no clear relationship between the days after the strike and the intensity change as can be seen in figure 5.4. Strike 6, which does not have any overlap shows a change in speed ranging from a decrease of 2.7% to an increase of 2.7%. From table 5.8 and figure 5.4 can be seen that the average intensity increases the days after the strike is between 2.4% and 5.4%.

The intensity exactly one week after the strike is also compared to the intensity during the strike. The percentage change can be seen in figure 5.9.

**Table 5.9:** Intensity change in percentage the days after the strike compared to the strike (06:00-22:00)

| Days after strike | Strike Number | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | average |
| 1 week | 2.6 * | -1.7 | -3.6 | -3.6 | -4.9 | 0.1 | -8.8 | -4.9 | -3.1 |

* During this day a strike happened in another part of the country

From table 5.9 can be seen that on average the intensity decreases 3.1% exactly 1 week after the strike. This ranges from an increase of 2.6% to a decrease of 8.8%. It is important to note that 7 days after strike 1, strike 5 was present. This could have an impact on the results of strike 1.

**Table 5.10:** Significance test of dependent variable intensity

| Group name | F-statistic | significance |
|---|---|---|
| Normal day vs after strike | 26.111 | <0.001 |
| Week after strike | 10.413 | 0.001 |

Table 5.10 shows that both the normal days compared to the days after the strike as well as the week after the strike show a significant difference.

## 5.3. Summary

In this section the results will be summarized and the relation with congestion will be explained. This is first done for the average effect, then the national versus regional effect. Finally, the results of the days after the strike are noted.

The average intensity and speed change throughout the day, during the morning rush hour and during the evening rush hour can be found in table 5.11.

**Table 5.11:** Intensity and speed change in percentage

| Period | Intensity | Speed |
|---|---|---|
| Day (06:00 - 22:00) | 6.9 | -1.9 |
| Morning rush hour (07:00 - 09:00) | 3.4 | -1.9 |
| Evening rush hour (16:00 - 19:00) | 9.9 | -6.1 |

Using the principle to define congestion mentioned in section 3.2.1, that congestion is present when there is an increase or little change in intensity combined with a decrease in speed. It can be assumed that there is a similar increase in congestion during the day and during the morning rush hour, this is because of the same speed decrease. The difference in intensity not having the same impact on the speed could be explained that during the day normally no congestion is present and therefore a small increase will not lead to a decreasing speed. During the evening rush hour, the increase of congestion is even higher because the speed decreases and intensity increases more.

As mentioned in section 4.1 strike number 4 and 6 are national strikes and the others are all regional strikes. To compare the effect of the national strikes against the regional strikes the results for the intensity and speed are averaged, this can be seen in table 5.12.

**Table 5.12:** National versus regional strikes in percentage

| | Intensity | | Speed | |
|---|---|---|---|---|
| Period | National | Regional | National | Regional |
| Day (06:00 - 22:00) | 7.4 | 6.7 | -3.5 | -1.4 |
| Morning rush hour (07:00 - 09:00) | 6.4 | 2.4 | -3.1 | -1.4 |
| Evening rush hour (16:00 - 19:00) | 10.9 | 9.6 | -9.1 | -5.2 |

From table 5.12 can be concluded that there is on average more increase of congestion for national strikes than there is for regional strikes when using the same principle to define congestion. This is because national strikes have a higher increase in intensity and decrease in speed than regional strikes. It is however important to note that the effects measured in the region North are a lot lower than those of the region Noord-Holland.

Next, the results of the days after the strike are summarized. As mentioned, there is a lot of overlap between the days after the strikes for different strikes. It is assumed that due to this overlap no clear relation between the intensity/speed and days after the strikes can be found. Therefore there is only looked at the average of all strikes and strike 6, when there was no overlap between strikes. These results can be found in table 5.13.

**Table 5.13:** Days after the strike comparison (06:00-22:00)

| | Intensity | | Speed | |
|---|---|---|---|---|
| Period | strike 6 | average all strikes | strike 6 | average all strikes |
| Day 1 | -0.0 | 5.8 | -1.0 | -1.2 |
| Day 2 | 2.7 | 3.8 | -0.7 | -1.9 |
| Day 3 | -0.2 | 2.8 | -1.4 | -0.4 |
| Day 4 | 0.7 | 4.8 | -3.2 | -1.1 |
| Day 5 | -1.6 | 3.8 | -2.1 | -0.5 |
| Day 6 | -2.7 | 4.7 | -1.5 | -0.5 |
| Day 7 | -1.0 | 2.4 | -1.3 | -1.7 |

In table 5.13 can be seen that the average intensity change is a lot higher than for strike number 6, this could be due to overlap. For every day can be seen that there is a slight increase in congestion using the principle of defining congestion. However, there is no clear trend of the speed and intensity going back to normal after the strikes.

Finally, the speed and intensity exactly one week after the strikes are compared to the strikes. The results show that there is no significant difference between the speeds and therefore no assumptions can be made for the speed. The intensity however decreases on average by 3.1% the week after the strikes. Due to no significant data for the speed, no assumptions can be made regarding congestion.

# 6 Conclusions and recommendations

In this chapter the conclusions and recommendations are provided. First, the hypotheses are reviewed, after which the implementations of the results are given. Section 6.3 gives explains what future research can be done by analyzing this thesis. Finally, a general conclusion is given based on the thesis.

## 6.1. Findings based on hypotheses

This research aimed to find the effect of national and regional public transport strikes on road congestion. In chapter 2.3 hypotheses were made based on the existing literature on the effect of public transport strikes. The first two hypotheses expected an increase in car usage and a decrease in travel speed during a strike.

The results show that on average car usage increases by 6.9%, which ranges from the minimum increase of 2.8% up to 12.6%. Besides an increase in car usage, also the average speed decreases. On average the speed decreases by 1.9%, ranging from an increase of 0.1% to a decrease of 4.5%. This is lower than the existing literature measured. A reason for this could be that these strikes happened during the holiday period, in which people often travel less and thus the effect of a public transport strike is less.

The third hypothesis mentioned that during rush hours the effect on the road network was stronger and the duration of rush hour increased. There is a significant difference between the effect on the morning and evening rush hour. On average the morning rush hour experiences a decrease in speed of 1.9% and an increase in intensity of 3.4%. However, during the evening rush hour the average speed decreases by 6.1% and the intensity increases by 9.9%. Due to the data that is used only providing the average speed and intensity per hour no clear increase in rush hour could be measured because the accuracy of the increase would be too low.

Due to the insignificance of the duration of the strikes, no conclusions can be drawn for the fourth hypothesis: a longer-lasting strike has more impact. The location of the strike has however a significant impact, as the hypothesis mentioned: a national strike has a bigger impact than a regional strike. On average regional strikes measure an increase in intensity of 6.7% whereas national strikes measure an increase of 7.4%. For speed, regional strikes experience on average a decrease of 1.4% whereas national strikes experience a decrease of 3.5%.

Because all strikes that were taken into account for this research were during weekdays, no results are measured for weekend days. Thus, no results are calculated for the fifth hypothesis: strikes on weekdays will have a bigger impact than strikes on the weekend.

The next hypothesis expected a slight effect the days after the strike that would slowly get back to normal, this is not the case for both the intensity and the speed. There is no clear connection between the days after the strike and the intensity/speed getting back to normal. One of the reasons could be, that due to the overlap between days after the strike, different strikes have an impact on each other.

Lastly, the last hypothesis mentioned the intensity exactly one week after the strike to be lower and the speed to be higher than during the strike. This is the case for the intensity, a decrease of 3.1% on average. However, the speed was not significant and therefore no conclusions can be drawn about the speed change.

## 6.2. Implementation of the results

This section explains how the results can be used regarding strikes in the future. This will be first done for traffic management and afterward for strike regulations.

The results show that there is an increase in congestion throughout the day. To reduce the impact of the strikes on the road network rush hour lanes could be opened during the day to increase the capacity and thus reduce the change of congestion. Besides that, the results also show a significant increase in traffic during the evening rush hour in comparison with the morning rush hour and day. to reduce this effect, driving especially outside the evening rush hour can be encouraged.

The results indicate that the effect of a strike is significantly higher during the evening rush hour than during the day or morning rush hour. A change in strike regulation could be that only strikes may happen during the morning instead of the whole day. With this regulation, the evening rush hour is unaffected and will probably experience less hindrance from the strike. Additionally, the national strikes have a bigger impact on the road network than the regional strikes. Therefore, another regulation could be to only allow regional strikes to reduce the impact as much as possible.

## 6.3. Future research

Two limiting factors of this research were the data quality and the strike selection. Besides that, there is a difference between a morning rush hour and an evening rush hour that should be researched further.

**Data quality**

Future research should use more accurate data with a more regular time interval. This research could not measure any effect on the duration of the rush hour due to a too-large time interval. A smaller time interval should be able to measure this effect. Besides the time interval, the data quality itself was poor, a lot of road segments could not be used due to no available data for each segment and only two variables are taken into account. Future research should research the effect on different variables such as travel time. Besides that, there is still a lot of research to be done with a complete road network to get even more accurate results.

**Strike selection**

The researched strikes were all during the holiday period, therefore the outcome of a non-holiday period strike could have a different effect. This effect should be measured in future research. Besides that the effect on the road network the days after the strike could is still unclear after this thesis due to an overlap of dates. Thus future research should still research this effect with non-overlapping strike days.

**Rush hour**

One of the conclusions from this paper is that there is a difference between the morning rush hour and the evening rush hour. This should be researched further because if the effect on the morning rush hour is smaller the government could only allow strikes that happen in the morning to reduce the total impact on the road network.

## 6.4. Conclusion

This research showed an increase in intensity and a decrease in travel speed during strikes, this is for national strikes greater than for regional strikes. Especially the evening rush hour is more susceptible to strikes. To reduce the impact of future strikes regulations can be made regarding the locations and timing of the strikes. Besides that, traffic management could advise people to travel outside the evening rush hour and open the rush hour lane the entire day. There is still a lot of research to do regarding the effect of public transport strikes on road congestion. This research advises doing more research with better data quality, different strike selections and researching more about the effect of the different rush hours.

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# A

# ANWB maps


**Figure A.1:** Chance at congestion in the morning rush hours (ANWB, 2023a)


**Figure A.2:** Chance at congestion in the evening rush hours (ANWB, 2023a)

# B

# Road segments

In the following tables the road segment is given with the road number and with the hectometer location.

**Table B.1:** Road segments per strike [1/2]

| **Road Segment** | **Strike Number** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| A1 h19.4 | | | X | X | | X | X | |
| A1 h49.8 | | | | X | X | X | | X |
| A1 h140.1 | | | | X | X | X | | X |
| A2 h88.9 | | | | X | X | X | | X |
| A2 h109.2 | | | | X | X | X | | X |
| A2 h173.0 | | | | X | X | X | | X |
| A2 h243.7 | | | | X | X | X | | X |
| A4 h6.6 | | | X | X | | X | X | |
| A4 h30.8 | | X | | X | | X | | |
| A4 h34.8 | | X | | X | | X | | |
| A4 h47.5 | | X | | X | | X | | |
| A4 h49.8 | | X | | X | | X | | |
| A6 h68.3 | X | | | X | | X | | |
| A6 h298.5 | X | | | X | | X | | |
| A7 h27.2 | X | | | X | | X | | |
| A7 h73.6 | X | | | X | | X | | |
| A7 h218.2 | X | | | X | | X | | |
| A9 h27.7 | | | X | X | | X | X | |
| A9 h36.7 | | | X | X | | X | X | |
| A9 h68.3 | | | X | X | | X | X | |
| A10 h17.3 | | | X | X | | X | X | |
| A12 h28.2 | | X | | X | | X | | |
| A12 h60.4 | | | | X | | X | | |
| A12 h117.8 | | | | X | X | X | | X |
| A12 h143.8 | | | | X | X | X | | X |

**Table B.2:** Road segments per strike [2/2]

| Road Segment | Strike Number | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| A15 h48.3 | | X | | X | | X | | |
| A15 h80.6 | | X | | X | | X | | |
| A15 h127.0 | | | | X | X | X | | X |
| A16 h17.8 | | X | | X | | X | | |
| A16 h42.6 | | | | X | X | X | | X |
| A17 h3.9 | | | | X | X | X | | X |
| A20 h33.4 | | X | | X | | X | | |
| A20 h46.0 | | X | | X | | X | | |
| A27 h33.1 | | | | X | X | X | | X |
| A27 h52.3 | | | | X | X | X | | X |
| A27 h81.4 | | | | X | | X | | |
| A27 h93.3 | | | | X | | X | | |
| A27 h103.6 | | | | X | | X | | |
| A28 h77.0 | | | | X | X | X | | X |
| A28 h100.3 | X | | | X | | X | | |
| A28 h131.6 | X | | | X | | X | | |
| A28 h165.1 | X | | | X | | X | | |
| A29 h14.1 | | X | | X | | X | | |
| A32 h45.3 | X | | | X | | X | | |
| A32 h65.5 | X | | | X | | X | | |
| A37 h29.0 | X | | | X | | X | | |
| A50 h142.4 | | | | X | X | X | | X |
| A50 h164.3 | | | | X | X | X | | X |
| A50 h185.2 | | | | X | X | X | | X |
| A58 h17.0 | | | | X | X | X | | X |
| A58 h32.0 | | | | X | X | X | | X |
| A58 h54.7 | | | | X | X | X | | X |
| A58 h100.6 | | | | X | X | X | | X |
| A58 h145.3 | | | | X | X | X | | X |
| A59 h101.7 | | | | X | X | X | | X |
| A59 h107.5 | | | | X | X | X | | X |
| A67 h24.6 | | | | X | X | X | | X |
| A67 h54.2 | | | | X | X | X | | X |
| A73 h13.5 | | | | X | X | X | | X |
| A73 h49.0 | | | | X | X | X | | X |
| A73 h99.1 | | | | X | X | X | | X |
| A76 h5.7 | | | | X | X | X | | X |