Traffic in Transition: Assessing Hoefkade Closure's Influence on Surrounding Streets

An Insight into Traffic Patterns and Safety Implications Following Hoefkade Closure in The Hague: Lessons for Urban Infrastructure Projects

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Figure Cover Sheet - Bollards on the Hoefkade in The Hague (Jansen, 2023)

Preface

This report is written as a bachelor thesis for the bachelor Civil Engineering at Delft University of Technology.

The report can be read by all those interested in the subject Transport and Planning without previous knowledge of the subject. However, it can be helpful to have a basic understanding of the subject of road closure.

I would like to thank my supervisors Dr. Ir. Yufei Yuan, Kuldeep Kavta and Dr. Shadi Sharif Azadeh for answering my questions and for guiding me during the writing of this report. I would also like to thank my fellow students Brigitte Nauta, Casper Polet, Daan van de Brug and Jarno Jorritsma who reviewed my work every week.

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Abstract

The municipality of The Hague decided to permanently close the Hoefkade, one of the most famous streets in The Hague, Netherlands, to motorised traffic by placing bollards in June 2020. These bollards are placed exactly on the border between the neighbourhoods Schilderswijk and Stationsbuurt to limit the traffic between these places and to increase the attractiveness and traffic safety on the Hoefkade (Gemeente Den Haag, 2019c). This report is the first study to investigate the consequences of this road closure and answers the following research question: "*To what extent has the closure of the Hoefkade in The Hague affected traffic flows and the number of traffic crashes in the surrounding streets, and what lessons can be learned for future similar projects?*"

The research question is answered by analysing the traffic flows and the number of traffic crashes of the surrounding streets before and after the closure of the Hoefkade. This data is provided by the municipality of The Hague and the online website Smart Traffic Accident Reporting. This includes traffic data on 41 different segment in the neighbourhoods Schilderswijk, Stationsbuurt, and Laak. Based on this data using a mixed-methods approach, a comparative, correlation, and spatial analysis will be conducted. These analyses provide a comprehensive understanding.

The results show that there is no overall significant difference in traffic flows in the surrounding streets, but there are local significant differences. The streets in the Schilderswijk and Stationsbuurt had a significant decrease in traffic, whereas the streets in Laak had a significant increase. This indicates a redistribution of traffic, with drivers using alternative routes due to, among other things, the road closure, multiple roadworks, and several new speed cameras. Furthermore, there was a significant increase in the number of traffic crashes in Laak. This may be due to the correlation with traffic flow, where an increase in traffic flow is associated with more traffic crashes. Additionally, weather conditions and poor road conditions may have contributed to this increase.

The research into the closure of the Hoefkade has provided the following lessons: policymakers should use traffic models and simulations to predict traffic shifts and address possible measures, ensure traffic safety by implementing additional measures, conduct extensive traffic analyses before and after road closures, and involve the local community in the process of making a decision for future similar projects. These insights can help policymakers better manage the effects of road closures on traffic flows and safety for future similar projects.

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1. Introduction

The Hague, the political heart of the Netherlands, has the third-highest population in the Netherlands, after Amsterdam and Rotterdam. This number equals 562,839 inhabitants in 2023, which is an increase of 28% compared to 2000 (Centraal Bureau voor de Statistiek, 2023). The city is well-known for its dynamic economy and diverse population. One of the most famous streets in The Hague is the Hoefkade, a long street that runs through four neighbourhoods, namely Groente-en Fruitmarkt, Schilderswijk, Stationsbuurt and Transvaalkwartier. Figure 1 shows a satellite map of the centre of The Hague, with the Hoefkade marked in orange, and the neighbourhoods framed in black. This street used to be a crucial connection for motorised traffic, cyclists, and pedestrians between the city centre and the surrounding neighbourhoods (Omroep West, 2019). However, in the years before 2020, traffic on the Hoefkade became more problematic due to congestion, cut-through traffic, and a lack of traffic safety and liveability in the surrounding neighbourhoods (Gemeente Den Haag, 2019a). Research has indicated that sixty percent of motorists driving on the Hoefkade during rush hours do not need to be in the Schilderswijk (Gemeente Den Haag, 2019b). In response, the municipality of The Hague has decided to close the Hoefkade to motorised traffic as part of a larger urban renewal project aimed at increasing attractiveness and traffic safety on the Hoefkade and limiting motorised traffic between the Schilderswijk and Stationsbuurt (Gemeente Den Haag, 2019c). On Monday, June 22, 2020, the Hoefkade between the intersections with Fannius Scholtenstraat and Naaldwijksestraat was officially permanently closed to motorised traffic by placing bollards, with exceptions for emergency services (Omroep West, 2020). Figure 1 shows the location of the bollards, which is on the red cross. These bollards are placed exactly on the border between the Schilderswijk and Stationsbuurt.

Figure 1. A map of the centre of The Hague, with the Hoefkade marked in orange, the neighbourhoods framed in black, and the bollards on the red cross (OpenStreetMap, 2024)

1.1 Problem Analysis

The closure of the Hoefkade has been a major change for the traffic infrastructure of The Hague. This closure was intended to increase the attractiveness and traffic safety on the Hoefkade and to limit motorised traffic between the Schilderswijk and Stationsbuurt (Gemeente Den Haag, 2019c). However, the closure also raises questions about the consequences that may occur in the surrounding streets. One of the most important consequences is the effect that the closure of the Hoefkade can have on the traffic flow in the surrounding streets. The changes that occur can lead to traffic congestion. Furthermore, due to the shift in traffic flows, there could be an increase in traffic crashes in the surrounding streets instead of on the Hoefkade. However, these are all assumptions that have not been confirmed. After the closure of the Hoefkade, the municipality of The Hague did not conduct any research into the consequences that this closure had on the surrounding streets. It has never been confirmed whether the closure of the Hoefkade has achieved the goals for which it was closed in 2020. For this reason, it is important to investigate what possible effect the closure of the Hoefkade has had on traffic flows and the number of traffic crashes in the surrounding streets. This can be researched by using the traffic flows and the number of traffic crashes of the surrounding streets before and after the closure of the Hoefkade. By comparing the differences, this research can show how the road closure possibly affected the surrounding streets, and lessons can be learned for future similar projects.

1.2 Scope

The subject of this research is the possible effect that the closure of the Hoefkade in The Hague has had on traffic flows and the number of traffic crashes in the surrounding streets, and what lessons can be learned from this for future similar projects. Understanding this is essential, as it can provide insights for future projects where major streets are permanently closed. This research can only be worked on for seven weeks, which is a limited time to cover everything. The closure of the Hoefkade may have had several consequences, such as the change in car use of the street's residents. Furthermore, this change may have had an impact on the air and noise quality of the street or the local economy. Also, the severity of the traffic crashes may have changed after the closure of the Hoefkade. However, it is not feasible to cover all the effects of the closure of the Hoefkade, as seven weeks is insufficient. Further research needs to be done to get that information.

1.3 Relevance

Both societal and scientific relevance are present in this research. Starting with the societal relevance. The placement of bollards on the Hoefkade has had consequences for residents, travellers, and entrepreneurs on the Hoefkade and in the surrounding area. The turnover of several entrepreneurs on the Hoefkade has decreased significantly after the closure (Rubio, 2021). Furthermore, after the closure of the Hoefkade, residents of the Schilderswijk protested multiple times against the traffic measure (Mulder, 2021). Many people in the local community are not satisfied with the closure of the street and do not see the usefulness of the traffic measure (Rubio, 2020a). For this reason, it is important to investigate whether the goals of the closure of the Hoefkade have been achieved, namely an increase in attractiveness and traffic safety on the Hoefkade and less traffic between the Schilderswijk and Stationsbuurt. This study examines this and this is important information to maintain the satisfaction of the local community. However, this information is also important for policymakers in other places facing similar challenges. These policymakers can learn from this road closure and draw lessons for future similar projects.

This research can also contribute scientifically to the literature of traffic. To our knowledge, no previous research has been conducted into the effect that a permanent road closure may have had on traffic flows and/or the number of traffic crashes. This research could be the beginning of filling this gap in academic articles on this subject. Analysing changes in traffic flows and the number of traffic crashes can provide insights for policymakers. Furthermore, the findings of this research can be a reference project for future studies.

1.4 Research Question

The purpose of this research is to draw lessons for future similar projects from the closure of the Hoefkade in The Hague regarding the traffic flow and traffic safety of the surrounding streets. This report addresses the following research question:

To what extent has the closure of the Hoefkade in The Hague affected traffic flows and the number of traffic crashes in the surrounding streets, and what lessons can be learned for future similar projects?

This research question will be answered by collecting data on traffic flows and the number of traffic crashes in the surrounding streets before and after the closure of the Hoefkade. Based on this data, a comparative analysis, correlation analysis, and spatial analysis will be conducted. The streets that the municipality of The Hague has provided traffic flow data for will be analysed in this report. These are various streets: the Hoefkade itself, streets near the bollards, streets perpendicular to the Hoefkade, and streets parallel to the Hoefkade. A portion of the Hoefkade will be included in this study as one of the surrounding streets. This is because the Hoefkade is so long, and there are also changes occurring within the street itself that can be shown in the spatial analysis. The streets parallel to the Hoefkade are also included in the study because these streets could be used as alternative routes for traffic after the placement of the bollards. All the streets that will be analysed are located in the Schilderswijk, Stationsbuurt, or Laak. These neighbourhoods are framed in black in Figure 1. Chapter 4 will provide an overview of the surrounding streets analysed in this study. From this information, a conclusion can be drawn. The research question can be divided into multiple sub-questions to obtain a better understanding of the question. These sub-questions are:

1) *Which analysis method has been used in previous studies to compare the same variable at two different times?*
   This sub-question is essential for this report, as the analysis method is used to answer the research question. In this case, the traffic flows and the number of traffic crashes are the variables, and the two different moments are the moment before and the moment after the closure of the Hoefkade. By answering this sub-question, it can be decided which analysis method best fits this research. The rest of the entire report pertains the selected analysis method. This sub-question will be answered in Chapter 2, which is the literature review.
2) *Which research design is used in this study, and why is it suitable for answering the research question?*
   This sub-question is crucial for this report, as the research design is the guideline for this study. The research design is the methodology that will be used throughout the report. Additionally, the research design has information on how data will be collected. Answering this sub-question will make sure the reader understands why the choice of research design was made and what the approach of the research will be. This will be addressed in Chapter 3, which covers the methodology.
3) *For which streets in the vicinity of the bollards on the Hoefkade are data available regarding traffic flow and the number of traffic crashes?*
   This sub-question is crucial to this research. The specific streets near the bollards where data is available on traffic flow and the number of traffic crashes will be analysed in this study. By identifying which specific streets have data on traffic flow and the number of traffic crashes

near the bollards, the effect of the closure of the Hoefkade on those streets can be analysed. Furthermore, this can give insight into which areas have been affected by the closure of the Hoefkade and what lessons can be learned for future similar projects. This sub-question will be addressed in Chapter 4, which focuses on data collection.

4) *How have the traffic flow and the number of traffic crashes in the surrounding streets changed after the closure of the Hoefkade?*
   By answering this sub-question, an image can be created of the dynamics of traffic (crashes) after the closure of the Hoefkade. It is crucial to know how traffic flow and the number of traffic crashes in the area has changed after the road closure. The differences between the traffic flows before and after the road closure can be compared with each other to investigate whether there is a significant difference, which shows to what extent the road closure has affected the traffic flows and the number of traffic crashes. Furthermore, by understanding the changes in traffic flows and the number of traffic crashes, recommendations can be made for future similar projects. This will be addressed in Chapter 5, which covers the analysis of the data collection.
5) *What are the key lessons that can be learned from the analyses of the Hoefkade closure?*
   By answering this sub-question, the lessons learned from this study will be known. These lessons can be recommended for future similar projects. These insights could be important for policymakers and traffic authorities in other cities to make effective decisions. This will be addressed in Chapter 6, which covers the discussion.

1.5 Stakeholders

There are multiple stakeholders involved in the closure of the Hoefkade, each with their own role and task. The main stakeholders are the municipality of The Hague, residents of the Schilderswijk, Stationsbuurt and Laak, entrepreneurs on the Hoefkade and surrounding streets, and traffic experts.

The municipality of The Hague plays a crucial role in the closure of the Hoefkade. They are responsible for the design and implementation of all traffic policies in The Hague. They have provided traffic flow data for several streets in The Hague, which is essential for this study. Furthermore, they may be interested in the results of this research to assess whether the project's objectives have been achieved and to learn lessons for future similar projects. The residents of the Schilderswijk, Stationsbuurt and Laak are also important. These people are directly affected by changes in traffic flows and traffic safety in the neighbourhoods. Their perspectives and experiences can provide insights into the effects of the closure. Entrepreneurs on the Hoefkade and surrounding streets also play a role as stakeholders because changes in traffic flows and traffic safety can affect the accessibility of their businesses and thus their turnover. Residents and local entrepreneurs may be interested in the results of this research to see if the project's objectives have been achieved. This can lead to more understanding, but if the objectives are not met, it can also cause controversy. Finally, traffic experts have knowledge essential to this traffic policy. They may be interested in the results of this research to draw lessons for future similar projects.

1.6 Reading Guide

The structure of the report is as follows: Chapter one is an introduction to the report. Chapter two will provide a literature review, followed by a description of the methodology of the research in Chapter three. Subsequently, in Chapter four, the data will be collected, followed by its analysis in Chapter five. Chapter six will be the discussion. Finally, Chapter seven will provide a conclusion of the research question and recommendations.

2. Literature Review

No previous research has been done, to our knowledge, on the effect that a permanent road closure may have had on traffic flows and/or the number of traffic crashes. For this reason, findings from previous studies cannot be included in this research regarding road closures and their effects on traffic flows and traffic safety. However, there are comparable projects, that will be discussed in this Chapter. This Chapter will first discuss a case study in the United States, where researchers investigated the impact of road closures on Roosevelt elk using a comparative analysis with the paired t-test. Next, a case study in Japan will be addressed, where researchers examined the effect on traffic flows of closing a major road for roadworks. The researchers used a spatial analysis and simulations to determine which road closure would have the least significant impact on traffic flows. The analysis methods used in both studies, namely the comparative and the spatial analysis, can be applied in this research. The Chapter will conclude with an analysis of the case studies and research gaps.

2.1 Road Closure in Coos Bay, United States of America

The researchers Cole, Pope, and Anthony (1997) conducted a quantitative study in response to multiple road closures implemented to manage the movement and survival of Roosevelt elk. The study took place in the city of Coos Bay, Oregon, United States, where a traffic policy called Road Management Areas (RMA) was in effect from 1991 to 1995. Under this policy, in 35% of the area roads were closed and there was limited motorised vehicle access. The researchers investigated the extent to which limited motorised vehicle access in the area could affect the movement and survival of Roosevelt elk. They compared data from the years before 1991 with the period of the RMA. The conclusion was that "limited-vehicular access reduces human disturbance that results in reduced movements and poaching increased survival of Roosevelt elk" (Cole, Pope, & Anthony, 1997).

The research by Cole et al. took place a long time ago, and there are more differences than similarities between that study and this one. There is no permanent road closure, as the road was reopened after 1995. Furthermore, this study does not consider traffic flows or traffic safety. However, the methods used in this study may overlap with those used in Cole et al.'s research. There are also similarities between the studies. Cole et al.'s research focuses on the safety of Roosevelt elk, but this can be compared with traffic safety for this study. Moreover, the main similarity is that both studies compare the same variables at two different time points. In Cole et al.'s research, the variables are the movement and survival of Roosevelt elk. The moments are the moment before the implementation of the RMA and the period when this policy was maintained, with multiple streets in the area closed (Cole et al., 1997). In this study, the variables are the traffic flows and the number of traffic crashes. The moments are the moments before the closure of the Hoefkade and after the closure of the Hoefkade.

The analysis method used by the researchers to compare the variables at two different time points is a comparative analysis using statistical tests. This answers the first sub-question of this research, namely "*Which analysis method has been used in previous studies to compare the same variable at two different times?*" The researchers calculated the absolute and relative differences between the two different time points and then used the paired *t*-test since their distributions were normal. Furthermore, they used a significance level of 5% to significantly compare the differences between the two time points. The researchers not only determined the *t*-value but also calculated the *p*-value. The *p*-value was then compared to the significance level to determine whether there was a significant difference (Cole et al., 1997). This analysis method is also suitable for this study as it can demonstrate whether there is a significant difference between the traffic flows and the number of traffic crashes before and after the closure of the Hoefkade.

2.2 Road Closure in Hiroshima, Japan

The researchers Osogami, Mizuta, and Idé (2013) conducted a quantitative study for a transportation authority to investigate which lane of a major road in Hiroshima City, Japan, would be best closed for roadworks. In their study, they identified the optimal road closure using simulation, specifically the IBM Mega Traffic Simulator version 2. The researchers closed various streets using the simulation to determine which road closure would have the least significant impact on traffic flows. The selected road will be temporarily closed in Hiroshima for roadworks (Osogami, Mizuta, & Idé, 2013).

At first glance, this report may not seem comparable to this project, as there is no mention of a permanent road closure here and the road is yet to be closed. However, there are similarities between the report and this research. Traffic flows are analysed in both studies in response to a road closure. Both studies examine traffic flow before and after a road closure, with the difference that the data on traffic flow after the closure in the Osagami et al.'s study is simulated. Another similarity is the street that needs to be closed; in the report, this is the Gion Shindo road, a major road in Hiroshima, and in this research, it is the Hoefkade, a major road in The Hague.

This research does not use the same simulation for various reasons. Firstly, the IBM simulation used in the report is not freely available for individuals. The researchers who conducted the study all work at IBM and therefore have access to the simulation. Furthermore, they use the simulation to estimate traffic flows after the road closure, but in this case, that information is already available (Osogami et al., 2013). However, the spatial analysis conducted can also be applied to this research. The researchers took a square region from the area of OpenStreetMap to create various maps. These maps show the absolute difference in traffic flow—the number of vehicles per hour—before and after the road closure on the streets that have undergone a change (Osogami et al., 2013). Figure 2 shows one of the maps created by the researchers. Two colours are used, namely blue and green. The streets coloured blue did not undergo big changes, while the green streets did and have doubled. Minor streets are not coloured. Based on the maps created by the researchers, they concluded which lane should be closed. Using the maps to draw a conclusion can also be done in this research since maps provide a better understanding than just numbers.

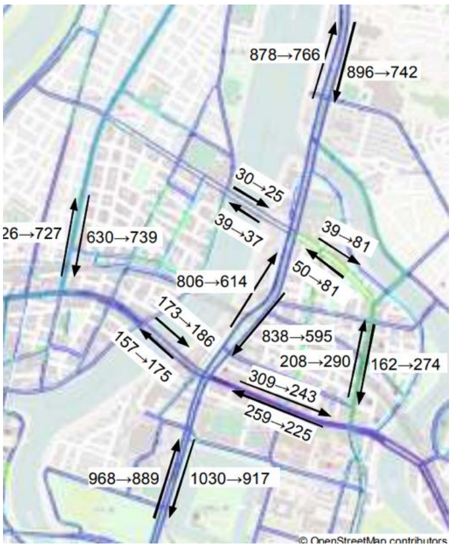

Figure 2. A map of the absolute differences in traffic flow in Hiroshima, Japan (Osogami, Mizuta, & idé, 2013)

2.3 Analysis and Research Gaps

The discussed case studies provide insights into the effect that a road closure can have on traffic flows and traffic safety. From the study by Cole, Pope, and Anthony (1997), it can be learned that limited access to motorised vehicles reduces the movement of Roosevelt elk and increases their survival rates. The research shows that using statistical tests is valuable for comparing data at two different time points. Despite the study focusing on elk, the same analysis method can be used in this research, namely comparative analysis using the paired t-test. By using this analysis, it can be determined whether there is a significant difference between traffic flow and the number of traffic crashes before and after the closure of the Hoefkade. This way, it can be determined whether the objectives of the municipality of The Hague have been achieved, from which lessons can be drawn for future similar projects.

The study by Osogami, Mizuta, and Idé (2013) shows that road closures can cause significant changes in traffic flows. The study takes place in Hiroshima, so it cannot be concluded that the same changes will occur in The Hague. However, the same spatial analysis can be used, where the absolute difference in traffic flows before and after the road closure can be mapped out. This provides a better understanding of the effect on traffic flows due to a road closure.

These studies show that similar analysis methods can be effective for analysing the effect of road closures on traffic flows and traffic safety. However, there are still research gaps. The results obtained in both studies cannot be directly applied to this research. The studies took place on the other side of the world and are about specific situations. This shows the need for more research focusing on similar problems in different places. Furthermore, there is a lack of studies investigating the long-term effects of permanent road closures on traffic flows and traffic safety. The above-mentioned studies were only about temporary road closures, leaving a gap in knowledge regarding the effects of permanent traffic measures. Additionally, there is a lack of studies investigating the correlation between traffic flows and the number of traffic crashes following a road closure. There is also a need for research on the effectiveness of traffic measures concerning permanent road closures.

During the literature review, efforts were made to identify comparable approaches used in other studies to investigate the effect of permanent road closures on traffic flows and traffic safety. However, there is no relevant literature available on this topic currently. This shows that there are research gaps that future studies can focus on to gain more insight into this subject. Furthermore, the findings of this research can be the beginning of filling these gaps.

3. Methodology

This Chapter covers the methodology of the research. First, the research design will be presented, after which the literature review will be provided. The data collection is then discussed, and the Chapter ends with the analysis of the data collection.

3.1 Research Design

This research utilises a mixed-methods approach to understand the extent to which the closure of the Hoefkade in The Hague has affected traffic flows and the number of traffic crashes in the surrounding streets. This approach combines both quantitative and qualitative methods so that lessons can be learned for future similar projects. Furthermore, all the data collected is secondary, meaning it has been collected previously. Using existing data minimises the time needed to collect data, and having more time for the analyses. This answers the second sub-question of this research, namely "*Which research design is used in this study, and why is it suitable for answering the research question?*"

Quantitative research starts with gathering insights from road closures in other comparable projects. Furthermore, traffic data will be collected from the Hoefkade and the surrounding streets regarding traffic flows and the number of traffic crashes before and after the closure of the Hoefkade on June 22, 2020. This data will come, respectively, from the municipality of The Hague and Smart Traffic Accident Reporting (STAR) and will all be numbers. Additionally, these numbers will be analysed in three different ways: a comparative analysis using the paired t-test and the Wilcoxon singed rank test, along with a correlation analysis to calculate the relationship between traffic flows and the number of traffic crashes, and a qualitative spatial analysis will be conducted. This involves mapping the data to identify patterns that may not be seen from the comparative and correlation analysis alone.

The mixed-methods approach makes sure that both numerical and spatial data are considered to provide a comprehensive understanding in this study. Subsequently, these changes can be analysed. Based on all the information gathered, it can be determined to what extent the closure of the Hoefkade has affected traffic flows and the number of traffic crashes in the surrounding streets. Lessons can be learned and discussed based on this.

3.2 Literature Review

First, a literature review is conducted. No previous research has been done, to our knowledge, into the relationship between a road closure and traffic flows and/or the number of traffic crashes. For this reason, this review discusses comparable projects.

All the information is obtained through various academic articles. These articles can be found on Google Scholar, Scopus, TU WorldCat, and the Web of Science Core Collection. To find relevant articles, the research question was divided to get search terms, which include: 'closure*', 'traffic', 'flow*', 'crash*', and related terms, just like 't-test' and 'road*', to present them in the selection features of the databases. These search terms were combined in different ways using Boolean operators such as 'AND', 'OR', and 'NOT' to minimise the searches and obtain better search results.

Furthermore, when collecting information, several criteria are considered. First of all, all sources older than thirty years are rejected, as this is not current information. This could distort the current understanding of road closures in cities. After that, it is determined whether the information is relevant to the research question by checking whether the source is about cities rather than villages, as the research question is focused on the Hoefkade, which is located in the city centre of The Hague.

Additionally, preference is given to peer-reviewed sources where experts have critically assessed this information. The reliability and quality of these sources are therefore high. Also, as many different authors and academic institutions as possible are used to provide a diverse perspective.

3.3 Data Collection

After the literature review, traffic data from the Hoefkade in The Hague and the surrounding streets will be collected and presented. These traffic data are the traffic flows per street before and after the closure of the Hoefkade and the number of traffic crashes on the same streets before and after the road closure.

The data cannot be obtained from academic articles, so different search terms are entered into Google. These search terms will be in Dutch, as there is a greater chance that traffic data will be returned as a search result. Several search terms are used, such as ‘Hoefkade’, ‘verkeersintensiteit’ (=*traffic flow*), ‘ongeluk’ (= *crash*), and ‘gewonden’ (=*injured*). The surrounding streets are also used as search terms, such as ‘Oranjelaan’ and ‘Parallelweg.’

When selecting sources, several criteria are taken into account. First of all, all sources older than five years are rejected, as this is not current information. After that, it is determined whether the collected data is relevant to the research question by checking whether the data is about the Hoefkade and the streets around it. Furthermore, the sources of the traffic data must be reliable, so this data cannot be selected from random individuals. Reliability can come from confirmations from other sources, where the numbers correspond with each other, or from government agencies. In addition, all data must be accurate and contain no inconsistencies.

The average motorised traffic flow per street before and after the closure of the Hoefkade have been published in a public government report by the municipality of The Hague. They have also indicated the maximum traffic speed for each street in the same report (Gemeente Den Haag, 2022). This information will also be used in this study. Additionally, the number of traffic crashes in the surrounding streets before and after the closure of the Hoefkade can be obtained from the online website STAR, Smart Traffic Accident Reporting. This website provides an overview of all traffic crashes in the Netherlands since 2019 and their exact locations (Smart Traffic Accident Reporting, 2024). Both sources were found by typing the above search terms into Google. For convenience, all data will be presented in tables and bar charts together with the absolute and relative difference between the variables before and after the closure of the Hoefkade. The absolute and relative differences are calculated using Python. The absolute difference is determined by subtracting the traffic flow value after the closure from the value before the closure of the Hoefkade. Furthermore, the relative difference is calculated by dividing the absolute difference by the traffic flow value before the closure of the Hoefkade. This process is repeated for the values of the average number of traffic crashes.

3.4 Data Analysis

After the data has been presented, it can be analysed. No previous research has been done, to our knowledge, into the effect that a road closure may have had on traffic flows and/or the number of traffic crashes. Furthermore, no similar research has been conducted on the effect that a road closure can have on other traffic data. For this reason, this research is carried out using several different accessible analysis methods since there is no reference project. The purpose of this report is to investigate to what extent the closure of the Hoefkade in The Hague has affected traffic flows and the number of traffic crashes in the surrounding streets. It is important to know what information is available so that analysis methods can be chosen based on it. The municipality of The Hague and Smart Traffic Accident Reporting have, respectively, made information available about the average traffic flows and the number of traffic crashes in the surrounding streets before and after the closure of the Hoefkade. The traffic flow data is available on 41 different line segments, with the long streets divided into several parts to provide a detailed picture. Out of the 41 segments provided by the municipality of The Hague, 40 will be used. The one segment that will not be used is the segment of the Hoefkade where the bollards have been placed. This segment has undoubtedly undergone significant changes in traffic flows and the number of traffic crashes, as no regular traffic is allowed through except for emergency services (Omroep West, 2020). Including information about this segment may distort the results of the comparative and correlation analyses. Therefore, 40 segments will be used. This is limited data, but this does not mean that research cannot be conducted. For this reason, several analyses are carried out to draw a conclusion out of the numbers. This Section first discusses the comparative analysis, after which the correlation analysis is discussed, and it will end with the spatial analysis.

3.4.1 Comparative Analysis

The leading analysis method is the comparative analysis. This analysis focuses on comparing two different groups to identify significant differences. The two different groups are the group before the closure of the Hoefkade and the group after the closure of the Hoefkade. In this study, three distinctions will be made: streets with a maximum speed limit of 30 km/h and 50 km/h; streets that are close to the Hoefkade and streets that are further away. In this research, segments that intersect with the Hoefkade at least once are labelled as close, while all other segments are labelled as far. Furthermore, there is a distinction between the streets that are north of the railway tracks of The Hague Hollands Spoor (HS) station and streets that are south of it. The streets north of the station are all located in the Schilderswijk and Stationsbuurt, while those to the south are all in Laak. In total, fourteen comparisons will be made:

1) The average traffic flows of the surrounding streets before and after the closure of the Hoefkade are compared with each other.
2) The average traffic flows of the surrounding 30 km/h streets before and after the closure of the Hoefkade are compared with each other.
3) The average traffic flows of the surrounding 50 km/h streets before and after the closure of the Hoefkade are compared with each other.
4) The average traffic flows of the streets close to the Hoefkade before and after the closure of it are compared with each other.
5) The traffic flows of the streets far from the Hoefkade before and after the closure of it are compared with each other.
6) The average traffic flows of the streets north of the railway tracks of The Hague HS station before and after the closure of the Hoefkade are compared with each other.
7) The average traffic flows of the streets south of the railway tracks of The Hague HS station before and after the closure of the Hoefkade are compared with each other.

Note that the other seven comparisons are exactly the same, but with ‘traffic flows’ replaced by ‘number of traffic crashes.’ The comparative analysis consists of two parts, namely the statistical tests and the calculation of the effect size. In this Section, first the method of performing these statistical tests will be explained, followed by an explanation of the calculation of the effect size.

3.4.1.1 Statistical Tests

The comparative analysis is carried out using statistical tests. These statistical tests determine whether there is a significant difference between the values before and after the closure of the Hoefkade. Two different statistical tests will be used in this study, namely the paired t-test and the Wilcoxon signed rank test.

The paired t-test is carried out in its entirety by determining whether there is a significant difference between the variables, traffic flow or number of traffic crashes, before and after the closure of the

Hoefkade. These are therefore the first and eighth comparisons that will be conducted. There are a number of requirements that should be met to use this statistical test (Rietveld & van Hout, 2017):

1) The same variable must be measured at two different time points.
2) There must be at least thirty data points to draw a reliable conclusion.
3) The variable must be continuous.
4) The distribution of differences between the paired data must be normally distributed.

In this case, requirements one and two are met, as the same variable is measured at two different time points, namely before and after the closure of the Hoefkade, and there are 40 data points available. However, compliance with requirement three should be explained. According to the Central Bureau for Statistics (2024), traffic flow is the average number of vehicles passing per unit of time at a (fixed) measuring point. This number is an average and therefore does not have to be a whole number, making it a continuous variable. Furthermore, the average number of traffic crashes is also a continuous value, even though the number of traffic crashes is discrete (Robinson, 2012). After all, an average is taken over these values, making it a continuous variable. In the following analyses, both variables can therefore be regarded as continuous. Moreover, compliance with requirement four should first be demonstrated.

The distribution of the differences between the values before and after the closure of the Hoefkade is essential. After all, this distribution determines whether a parametric or non-parametric test should be performed. The Shapiro-Wilk test is a test used to calculate whether a distribution is normal. This test will be used in this study to demonstrate that the distribution of the differences in the data is normal. The sample size must be between 3 and 5000, where the test is more reliable if the sample size is less than or equal to 50, which applies in this case (Royston, 1995). In the Shapiro-Wilk Test, there are two hypotheses:

1) The null hypothesis H_0: the distribution of the differences is normal.
2) The alternative hypothesis H_1: the distribution of the differences is not normal.

Furthermore, the chosen significance level in studies is often equal to 5%, i.e. 0.05 (Cole et al., 1997). This significance level will also be chosen in this study. Python has a function, "scipy.stats.shapiro", where an array can be entered, after which Python calculates the corresponding p-value. This function will be applied twice: the first time with an array of the absolute differences in the average traffic flow and the second time with an array of the absolute differences in the average number of traffic crashes. The second output of the Python function is the p-value of the entered array. If the calculated p-value is larger than the chosen significance level, the alternative hypothesis is rejected, so the distribution is normal (Razali & Yap, 2011). The Shapiro-Wilk test will demonstrate that the distribution is normal, allowing the use of the parametric paired t-test (Herbold, 2020). The paired t-test will then be used to determine whether there is a significant difference between the values of the traffic flow and number of traffic crashes before and after the closure of the Hoefkade.

The paired t-test is used if the distribution is normal. Furthermore, this test, just like the Shapiro-Wilk test, uses a significance level of 5%, i.e. 0.05. In addition, it is recommended to apply the two-tailed test since no specific effect is expected (Gang et al., 2018). The group before the closure of the Hoefkade can be called X_i, and the group after the closure of the Hoefkade can be called Y_i. In addition, the difference between these two groups can be noted as $D_i = X_i - Y_i$, which is an array of the absolute differences in the average traffic flow or the number of traffic crashes. There are two hypotheses in the paired t-test for the average traffic flow:

1) The null hypothesis H_0: There is no significant difference between the average traffic flow before and after the closure of the Hoefkade in the surrounding streets. This means $\mu_D = 0$.

2) The alternative hypothesis H_1 : There is a significant difference between the average traffic flow before and after the closure of the Hoefkade in the surrounding streets. This means $\mu_D \neq 0$.

Note that the hypotheses for the paired t-test for the number of traffic crashes are exactly the same, but with 'traffic flow' replaced with 'number of traffic crashes'. Afterwards, the test can be carried out by filling in Equation (1), from which the *T*-value is obtained (Hedberg & Ayers, 2014).

$$T = \frac{\overline{D}}{\frac{\sigma_D}{\sqrt{n}}} \tag{1}$$

T = T – value

$\overline{D}$ = the sample mean of *D*

σ_D = the sample standard deviation of *D*

n = the sample size; In this case, the sample size is 40, as there are 40 data points.

The obtained *T*-value should be compared with the critical *t*-value. This value depends on the significance level, type of test, and degree of freedom, which is equal to n – 1. In this case, the critical *t*-value is 2.023, which is derived from the t-table (San Jose State University, 2024). If the *T*-value obtained is between -2.023 and 2.023, the alternative hypothesis is rejected, and therefore, there is no significant difference after the closure of the Hoefkade (Kim, Park & Wang, 2024).

In addition, twelve other comparisons need to be made, where three distinctions have been made. This is done to determine whether the streets had a significant difference after the closure of the Hoefkade. However, the paired t-test cannot be used, as there are only 16 data points available for the 30 km/h streets, 24 for the 50 km/h streets, 13 for the streets close to the Hoefkade, 27 for the streets further away, 28 for the streets north of the railway tracks of The Hague HS station and 12 for the streets south of it. For this reason, the non-parametric Wilcoxon signed rank test will be used. This test is ideal for use with small sample sizes (Divine, Norton, Hunt, & Dienemann, 2013). After all, at least two data points are needed to use the Wilcoxon signed rank test, which is true in all cases (Rosner, Robert, & Mei-Ling, 2006). This test will be conducted twelve times, but in this Section, it is explained how comparison two can be performed. This is a comparison of the traffic flow before and after the closure of the Hoefkade on the surrounding 30 km/h streets. Note that all twelve comparisons will be conducted in exactly the same way, but only one will be shown here. For conducting comparison three, '30' should be replaced with '50'; for comparison four 'surrounding 30 km/h streets' should be replaced with 'streets close to the Hoefkade', for comparison five with 'streets far from the Hoefkade', for comparison six with 'streets north of the railway tracks of The Hague HS station' and for comparison seven with 'streets south of the railway tracks of The Hague HS station.' This is also done for the comparisons for the average number of traffic crashes.

For consistency, the Wilcoxon signed rank test also uses a significance level of 5% and a two-tailed test. This test has two groups, similar to the paired t-test. The group before the closure of the Hoefkade can be called X_i, and the group after the closure of the Hoefkade can be called Y_i. In addition, the difference between these two groups can be noted as $D_i = X_i - Y_i$, which is an array of the absolute differences in the average traffic flow for the 30 km/h streets. There are two hypotheses in the Wilcoxon signed rank test for the average traffic flow in 30 km/h streets:

1) The null hypothesis H_0: There is no significant difference between the average traffic flow before and after the closure of the Hoefkade in the surrounding 30 km/h streets. This means $\mu_D = 0$.

2) The alternative hypothesis H_1 : There is a significant difference between the average traffic flow before and after the closure of the Hoefkade in the surrounding 30 km/h streets. This means $\mu_D \neq 0$.

The Wilcoxon signed rank test can be performed using the Python function "scipy.stats.wilcoxon". Two arrays should be entered into this function, where the first array contains the average traffic flow before the closure of the Hoefkade for segments with a maximum traffic speed of 30 km/h, and the second array contains the same segments with the average traffic flow after the closure of the Hoefkade. The second output of the Python function is the *p*-value of the entered arrays. If the *p*-value obtained is larger than the chosen significance level, the alternative hypothesis is rejected, and therefore, there is no significant difference after the closure of the Hoefkade. If the *p*-value obtained is smaller than the chosen significance level of 0.05, the null hypothesis is rejected. Therefore, the alternative hypothesis is accepted, and it is concluded that there is a significant difference between the average traffic flow before and after the closure of the Hoefkade for the type of surrounding street (Oyeka & Ebuh, 2012).

3.4.1.2 Effect Size

After performing the statistical tests, the effect size is calculated. According to Sullivan and Feinn (2012), the effect size is the magnitude of the difference between groups and is the main finding of a quantitative study. A *p*-value will show whether there is a significant difference, but this value will not be able to show how large this effect was. The combination between showing the *p*-value and effect size is essential for this reason (Sullivan & Feinn, 2012).

There are several ways to measure effect size, but Cohen's *d* is one of the most commonly used effect sizes when comparing two groups (Diener, 2010). For this reason, this effect size will be used in this study. In this case, the two groups are: the moment before and the moment after the closure of the Hoefkade. An effect size will be calculated for all fourteen comparisons. By comparing these effect sizes, it can be concluded which type of surrounding streets experienced the most impact after the closure of the Hoefkade.

Cohen's *d* effect size is useful since it makes it simple to compare these values with other *d*-values to determine which variable had the biggest changes (Sullivan & Feinn, 2012). The *d*-value can be obtained by filling in Equation (2) (Rosnow & Rosenthal, 1996).

$$d = \frac{M_1 - M_2}{\sigma_{pooled}} \tag{2}$$

M_1 = the mean of group 1; in this case, it is the group before the closure of the Hoefkade.

M_2 = the mean of group 2; in this case, it is the group after the closure of the Hoefkade.

σ_{pooled} = the pooled standard deviation; this can be calculated by filling in Equation (3).

$$\sigma_{pooled} = \sqrt{\frac{\sigma_1^2 + \sigma_2^2}{2}} \tag{3}$$

σ_1 = the standard deviation of group 1; in this case, the standard deviation of the group before the closure of the Hoefkade.

σ_2 = the standard deviation of group 2; in this case, the standard deviation of the group after the closure of the Hoefkade.

The calculation of the effect size for the first comparison can be done by calculating the standard deviation of the values of the traffic flow from all surrounding streets both before and after the closure. These standard deviations can then be filled in Equation (3) to get the pooled standard deviation using

Python. Moreover, the mean of the values of the traffic flow before and after the closure should be calculated, after which Equation (2) can be filled in. Calculating the other effect sizes has the exact same process using Python.

The *d*-value can be used to determine the magnitude of the effect of the closure of the Hoefkade on the variable. The Cohen's Standard is selected based on the absolute *d*-value, as shown in Table I. A *d*-value larger than 1.3 indicates that the closure of the Hoefkade has had a 'very large' effect on the variable (Cohen, 1988). The *d*-values can provide insights that the statistical tests in the first instance could not provide.

Table I

Cohen's Standard (Cohen, 1988)

Effect size d	Cohen's Standard
$0.0 \leq d < 0.5$	Small
$0.5 \leq d < 0.8$	Medium
$0.8 \leq d < 1.3$	Large
$d \geq 1.3$	Very Large

3.4.2 Correlation Analysis

After the comparative analysis has been performed, the correlation analysis will be conducted. This analysis can certainly be relevant for this research, as it calculates the correlation between the average traffic flow and the average number of traffic crashes before and after the closure of the Hoefkade. These insights cannot be obtained from comparative analysis. According to Asuero, Sayago, and González (2006), correlation is the degree of association between two variables, which in this case are the average traffic flow and the average number of traffic crashes.

The correlation analysis will be conducted using Python, as performing the analysis manually is time-consuming. The correlation analysis will first be performed on the entire dataset, after which a distinction will be made between the 30 km/h streets and the 50 km/h streets. Additionally, this analysis will be carried out for the streets close to and far from the Hoefkade. Finally, this will also be carried out for the streets north of the railway tracks of The Hague Hollands Spoor station and the tracks south of it. Thus, the analysis will be conducted separately seven times. Per analysis, four arrays will be created in Python, namely the average traffic flow before and after the closure of the Hoefkade, and the average number of traffic crashes before and after the closure of the Hoefkade.

To perform the correlation analysis, the correlation coefficient should be calculated. There are many different correlation coefficients, but one of the most commonly used is the Spearman's rank correlation coefficient ρ (Schober, Boer & Schwarte, 2018). To obtain a reliable correlation coefficient, there should be between 5 and 1000 sample sizes, which applies in all seven cases (de Winter, Gosling & Potter, 2016). According to Hauke and Kossowski (2011), "Spearman's rank correlation coefficient is a nonparametric rank statistic and assesses how well an arbitrary monotonic function can describe the relationship between two variables, without making any assumptions about the frequency distribution of the variables." The values of this coefficient range between -1 and 1 (Schober et al., 2018). Calculating the Spearman's rank correlation coefficient is done using the function "scipy.stats.spearmanr" in Python, where two arrays are inputted, after which the Spearman's rank correlation coefficient is given along with the corresponding *p*-values. This is repeated twice. The first time is for the correlation coefficient before the closure of the Hoefkade, with the corresponding input from the arrays of the traffic flow and the number of traffic crashes. The second time is for after the closure of the Hoefkade, with the corresponding input from the array of the traffic flow and the average number of traffic crashes. Subsequently, the correlation coefficients should be interpreted using Table

II. These interpretations show the correlation between two different variables, with a negative correlation indicating an inverse relationship between the two variables.

Table II

Interpretation of Spearman's Correlation Coefficient (Akoglu, 2018)

Spearman's Correlation Coefficient ρ		**Interpretation**
+1	**- 1**	Perfect
$+0.8 \leq \rho < +1$	**$-1 < \rho \leq -0.8$**	Very strong
$+0.6 \leq \rho < +0.8$	**$-0.8 < \rho \leq -0.6$**	Moderately strong
$+0.3 \leq \rho < +0.6$	**$-0.6 < \rho \leq -0.3$**	Fair
$0 < \rho < +0.3$	**$-0.3 < \rho < 0$**	Poor
0		None

After the correlation coefficients have been interpreted, the corresponding *p*-values must be looked at. It needs to be determined whether the obtained *p*-values are statistically significant. For consistency, a significance level of 5%, i.e. 0.05, is used, just like in Section 3.4.1. In this case, there are two hypotheses:

1) The null hypothesis H_0: There is no significant correlation between the average traffic flow and the number of traffic crashes.
2) The alternative hypothesis H_1: There is a significant correlation between the average traffic flow and the number of traffic crashes.

If the obtained *p*-value is greater than the chosen significance level of 5%, the alternative hypothesis is rejected, meaning that despite the value of the calculated correlation, there is no relationship between the average traffic flow and the number of traffic crashes. In that case, the value of the correlation is purely coincidental, and there could be other factors that play a role (Xiao, Ye, Esteves, & Rong, 2015). There is then no relationship between the average traffic flow and the number of traffic crashes.

Two Spearman's rank correlation coefficients have now been calculated per type of surrounding street, the first being the correlation before the closure of the Hoefkade and the second the correlation after the closure. These two values should be compared to see if there is a significant difference. Significantly comparing two Spearman's rank correlation coefficients is done using the standard Fisher's z-transformation. This is a transformation in which the Pearson correlation coefficient *r* is converted to the normally distributed variable *z*, so that the coefficients can be tested for significance (Isaac & Chikweru, 2018). According to Myers and Sirois (2006), the most reliable way to use this transformation is to pretend that the Spearman's rank correlation coefficients are Pearson correlation coefficients. This test also uses a significance level of 5% and a two-tailed test. The *z*-value can then be read from the *z*-table, which shows that the *z*-value in this case is equal to 1.96 (University of Arizona, 2024). The Fisher's z-transform has two hypotheses:

1) The null hypothesis H_0: There is no significant difference between the correlation coefficients before and after the closure of the Hoefkade.
2) The alternative hypothesis H_1: There is a significant difference between the two correlation coefficients before and after the closure of the Hoefkade.

The following steps must then be done (Bishara & Hittner, 2016). First, the *z*-value for each correlation coefficient needs to be calculated by filling in Equation (4).

$$z = 0.5\ln\left(\frac{1+r}{1-r}\right) \quad (4)$$

z = z-value

r = Pearson correlation coefficient, which in this case is the Spearman's rank correlation coefficient.

Next, the standard error of the z-value needs to be calculated by substituting Equation (5).

$$\sigma_z = \frac{1}{\sqrt{N-3}} \tag{5}$$

σ_z = standard error of z

N = sample size

The z-value of the correlation before the closure of the Hoefkade is denoted as z_1, and after the closure as z_2, with the corresponding standard errors denoted as σ_{z_1} en σ_{z_2} respectively. After having this information calculated, Equation (6) need to be filled in (Myers & Sirois, 2006).

$$Z = \frac{z_1 - z_2}{\sqrt{{\sigma_{z_1}}^2 + {\sigma_{z_2}}^2}} \tag{6}$$

Z = Z-value

z_1 = z-value of the first correlation coefficient

z_2 = z-value of the second correlation coefficient

σ_{z_1} = standard error of z_1

σ_{z_2} = standard error of z_2

The z-value calculated in Equation (6) should then be compared to 1.96. If the calculated number is between -1.96 and 1.96, the alternative hypothesis is rejected, indicating that there is no significant difference between the two correlation coefficients after the closure of the Hoefkade (Isaac & Chikweru, 2018). Otherwise, there is a significant difference between the correlation coefficients, which suggests that the closure of the Hoefkade has influenced the correlation between the average traffic flow and the average number of traffic crashes.

3.4.3 Spatial Analysis

After the comparative and correlation analyses have been performed, the spatial analysis can be conducted. In this analysis, a total of two maps are created. These maps will be made using a satellite image of the centre of The Hague obtained from OpenStreetMap. In both maps, the absolute difference between traffic flows and the number of traffic crashes per segment will be shown using two different colours and line widths. The absolute difference is obtained from the tables where the data for traffic flow and the number of traffic crashes are presented. Furthermore, the annotations can be placed using Microsoft Paint.

The first map will be for the traffic flows, where the streets where more traffic passes, after the closure of the Hoefkade, will be made red and the streets where less traffic passes will be made green. Additionally, this will be done in the second map for the number of traffic crashes, where the streets that have more traffic crashes will be made red and the streets that have less traffic will be made green. The background of the maps has been chosen to be black and white to make sure that the reader's attention is to the green and red colours instead of the background colours.

The line width will show how much the traffic flow or number of crashes have changed, so the bigger the difference, the thicker the line will be. In Microsoft Paint, there is a function that allows the line width to be adjusted to an exact number of points. For traffic flow, the line width in points is calculated by dividing the absolute difference by 1000. For example, an absolute difference of 4888 vehicles per day results in a line width of 4.888 points. For the number of traffic crashes, the line width is equal to the absolute difference. For instance, an absolute difference of six traffic crashes results in a line width of six points. This way, the line width is as precise as possible.

This analysis can illustrate whether there are changing patterns in traffic flows and the number of traffic crashes after the closure of the Hoefkade. This visualisation can provide insights that are hard to visualise with just numbers and diagrams. Furthermore, these maps can show whether there is a connection between traffic flows and the number of traffic crashes. This could be the case if more traffic crashes occur on a street where there is more traffic after the closure of the Hoefkade. Furthermore, it is easy to identify which areas have been most affected by the road closure. Based on the comparative analysis, correlation analysis and spatial analysis, the research question can be answered.

4. Data Collection

In this Chapter, the data necessary for conducting this research will be presented. First, the data regarding the traffic flow will be presented, followed by the data on traffic crashes.

4.1 Data Collection for Traffic Flow

To determine the extent to which the closure of the Hoefkade in The Hague has affected the traffic flows in the surrounding streets, the traffic flow of those streets is needed. This traffic flow should be known at two different times, namely before and after the closure of the Hoefkade.

The municipality of The Hague has released the average motorised traffic flow for 41 segments in The Hague before and after the closure of the Hoefkade. The average traffic flow obtained is the number of vehicles per day. This average traffic flow is the average for the year before and the year after the closure of the Hoefkade in 2020, so the years 2019 and 2021 (Gemeente Den Haag, 2022). Some segments are a single street, but other streets are divided into multiple segments. The division of certain streets is done because the traffic flow is not the same in every part of the street. Long streets are divided into segments, and streets that intersect the Hoefkade are divided into multiple sections, namely the section north of the Hoefkade and the section south of the Hoefkade. In this study, the exact same segments are used as those published by the municipality of The Hague.

Figure 3 shows the 41 different segments. The black-grey striped lines in the middle of the figure is the railway tracks of The Hague Hollands Spoor (HS) station. This map is from OpenStreetMap, with markings made in Microsoft Paint. The colours of the segments have no meaning.

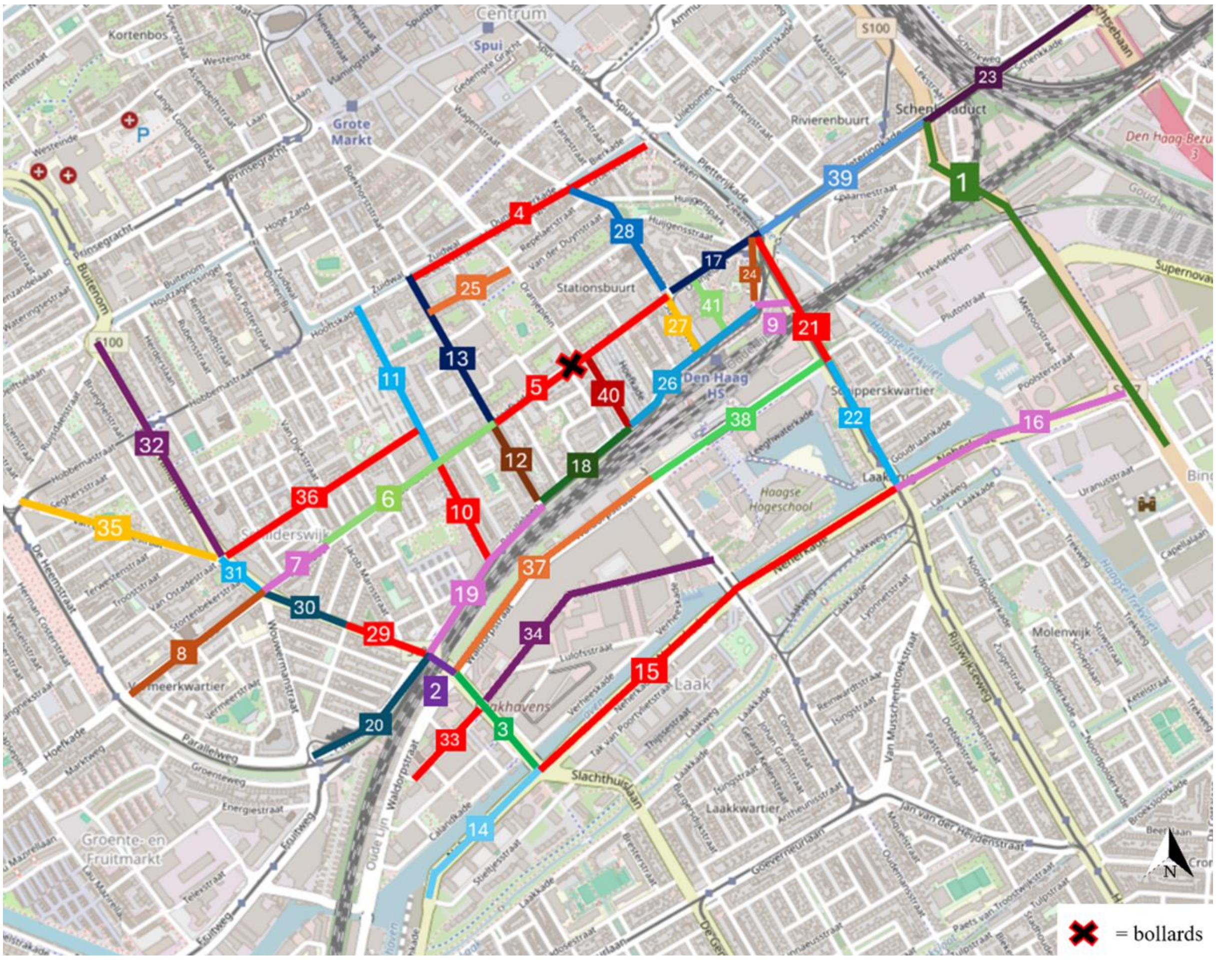

Figure 3. A map of the centre of The Hague, with 41 segments coloured and numbered (OpenStreetMap, 2024)

In Appendix A, Table X can be found. In this Table, the 41 segments are listed with their numbering in the first column, “Number.” This numbering corresponds to the numbering in Figure 3. With this, the first part of the third sub-question is answered, namely ”*For which streets in the vicinity of the bollards are data available regarding traffic flow?*” After all, the street names can be found in Table X, and the location of these streets can be found in Figure 3. Furthermore, each segment in the table is labelled as either “Close” or “Far” relative to the Hoefkade in the “Distance” column. A distinction has also been made between the streets located north of the railway tracks of The Hague HS station and those located south. Additionally, the maximum traffic speeds, and average traffic flow before and after the closure are provided per segment in the Table. This information is obtained from the report published by the municipality of The Hague (Gemeente Den Haag, 2022). Moreover, the absolute and relative differences in traffic flow were calculated using Python. The code used for this can be found in Appendix C.

In Section 3.4, it was discussed that one of the segments provided by the municipality of The Hague will not be used during the comparative and correlation analyses. This segment is segment 5, which covers the Hoefkade from the Stationsweg to the Koningstraat. Bollards were placed on this segment in June 2020, as shown in Figure 3, and in Table X in Appendix A, it can be seen that this segment has undergone significant absolute and relative changes, as no regular traffic is allowed through. Therefore, this segment is not classified as a “surrounding street.” Segments 6, 7, and 8, which are also part of the Hoefkade, are considered surrounding streets because the street is long, and these segments have also had changes that can be highlighted in the spatial analysis.

In Section 3.4.1, it was also discussed that seven comparisons will be made for the traffic flows before and after the closure of the Hoefkade. These comparisons will cover all surrounding streets, the surrounding 30 km/h streets, the surrounding 50 km/h streets, the streets close to the Hoefkade, the streets further away, the streets north of the train tracks of The Hague HS Station and those south of it.

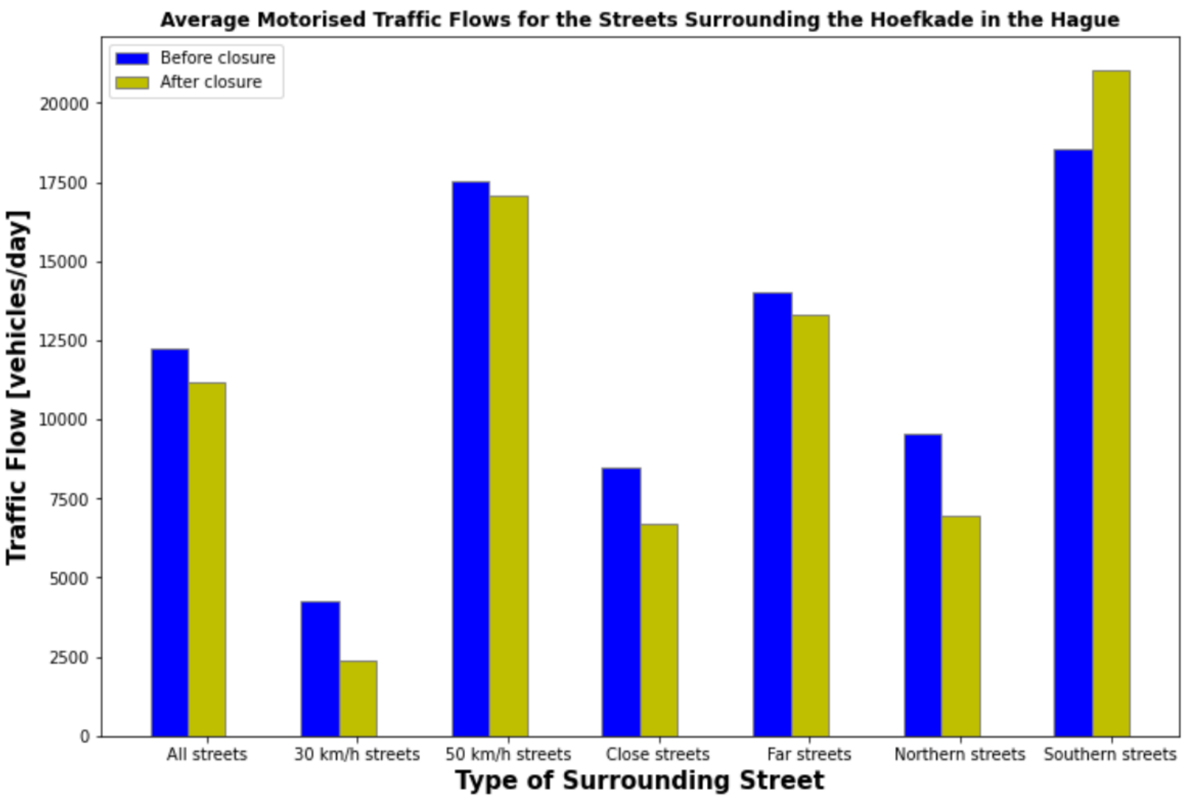

Figure 4. Average motorised traffic flows in vehicles per day before and after the closure of the Hoefkade per type of surrounding street (Gemeente Den Haag, 2022)

Figure 4 shows seven different bar charts for each type of surrounding street. An average of the traffic flow before and after the closure was taken for each type of surrounding street using Python. Based on these bar charts, one can immediately see whether there has been an increase or decrease in the traffic flow. The code used to create these charts can be found in Appendix C.

4.2 Data Collection for Traffic Crashes

To determine the extent to which the closure of the Hoefkade in The Hague has influenced the number of traffic crashes in the surrounding streets, the number of traffic crashes in those streets is needed. This number must be known at two different times, namely before and after the closure of the Hoefkade.

The online source STAR, Smart Traffic Accident Reporting, was used. This is a Dutch website that shows all traffic crashes that have occurred in the Netherlands since 2019. For consistency, the same segments released by the municipality of The Hague were used, as discussed in Section 4.1. With this, the second part of the third sub-question is answered, namely "*For which streets in the vicinity of the bollards are data available regarding the number of traffic crashes?*" For each segment, the number of traffic crashes that occurred on that segment and the year in which they happened were reviewed. The years before and after the closure of the Hoefkade in 2020 were considered, specifically in 2019 and 2021. These years were chosen for consistency since the traffic flows were also given for those years.

In Appendix B, Table XI can be found. In this Table, the 41 segments are again listed with their numbering. The first seven columns of Table XI are identical to those of Table X, and the numbering corresponds with Figure 3. Additionally, the average number of traffic crashes before and after the closure of the Hoefkade is shown in Table XI (Smart Traffic Accident Reporting, 2024). Moreover, the absolute and relative differences were calculated using Python. Segment 5 will also not be included for the analyses for the number of traffic crashes. Additionally, just like in Section 4.1, seven different bar charts have been created, each representing a type of surrounding street, which is shown in Figure 5. An average of the number of traffic crashes before and after the closure was taken for each type of surrounding street using Python. Based on these bar charts, one can immediately see whether there is an increase or decrease. The code used to create these charts can be found in Appendix C.

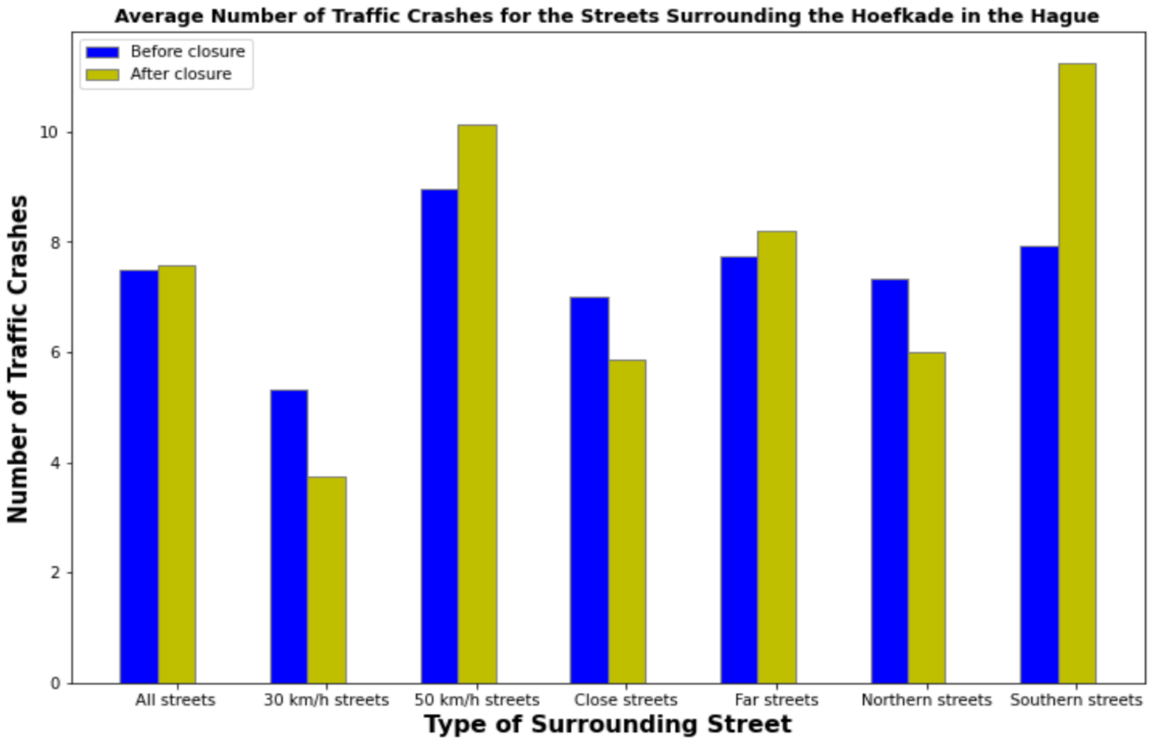

Figure 5. Average number of traffic crashes before and after the closure of the Hoefkade per type of surrounding street (Smart Traffic Accident Reporting, 2024)

5. Data Analysis

In this Chapter, the collected data will be analysed. The Chapter begins with a comparative analysis, followed by a correlation analysis. Finally, a spatial analysis will be conducted.

5.1 Comparative Analysis

This Section will answer the fourth sub-question, namely "*How have the traffic flow and the number of traffic crashes in the surrounding streets changed after the closure of the Hoefkade?*", through a comparative analysis. This will be conducted by first performing statistical tests, followed by calculating the effect size. The aim of the comparative analysis is to determine if there is a significant difference between the average traffic flow and the average number of traffic crashes before and after the closure of the Hoefkade in the surrounding streets. In Section 3.4.1, a step-by-step explanation is provided, supported by academic articles, on how this analysis can be correctly conducted.

5.1.1 Statistical Tests

The comparative analysis begins with performing the parametric paired t-test. First, it should be proven that the distribution of the absolute differences in the average traffic flow and the number of traffic crashes is normally distributed, as discussed in Section 3.4.1.1. The Python "scipy.stats.shapiro" function is applied twice: the first time for the traffic flow and the second time for traffic crashes. The output of this function is the p-value, which in this case is $p = 0.851$ and $p = 0.0953$, respectively. Both values are larger than the significance level of 0.05, so it has been proven that the distribution of the absolute differences is normal. Now it has been proven that requirement four is met, so the the paired t-test can be used. The Python code used in Section 5.1 can be found in Appendix D. First, the statistical tests for the traffic flows will be calculated, followed by those for the traffic crashes.

5.1.1.1 Statistical Tests for Traffic Flow

In this Section, statistical tests for the traffic flows will be performed. First, it will be determined whether there is a significant difference between the average traffic flow before and after the closure of the Hoefkade for all surrounding streets. This will be done using the paired t-test. In Section 3.4.1.1, the hypotheses of the paired t-test have already been mentioned, but they are repeated here as they are crucial. There are two hypotheses in the paired t-test:

1) The null hypothesis H_0: There is no significant difference between the average traffic flow before and after the closure of the Hoefkade in the surrounding streets. This means $\mu_D = 0$.
2) The alternative hypothesis H_1 : There is a significant difference between the average traffic flow before and after the closure of the Hoefkade in the surrounding streets. This means $\mu_D \neq 0$.

The mean, standard deviation, and sample size of the array with absolute differences need to be calculated. This has been done using Python, and the results are $\bar{D} = -1060.825$, $\sigma_D = 3347.193$ and $n = 40$. This information should be used to fill in Equation (1).

$$T = \frac{\bar{D}}{\frac{\sigma_D}{\sqrt{n}}} = \frac{-1060.825}{\frac{3347.193}{\sqrt{40}}} = -2.004$$

The obtained T-value of -2.004 lies between -2.023 and 2.023, so the alternative hypothesis is rejected. Therefore, the null hypothesis is accepted, and it is concluded that there is no significant difference between the average traffic flows before and after the closure of the Hoefkade in the surrounding streets.

Furthermore, three distinctions have been made in this study where the paired t-test cannot be used, as discussed in Section 3.4.1.1. The Wilcoxon signed rank test can be used, and its hypotheses are the same as those of the paired t-test, as noted above. In Python, the output of the "scipy.stats.wilcoxon" function is the p-value. If the p-value obtained is smaller than the chosen significance level of 0.05, the null hypothesis is rejected. Therefore, the alternative hypothesis is accepted, and it is concluded that there is a significant difference between the average traffic flow before and after the closure of the Hoefkade for the type of surrounding street.

In Table III, the p-values for each type of surrounding street for traffic flow can be found. These p-values have been compared to the significance level of 0.05, after which it was concluded whether there was a significant difference. Furthermore, the "Change" column in the Table indicates whether there has been an increase or decrease in the average traffic flow. This has been determined using Figure 4, where the bar charts clearly show whether the average traffic flow has increased after the closure of the Hoefkade. The Table shows that all types of surrounding street have had a significant difference, except for the 50 km/h streets and the streets that are far from the Hoefkade. Therefore, it can be concluded that there is a significant difference in the average traffic flow before and after the closure of the Hoefkade for the 30 km/h streets, streets close to the Hoefkade and the streets north of the railway tracks of HS station, resulting in less traffic on these streets. However, there is a significant difference in the average traffic flow before and after the closure of the Hoefkade for the streets south of the railway tracks of HS station, resulting in more traffic on these streets.

Table III

p-values of every type of surrounding street for traffic flow

Type of Surrounding Street	**Change**	***p***	**Hypotheses**
30 km/h streets	Decrease	0.00269	Significant difference
50 km/h streets	Decrease	0.726	No significant difference
Streets close to the Hoefkade	Decrease	0.0134	Significant difference
Streets far from the Hoefkade	Decrease	0.456	No significant difference
Streets north of the railway tracks of HS station	Decrease	0.0000613	Significant difference
Streets south of the railway tracks of HS station	Increase	0.00146	Significant difference

5.1.1.2 Statistical Tests for Traffic Crashes

In this Section, statistical tests are conducted for the number of traffic crashes. This is done in the same way as in Section 5.1.1.1, but with different values and slightly different hypotheses. Furthermore, the hypotheses are as follows:

1) The null hypothesis H_0: There is no significant difference between the average number of traffic crashes before and after the closure of the Hoefkade in the surrounding streets. This means $\mu_D = 0$.
2) The alternative hypothesis H_1 : There is a significant difference between the average number of traffic crashes before and after the closure of the Hoefkade in the surrounding streets. This means $\mu_D \neq 0$.

The mean, standard deviation, and sample size of the array with absolute differences need to be calculated. This has been done using Python, and the results are $\overline{D} = 0.075$, $\sigma_D = 3.771$ and n = 40. This information should be used to fill in Equation (1).

$$T = \frac{\bar{D}}{\frac{\sigma_D}{\sqrt{n}}} = \frac{0.075}{\frac{3.771}{\sqrt{40}}} = 0.126$$

The obtained T-value of 0.126 lies between -2.023 and 2.023, so the null hypothesis is accepted. Therefore, the alternative hypothesis is rejected, and it is concluded that there is no significant difference between the average number of traffic crashes before and after the closure of the Hoefkade in the surrounding streets.

Once again, as in Section 5.1.1.1, three distinctions have been made. Furthermore, the hypotheses of the Wilcoxon signed rank test are exactly the same as those of the paired t-test mentioned above. In Table IV, the p-values for each type of surrounding street for traffic crashes can be found. This Table is structured the same as Table III. The “Change” column again indicates whether there has been an increase or decrease in the average number of traffic crashes, which has been determined using Figure 5. The Table shows that there is no significant difference for any type of surrounding street, except for the streets south of the railway tracks of The Hague HS station. Therefore, it can be concluded that there is a significant difference in the average number of traffic crashes before and after the closure of the Hoefkade in the streets south of the railway tracks of The Hague HS station, resulting in more traffic crashes in these streets.

Table IV

p-values of every type of surrounding street for traffic crashes

Type of Surrounding Street	Change	p	Hypotheses
30 km/h streets	Decrease	0.0746	No significant difference
50 km/h streets	Increase	0.108	No significant difference
Streets close to the Hoefkade	Decrease	0.418	No significant difference
Streets far from the Hoefkade	Increase	0.457	No significant difference
Streets north of the railway tracks of HS station	Decrease	0.0802	No significant difference
Streets south of the railway tracks of HS station	Increase	0.00312	Significant difference

5.1.2 Effect Size

After conducting the statistical tests, the effect size can be calculated. In Section 3.4.1.2, the importance of this effect size and why calculating this value is important has already been discussed. First, the effect size for the traffic flows will be calculated, followed by the calculation for the traffic crashes.

5.1.2.1 Effect Size for Traffic Flow

In this Section, Cohen’s d-value is calculated for the average traffic flow. There are two groups: Group 1, which is the average traffic flow before the closure, and group 2, which is the average traffic flow after the closure of the Hoefkade.

First, the value is calculated overall. To calculate Cohen’s d-value for the entire dataset, Equation (3) must be filled in first using Python, and the result is $\sigma_{pooled} = 10184.359$. In addition to the calculated pooled standard deviation, the mean of groups 1 and 2 is also needed. This is again calculated using Python, and the results are $M_1 = 12228.125$ and $M_2 = 11167.300$. Filling this in Equation (2) gives the Cohen's d-value.

$$d = \frac{M_1 - M_2}{\sigma_{pooled}} = \frac{12228.125 - 11167.300}{10184.359} = 0.104$$

In Table I, Cohen's Standard can then be read. The obtained d-value is less than 0.5, so it can be concluded that the closure of the Hoefkade had a 'small' effect on the average traffic flow in the surrounding streets.

For calculating the other six effect sizes, the exact same method as described above is used, but this is all done in Python. The outcomes are shown in Table V. In this Table, each type of surrounding street is listed with the corresponding calculated d-value. Based on Table I, Cohen's Standard can then be determined. Table V shows that the closure of the Hoefkade had a 'small' effect on the average traffic flow for all types of surrounding streets, except for the 30 km/h streets. For these streets, the road closure had a 'large' effect on the average traffic flow.

Table V

d-values of every type of surrounding street for traffic flow

Type of Surrounding Street	*d*	Cohen's Standard
30 km/h streets	0.843	Large
50 km/h streets	0.0497	Small
Streets close to the Hoefkade	0.214	Small
Streets far from the Hoefkade	0.0685	Small
Streets north of the railway tracks of HS station	0.313	Small
Streets south of the railway tracks of HS station	-0.268	Small

5.1.2.2 Effect Size for Traffic Crashes

In this section, Cohen's d-value is calculated for traffic crashes. This is done in the same way as in Section 5.1.2.1, but with different values. To calculate Cohen's d-value, Equation (3) should first be filled in using Python, and the result is $\sigma_{pooled} = 6.342$. In addition to the calculated pooled standard deviation, the mean of group 1 and 2 is also needed. This is again calculated using Python, and the outcome is $M_1 = 7.500$ and $M_2 = 7.575$. Filling these into Equation (2) gives the Cohen's d-value.

$$d = \frac{M_1 - M_2}{\sigma_{pooled}} = \frac{7.500 - 7.575}{6.342} = -0.0118$$

In Table I, Cohen's Standard can then be read. The absolute obtained d-value is less than 0.5, so it can be concluded that the closure of the Hoefkade had a 'small' effect on the average number of traffic crashes in the surrounding streets.

For calculating the other six effect sizes, the exact same method as described above is used, but this is all done in Python. The outcomes are shown in Table VI. In this Table, each type of surrounding street is listed with the corresponding calculated d-value. Based on Table I, Cohen's Standard can then be determined. Table VI shows that the closure of the Hoefkade had a 'small' effect on the average number of traffic crashes for all types of surrounding streets, except for the streets south of the railway track of The Hague HS station. For these streets, the road closure had a 'medium' effect on the average number of traffic crashes.

Table VI

d-values of every type of surrounding street for traffic crashes

Type of Surrounding Street	*d*	Cohen's Standard
30 km/h streets	0.274	Small
50 km/h streets	-0.198	Small
Streets close to the Hoefkade	0.189	Small
Streets far from the Hoefkade	-0.0692	Small
Streets north of the railway tracks of HS station	0.207	Small
Streets south of the railway tracks of HS station	-0.618	Medium

5.2 Correlation Analysis

In this Section, correlation analysis will be conducted. This analysis determines the correlation between the average traffic flow and the number of traffic crashes before and after the closure of the Hoefkade. This analysis will be carried out using Python. The code used in this Section can be found in Appendix E. In Section 3.4.2, a step-by-step explanation is provided, supported by academic articles, on how this analysis can be correctly conducted. First, the correlation analysis will be conducted with the entire dataset, after which it will be done only for the 30 km/h streets, the 50 km/h streets, the streets close to the Hoefkade and those far from it, the street north of the railway tracks of The Hague Hollands Spoor station and those south of it.

To perform the correlation analysis, Spearman's rank correlation coefficient should first be calculated. The Spearman's rank correlation coefficient before the closure of the Hoefkade is 0.495, with p = 0.00118. The Spearman's rank correlation coefficient after the closure of the Hoefkade is 0.541, with p = 0.000312. Interpreting the Spearman's rank correlation coefficient is done using Table II. Both correlation coefficients fall between +0.3 and +0.6, indicating a 'fair' correlation. It can be concluded that the correlation between the average traffic flow and the number of traffic crashes, both before and after the closure of the Hoefkade, is 'fair' in the surrounding streets.

It is also necessary to determine if the corresponding p-values are statistically significant. There are two hypotheses here that were discussed earlier in Section 3.4.2, but they are repeated here as they are crucial:

1) The null hypothesis H_0: There is no significant correlation between the average traffic flow and the number of traffic crashes.
2) The alternative hypothesis H_1: There is a significant correlation between the average traffic flow and the number of traffic crashes.

Both p-values are smaller than the significance level of 0.05, as the p-value before the closure is 0.00118 and after the closure is 0.000312. This means that the null hypothesis is rejected, and it can be concluded that there is a significant 'fair' correlation between the traffic flow and the average number of traffic crashes, both before and after the closure of the Hoefkade, in the surrounding streets.

Furthermore, using Fisher's z-transformation, it can be calculated whether the difference in correlation coefficients is significant after the closure of the Hoefkade. This transformation also has two hypotheses:

1) The null hypothesis H_0: There is no significant difference between the correlation coefficients before and after the closure of the Hoefkade.
2) The alternative hypothesis H_1: There is a significant difference between the two correlation coefficients before and after the closure of the Hoefkade.

The z-values of the first and second Spearman's rank correlation coefficients and their standard deviations are needed. These values can be obtained by filling in Equations (4) and (5) using Python. The outcomes are $z_1 = 0.542$, $z_2 = 0.606$ and $\sigma_{z_1} = \sigma_{z_2} = 0.160$. Then, Equation (6) should be filled in.

$$Z = \frac{z_1 - z_2}{\sqrt{{\sigma_{z_1}}^2 + {\sigma_{z_2}}^2}} = \frac{0.542 - 0.606}{\sqrt{0.160^2 + 0.160^2}} = -0.281$$

This Z-value falls between -1.96 and 1.96, so the alternative hypothesis is rejected. Therefore, there is no significant difference between the correlation coefficients before and after the closure of the Hoefkade in the surrounding streets.

The above process is repeated six times using Python. Table VII presents the Spearman's correlation coefficient ρ between the average traffic flow and the number of traffic crashes for each type of surrounding street before the closure of the Hoefkade. This coefficient is interpreted using Table II. Additionally, the p-value is shown for each type of surrounding street to determine whether it is statistically significant. From Table VII, it can be concluded that there is no significant correlation between the average traffic flow and the number of traffic crashes for the 50 km/h streets, streets close to the Hoefkade, and streets south of the railway tracks of The Hague HS station, before the closure of the Hoefkade. Therefore, the value of the correlation in these streets is purely coincidental, and other factors may play a role. However, it can be concluded that there is a significant 'moderately strong' correlation between the average traffic flow and the number of traffic crashes in the 30 km/h streets and streets north of the railway tracks of The Hague HS station, and there is a significant 'fair' correlation in the streets far from the Hoefkade, before the closure of the Hoefkade.

Table VII

Spearman's correlation coefficient before the closure of the Hoefkade per type of surrounding street

Type of Surrounding Street	**Spearman's correlation coefficient ρ before**	**Interpretation**	***p***	**Statistically**
30 km/h streets	0.661	Moderately strong	0.00528	significant
50 km/h streets	0.221	Poor	0.300	Not significant
Streets close to the Hoefkade	0.474	Fair	0.101	Not significant
Streets far from the Hoefkade	0.413	Fair	0.0322	Significant
Streets north of the railway tracks of HS station	0.677	Moderately strong	0.0000771	Significant
Streets south of the railway tracks of HS station	-0.106	Poor	0.744	Not significant

Table VIII is structured the same as Table VII. However, in Table VIII, the Spearman's correlation coefficient after the closure of the Hoefkade is presented. It can be concluded that there is no significant correlation in the 30 km/h streets, 50 km/h streets, and the streets south of the railway tracks of The Hague HS station after the closure of the Hoefkade. Therefore, the value of the correlation in these streets is purely coincidental, and other factors may play a role. However, it can be concluded that there is a significant 'fair' correlation between the average traffic flow and the number of traffic crashes in the streets far from the Hoefkade and the streets north of the railway tracks of The Hague HS station, and a significant 'moderately strong' correlation in the streets close to the Hoefkade, after the closure.

Table VIII

Spearman's correlation coefficient after the closure of the Hoefkade per type of surrounding street

Type of Surrounding Street	Spearman's correlation coefficient *ρ* after	Interpretation	*p*	Statistically
30 km/h streets	0.287	Poor	0.281	Not significant
50 km/h streets	0.343	Fair	0.101	Not significant
Streets close to the Hoefkade	0.621	Moderately strong	0.0236	Significant
Streets far from the Hoefkade	0.477	Fair	0.012	Significant
Streets north of the railway tracks of HS station	0.574	Fair	0.00139	Significant
Streets south of the railway tracks of HS station	-0.179	Poor	0.578	Not significant

Furthermore, using Fisher's z-transformation, it can be determined whether the difference in Spearman's correlation coefficients is significant. Equation (6) is applied using Python, and the results are shown in Table IX. If the obtained *Z*-value falls between -1.96 and 1.96, there is no significant difference. As shown in Table IX, none of the correlation coefficients had a significant change after the closure of the Hoefkade.

Table IX

Z-values per type of surrounding street

Type of Surrounding Street	*Z*	Hypotheses
30 km/h streets	1.369	No significant difference
50 km/h streets	-0.451	No significant difference
Streets close to the Hoefkade	-0.515	No significant difference
Streets far from the Hoefkade	-0.285	No significant difference
Streets north of the railway tracks of HS station	0.620	No significant difference
Streets south of the railway tracks of HS station	0.176	No significant difference

5.3 Spatial Analysis

This Section will answer the fourth sub-question, namely "*How have the traffic flow and the number of traffic crashes in the surrounding streets changed after the closure of the Hoefkade?*", through a spatial analysis. Two maps were created using OpenStreetMap and Microsoft Paint. In Section 3.4.3, the process for performing this analysis is explained.

Figure 6 shows the first map that was created. This map shows the absolute difference in motorised traffic flows in vehicles per day per segment using two different colours and line thicknesses. The segments coloured red indicate an increase in traffic after the closure of the Hoefkade, whereas the segments coloured green indicate a decrease in traffic. Additionally, the line thicknesses represent the absolute difference. The numbers next to the lines indicate the absolute difference in vehicles per day between the traffic flows before and after the closure of the Hoefkade. In Appendix F, an enlarged version of Figure 6 can be found.

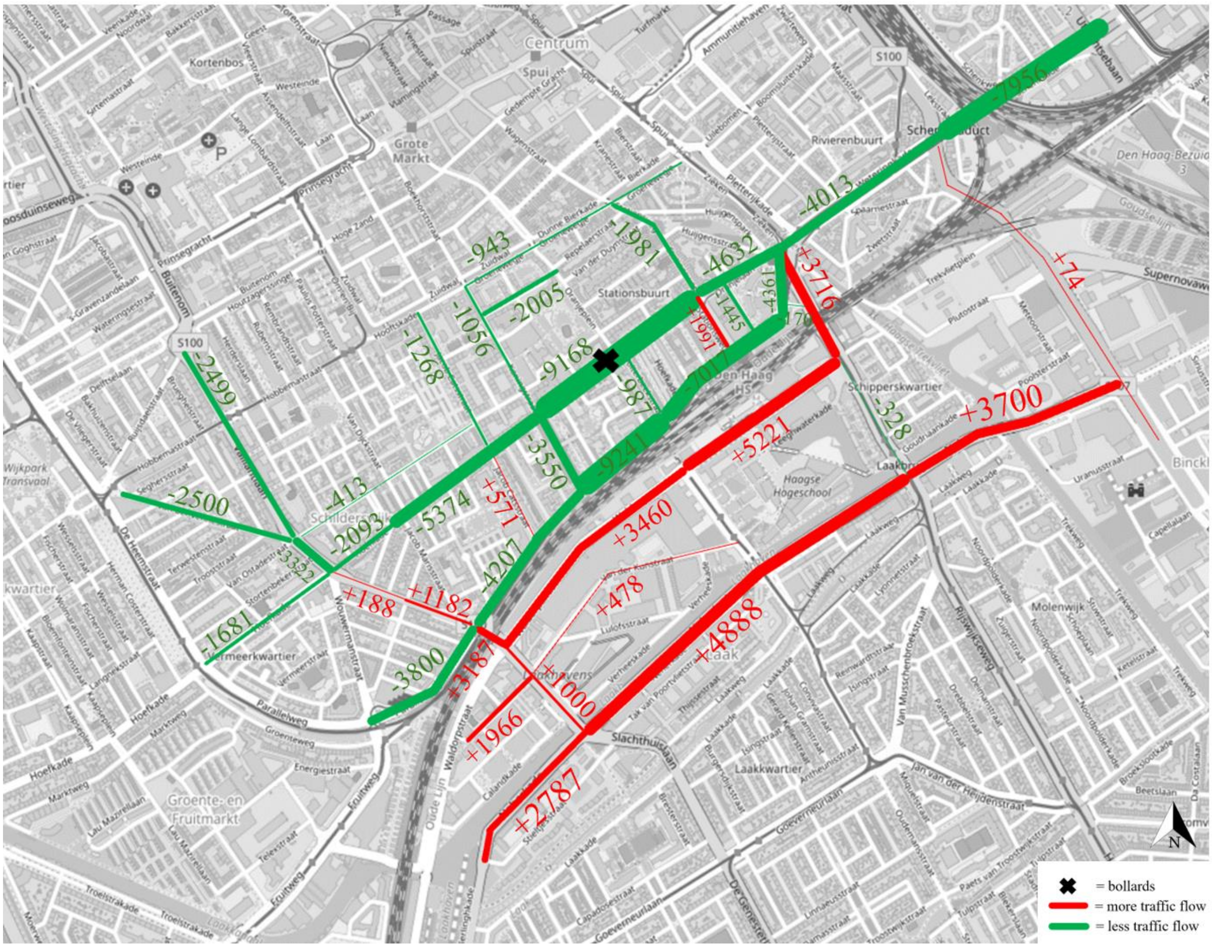

Figure 6. Absolute difference in motorised traffic flows in vehicles per day per segment (OpenStreetMap, 2024)

Figure 7 shows the second map that was created. This map shows the absolute difference in number of traffic crashes per segment using the colours, green and red, and line thicknesses. The segments coloured in red indicate an increase in traffic crashes after the closure of the Hoefkade, whereas the segments coloured in green indicate a decrease in traffic crashes. Additionally, the line thicknesses represent the absolute difference. The numbers next to the lines indicate the absolute difference between the number of crashes before and after the closure of the Hoefkade. In Appendix G, an enlarged version of Figure 7 can be found.

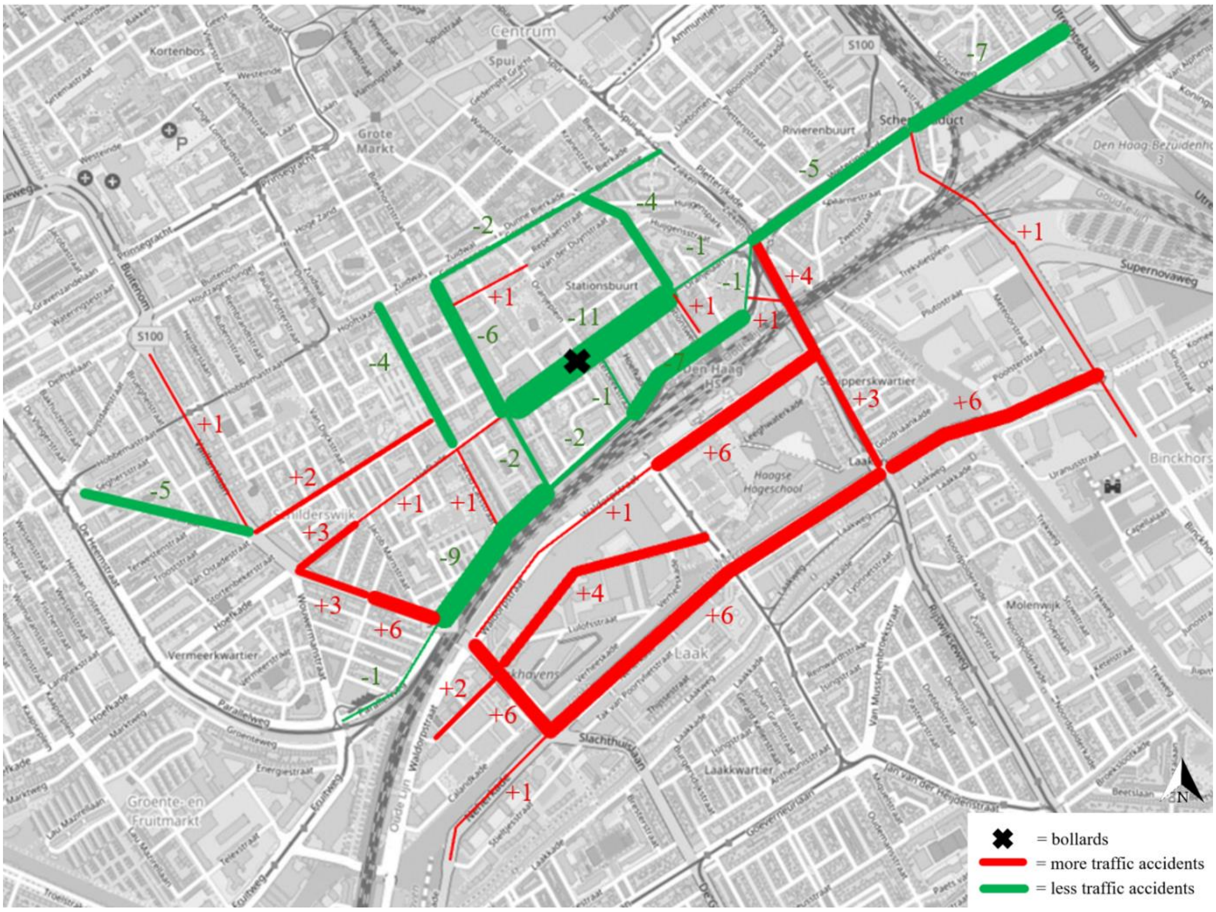

Figure 7. Absolute difference in traffic crashes per segment (OpenStreetMap, 2024)

6. Discussion

In this Chapter, the results of the comparative, correlation, and spatial analyses will be combined to gain a comprehensive understanding of the effect of the closure of the Hoefkade on traffic flows and the number of traffic crashes. First, the findings from the data analyses conducted in Chapter 5 will be presented, followed by an evaluation of the objectives of the municipality of The Hague. The Chapter ends with lessons for future similar projects.

6.1 Findings from Data Analyses

In this Section, the findings for the traffic flow will be discussed first, followed by the findings for the traffic crashes.

6.1.1 Findings for Traffic Flow

The comparative analysis shows that there is no significant difference between the traffic flows before and after the closure of the Hoefkade in the surrounding streets. However, when distinguishing the streets, the same analysis shows that there are significant differences among them. The lack of a significant difference for the entire dataset can be seen in the spatial analysis. Figure 6 shows that some streets had an increase in traffic while others had a decrease after the closure of the Hoefkade. These changes perhaps balance each other out, resulting in no significant difference. Furthermore, a calculation in Section 5.1.1.1 shows that the T-value is equal to -2.004. If this value was 0.019 smaller, there would have been a significant difference between the traffic flows before and after the closure in the surrounding streets. This small difference suggests that the closure of the Hoefkade did indeed lead to significant changes in traffic flows in the surrounding streets.

The comparative analysis shows that some streets had a significant decrease, whereas other streets had a significant increase. The 30 km/h streets had a significant decrease. This means that these streets had less traffic compared to before the closure of the Hoefkade. According to Cohen's Standard, the closure of the Hoefkade had a 'large' effect on the traffic flows in these streets, resulting in less traffic. Furthermore, the streets close to the Hoefkade, meaning all streets intersecting the Hoefkade, had a significant decrease in traffic flows. Additionally, all streets north of the railway tracks of The Hague Hollands Spoor station also had a significant decrease. The streets close to the Hoefkade and the 30 km/h streets are all located north of the railway tracks of The Hague HS station. Moreover, all streets north of the railway tracks are in the Schilderswijk and Stationsbuurt. On the other hand, the streets south of the railway tracks of The Hague HS station, in Laak, had a significant increase in traffic flows. According to Cohen's Standard, the closure of the Hoefkade had a 'small' effect on the traffic flows in all these streets. The spatial analysis supports these results as well. Figure 6 shows that, with the exception of four segments, all 24 segments north of the railway tracks are green, indicating less traffic after the closure of the Hoefkade. Additionally, with the exception of one segment, all 11 segments south of the railway tracks are red, indicating more traffic after the closure of the Hoefkade.

The decrease in traffic north of the railway tracks and the increase in traffic south of the railway tracks may be a result of the closure of the Hoefkade. The municipality of The Hague had indicated that through traffic between the Schilderswijk and Stationsbuurt should use Neherkade after the closure (Omroep West, 2020). The Neherkade corresponds to the segments 14, 15, and 16 and is located in Laak, and as shown clearly in Figure 3, this street is situated south of the railway tracks of The Hague HS station. The shift in traffic is also confirmed by business owners in the Schilderswijk, who reported that their delivery drivers now predominantly use Neherkade to reach the Schilderswijk after the closure of the Hoefkade (van Bree, 2024). This all suggests that traffic is shifting from the Schilderswijk and Stationsbuurt to Laak. This indicates a shift to alternative routes, showing that traffic was redistributed.

However, there can be multiple reasons why traffic in the Schilderswijk and Stationsbuurt has decreased and increased in Laak. This report will mention two other reasons: roadworks and the placement of speed cameras. Starting with the roadworks. In 2021, there were several roadworks north of the railway tracks of The Hague HS station (Gemeente Den Haag, 2021). Note that the year 2021 is the year used in this study for data after the closure of the Hoefkade. Parallelweg was one of the streets with roadworks, which corresponds to segments 18, 19, and 20. Van der Vennestraat, segment 35, also had roadworks. Figure 3 shows that these segments are located north of the railway tracks of The Hague HS station. Both roadworks took place during the summer, and both motorized and non-motorized traffic could not use these streets due to asphalt replacement (Schilderswijk, 2021). According to Walker and Calvert (2015), drivers react differently to roadworks. One way they may respond is by finding alternative routes to avoid the roadworks. In this case, the roadworks north of the railway tracks might discourage traffic from passing through these neighbourhoods, redirecting it to the south. For this reason, traffic in the Schilderswijk and Stationsbuurt could decrease, while traffic in Laak could increase.

Additionally, in 2021, a total of four new speed cameras were installed on the Vaillantlaan, which is segments 29, 30, 31, and 32, north of the railway tracks of The Hague HS station (van Koesveld, 2021). The Vaillantlaan is a 50 km/h street where drivers frequently exceeded the speed limit (van Dijk, 2021b). By installing the speed cameras, the municipality of The Hague wants drivers to adhere to the maximum traffic speed and reduce the traffic speed. Hosking et al. (2023) studied the effect of speed limit reductions on traffic flows in some streets in Tamaki Makaurau Auckland, New Zealand. Their research shows that a speed limit reduction does indeed result in less traffic. In this case, although there was not a speed limit reduction, the traffic speed at this location decreased due to the speed cameras. No specific research has been conducted, to our knowledge, on the effect of speed cameras on traffic flows. However, it is possible that drivers want to take alternative routes to avoid fines, resulting in a decrease in traffic on the Vaillantlaan and surrounding streets in the Schilderswijk, and an increase in traffic flows south of the railway tracks. These factors could also contribute to the changes in traffic flows.

6.1.2 Findings for Traffic Crashes

In Figure 5, it can be seen that the number of traffic crashes in the surrounding streets had a small increase after the closure of the Hoefkade. However, the comparative analysis shows that this increase is not significant. Furthermore, the comparative analysis shows that no type of surrounding street had a significant difference, except for the streets south of the railway tracks of The Hague HS station. These streets, in Laak, had a significant increase in the number of traffic crashes. According to Cohen's Standard, the closure of the Hoefkade had a 'medium' effect on the number of traffic crashes in these streets in Laak. The spatial analysis supports the comparative analysis once again. Figure 7 shows that all streets south of the railway tracks are red, indicating that more traffic crashes occurred in these streets after the closure of the Hoefkade.

The increase in traffic crashes may be related to the increase in traffic flow. The correlation analysis shows a significant 'fair' correlation between traffic flows and the number of traffic crashes, both before and after the closure of the Hoefkade in the surrounding streets. The correlation before and after the closure of the Hoefkade did not have a significant difference. Additionally, it was calculated whether there was a significant correlation for each type of surrounding street. After the closure of the Hoefkade, this was only the case for the streets far from the Hoefkade and the streets north of the railway tracks of The Hague HS station. However, all streets south of the railway tracks of The Hague HS station belong to the streets far from the Hoefkade. It can therefore be concluded that all streets have a significant 'fair' correlation between traffic flow and the number of traffic crashes. This correlation suggests that the increased traffic flow may have contributed to more traffic crashes. The spatial analysis supports these findings, as all streets that are red in Figure 6 are also red in Figure 7. This means that the streets with an increasing traffic flow also had an increase in the number of traffic crashes.

However, there can be multiple reasons why the number of traffic crashes in Laak significantly increased. This report will mention two other reasons: road maintenance and weather conditions. The municipality of The Hague started a multi-year road maintenance program in 2021. They are aware that the streets in The Hague need renovation and decided to take action from 2021 onwards. However, in 2021, there were no roadworks in Laak, but mainly in the Schilderswijk (Gemeente Den Haag, 2021). This might indicate that the streets in Laak were still in poor condition. Research by Sari and Yudhistira (2021) indicates that poor road conditions can result in an increase in traffic crashes. This could also be the case in the streets south of the railway tracks.

The increase in the number of traffic crashes in general can also be seasonal. Weather conditions such as snow or ice can cause an increase in traffic crashes. According to Theofilatos (2014), weather conditions influence the number of traffic negatively. In February 2021, there was a rare cold wave in the Netherlands after nine years without one (Regterschot, 2021). This cold wave can be the reason for an increase in traffic crashes. One example is a car that fell in the water on Neherkade due to slippery streets in February 2021, south of the railway tracks (van Dijk, 2021a). This also affected traffic safety.

6.2 Evaluation of Objectives of the Municipality of The Hague

In Chapter 1, it was mentioned that the municipality of The Hague closed the Hoefkade to motorised traffic to increase the attractiveness and traffic safety of the Hoefkade and to limit motorised traffic between the Schilderswijk and Stationsbuurt (Gemeente Den Haag, 2019c). Based on the data analyses, it can be determined whether these goals have been achieved.

The attractiveness of the Hoefkade was not measured in this report, but assumptions can be made based on academic and news articles. On one hand, the attractiveness of the Hoefkade improved due to the less traffic on the street, which can result in less air pollution and noise, which can positively impact human health and improve liveability (Khan, Ketzel, Kakosimos, Sorensen, & Jensen, 2018). All of this creates a better environment for the residents, pedestrians and cyclists on the Hoefkade. However, the attractiveness for entrepreneurs on the Hoefkade has decreased. As discussed in Section 1.3, the turnover of various entrepreneurs on the Hoefkade has drastically declined (Rubio, 2021). This indicates that attractiveness also decreased. Therefore, there are two sides to this part, and it cannot be concluded whether this goal has been achieved.

In Figure 7, it can be seen that segments 6 and 7 of the Hoefkade had an increase in traffic crashes after the closure. The comparative analysis shows that this difference is not significant. However, this indicates that there was no improvement in traffic safety on the Hoefkade despite the significant decrease in traffic flows. One of the reasons that more traffic crashes occur has already been mentioned in Section 6.1.2, namely due to weather conditions. Additionally, the behaviour of the driver plays a crucial role in traffic safety (Farooq, Moslem, & Duleba, 2019). Predicting driver behaviour is hard since everyone behaves differently. However, some drivers may exceed the speed limit since there are fewer cars on the road, leading to more traffic crashes as other vehicles from side streets do not anticipate this. Furthermore, drivers might show reckless behaviour as they disagree with the closure of the Hoefkade (Rubio, 2020a). All these factors can result in traffic safety not improving on the Hoefkade after the closure. Thus, this goal has not been achieved.

The third goal is to limit motorised traffic between the Schilderswijk and Stationsbuurt. As discussed in Section 6.1.1, traffic in the Schilderswijk and Stationsbuurt has significantly decreased. This can also be seen in Figure 6, where only four of the 28 segments north of the railway tracks of The Hague HS station are red. This means that the municipality of The Hague has achieved this goal.

In conclusion, the goals of the closure of the Hoefkade have been partially achieved. The attractiveness and traffic safety of the Hoefkade have not increased after the closure, but motorised traffic between the Schilderswijk and Stationsbuurt has significantly decreased. This indicates that the problem on the

Hoefkade has not been resolved, and other measures need to be taken to improve traffic safety. Furthermore, the issue of motorised traffic has been resolved on the Hoefkade, but the problem has shifted to another location, namely Laak. It could be that policymakers only wanted to remove the problem from the Hoefkade, so shifting it to another location might not be a concern and was possibly expected. However, the responsible councillor, Robert van Asten, aims to reduce traffic throughout the entire city, including Laak (Rubio, 2020b). This report shows that the municipality of The Hague needs to implement other traffic measures to achieve this goal and to address the issues related to traffic flows and traffic safety.

6.3 Lessons for Future Similar Projects

This report shows findings which policymakers can learn from for future similar projects. The following paragraphs will outline five lessons. With this, the fifth sub-question will be answered, namely "*What are the key lessons that can be learned from the analyses of the Hoefkade closure?*"

Starting with the lessons that can be learned from the redistribution of traffic. The findings show that traffic in the Schilderswijk and Stationsbuurt has significantly decreased, whereas it increased in Laak. The closure of the Hoefkade can be a reason for this, since traffic that used to go through the Schilderswijk and Stationsbuurt perhaps found an alternative route in Laak. Increasing traffic can lead to new congestion problems, causing travel times to increase (Pi, Yeon, Son, & Jang, 2021). Furthermore, more traffic can result in safety risks, both in terms of traffic safety and the negative health impacts (Kim et al., 2004). Policymakers must take into account the possible traffic shift due to a road closure. They should make sure that there are enough alternative routes that have the capacity for the additional traffic. Furthermore, they should be aware that the problems need to be solved and not moved to another location, which is what happened in The Hague. It is essential to use traffic models and simulations to predict the traffic shifts. In Section 2.2, it was discussed that researchers Osogami, Mizuta, and Idé (2013) used a simulation before the road closure in Hiroshima to determine which road could be best closed to minimise the impact on surrounding streets. This is an ideal way to easily map and understand the traffic shifts. Policymakers can then take measures to manage and regulate traffic. There are many different measures, but this report highlights three that have been researched and proven effective:

1) Using a system that efficiently controls traffic lights with the help of a Wireless Sensor Network (WSN) can improve and regulate traffic flow. This system is adaptive and adjusts to traffic conditions at intersections. It has been shown to be effective in solving traffic congestion (Yousef, Al-Karaki, & Shatnawi, 2010).
2) Providing multiple alternative routes helps in regulating traffic flows. Algorithms have been developed to ensure that not every driver is directed to the same alternative route on their GPS. This way, not all drivers use the same route, which distributes the traffic across multiple streets (Faro, & Giordano, 2016).
3) Promoting shared transportation and other modes of transport, such as bicycles, can help manage traffic and significantly reduce congestion. Policymakers can encourage this through public campaigns, meetings, or billboards (Alisoltani, Leclercq, & Zargayouna, 2021).

In summary, policymakers should use traffic models and simulations to predict traffic before implementing a road closure to take measures to manage and regulate traffic.

One of the most important lessons from this study is about traffic safety. The findings of this study show that traffic safety on the Hoefkade and surrounding streets has not improved, and in Laak it has even significantly deteriorated. The closure of the Hoefkade can be a reason for this, since there was an increase in traffic in Laak after the road closure. However, the behaviour of the drivers could also play a role in traffic safety. This shows that policymakers need to consider the redistribution of traffic when planning road closures. They should be aware that alternative routes can become busier and drivers may behave differently (Farooq et al., 2019). In addition to regulating traffic flows, which was discussed in the previous paragraph, additional measures to ensure traffic safety are essential. There are many different measures, but the following five have been previously researched:

1) Better street lighting can improve the safety of road users as it increases visibility, especially at night. Better street lighting can result in fewer traffic crashes (Bullough, Donnel, & Rea, 2013).
2) Ensuring drivers adhere to speed limits can reduce traffic crashes. According to Mohan, Bangdiwala, and Villaveces (2017), this can be achieved by narrowing streets, or by placing speed bumps (Antic, Pesic, Vujanic, & Lipovac, 2013).
3) Placing warning signs at dangerous intersections can help reduce the number of traffic crashes by alerting drivers to the danger zone (Jorgensen, & Larsen, 1999).
4) Increased police presence and enforcement, including camera systems, can help make a neighbourhood safer as drivers are more likely to adhere to traffic rules. This reduces dangerous driver behaviour and traffic crashes (Wang, Xu, & Fan, 2020).
5) Creating awareness campaigns to inform drivers about safe driving behaviour and the dangers of traffic violations can result in fewer traffic crashes (Hung, & Huyen, 2011).

In conclusion, policymakers should consider traffic safety in the neighbourhood when planning a road closure by implementing measures to minimise risks.

There was no extensive traffic analysis conducted before or after the closure of the Hoefkade, as far as is known. For this reason, there was little to no insight into the effects of the closure of the Hoefkade on traffic flows and the number of traffic crashes on the surrounding streets. This report is the first study to investigate this, and valuable findings are discussed in Section 6.1. Some of these findings could have been known beforehand if a traffic analysis was conducted. In this way, certain of the above measures could already be implemented at the same time as the implementation of the closure of the Hoefkade to avoid certain negative consequences. For future similar projects, it is therefore crucial to conduct traffic analyses before the road closure to predict possible negative consequences, that can be improved beforehand. These analyses should not only look at the target area, but also at the surrounding streets. As discussed above, this can be done using traffic models and simulations to predict not only traffic flows but also other issues such as the number of traffic crashes. Policymakers should therefore conduct extensive traffic analyses before implementing a road closure to predict and address potential consequences.

However, traffic analyses should also be conducted after the implementation of a road closure. By comparing traffic data before and after the closure, policymakers can determine whether the road closure has been effective. Furthermore, they can analyse how traffic (safety) has changed and whether measures need to be taken. These analyses should be conducted frequently since traffic is never the same and constantly changes. This means there should be continuous monitoring of the traffic to quickly identify and address consequences of road closures. There are multiple traffic monitoring systems, such as traffic cameras, inductive loops, and using GPS data (Jain, Saini, & Mittal, 2019). Policymakers must be prepared to adjust measures based on the monitoring results. Policymakers should therefore constantly conduct traffic analyses after a road closure to know the consequences. By monitoring the traffic, policymakers can respond quickly to problems and make adjustments to minimise negative impact.

After the closure of the Hoefkade, there were several protests from the local community of the Schilderswijk, indicating a lack of involvement and communication with them (Mulder, 2021). Section 1.3 already discussed that the local community was not satisfied with the closure of the Hoefkade, as they experienced negative changes due to the road closure (Rubio, 2020a). Furthermore, the local community started a petition to lower the bollards when roadworks take place in the neighbourhood (van Reeken, 2023). This way, they wanted to make their voices heard, which were not listened to when the traffic policy was implemented. Policymakers can prevent this by involving the local community from the beginning of the process in any traffic decision that can be made. Policymakers must act ethically, by listening to the interests of all stakeholders and considering these interests when making a traffic decision. This can be done in various ways, such as organizing meetings. In Christchurch, New Zealand, a road was temporarily closed to motorised traffic in 2019 to subsequently ask the local community's opinion, which was then incorporated into the municipality's traffic decision (Kingham, Curl, & Banwell, 2020). This is another way to gain valuable insights and knowledge about the specific problems and needs in their environment. The local community's input can help identify negative consequences. Furthermore, the acceptance by the community can be increased. In summary, policymakers benefit from involving all stakeholders in the process of making a decision for a road closure.

7. Conclusions and Recommendations

In this Chapter, Section 7.1 will answer the first part of the research question, namely "*To what extent has the closure of the Hoefkade in The Hague affected traffic flows and the number of traffic crashes in the surrounding streets?*" Furthermore, the recommendations will be discussed, which answer the second part of the research question, namely "*What lessons can be learned for future similar projects?*"

7.1 Conclusions

The research into the effect of the closure of the Hoefkade on traffic flows and the number of traffic crashes in the surrounding streets has provided valuable insights. The closure of the Hoefkade did not lead to an overall significant difference in traffic flows in the surrounding streets, but there were local significant differences after the closure. The 30 km/h streets had a 'large' significant decrease, and the streets north of the railway tracks of The Hague Hollands Spoor (HS) station had a 'small' significant decrease, according to Cohen's Standard. Furthermore, the streets south of the railway tracks of The Hague HS station had a 'small' significant increase. This indicates a redistribution of traffic, with drivers using alternative routes. Traffic has shifted from the Schilderswijk and Stationsbuurt to Laak. However, multiple roadworks took place in the Schilderswijk and several speed cameras were installed there, which may also have resulted in the traffic shift.

After the closure of the Hoefkade, there was a small increase in the number of traffic crashes in the surrounding streets, but this increase was not significant, except for the streets south of the railway tracks of The Hague HS station, which are located in Laak. These streets had a 'medium' significant increase in the number of traffic crashes, according to Cohen's Standard. The increase in traffic crashes may be related to the increase in traffic flow, since there is a 'fair' correlation between these two according to Spearman's correlation coefficient. However, weather conditions and poor road conditions may also have played a role in the increase in the number of traffic crashes, meaning that not all changes can be directly linked with the closure of the Hoefkade.

The municipality of The Hague closed the Hoefkade to increase the attractiveness and traffic safety of the street and to limit motorised traffic between the Schilderswijk and Stationsbuurt. The attractiveness of the Hoefkade has partly improved for residents, pedestrians and cyclists due to less traffic, but has decreased for entrepreneurs due to declining turnovers. Traffic safety on the Hoefkade did not improve, despite less traffic, partly due to weather conditions and the dangerous behaviour of drivers. The limitation of motorised traffic between the Schilderswijk and Stationsbuurt was successful, with a significant decrease in traffic in these neighbourhoods.

In short, the closure of the Hoefkade has indeed had an effect on traffic flows and the number of traffic crashes in the surrounding streets. Traffic safety has not improved and the traffic flow problems that previously existed on the Hoefkade have now simply shifted to Laak. However, the responsible councillor of The Hague wants to reduce traffic throughout the entire city. This indicates that the problem has not been solved, and additional measures need to be taken to further improve the traffic flows and safety in The Hague.

7.2 Recommendations

The findings of this research have led to multiple lessons that can be useful for policymakers for future similar projects. These lessons can be recommended for policymakers as they can help develop more effective strategies for managing traffic flows and the number of traffic crashes during a road closure in the city centre.

It has become clear that the closure of the Hoefkade, among other things, has resulted in a redistribution of traffic in The Hague, resulting in more traffic in Laak. Increasing traffic can lead to new congestion problems and longer travel times, and traffic safety risks and negative health effects. Policymakers must consider the presence and capacity of alternative routes when planning a road closure to prevent shifting the traffic flow problems to another place. The use of traffic models and simulations can help predict traffic shifts and implement measures to regulate and manage traffic. Examples of measures are using adaptive traffic lights, providing multiple alternative routes, and encouraging shared transportation and other modes of transport.

Furthermore, the findings regarding traffic safety have shown that it has deteriorated in Laak. This may be due to the increase in traffic in that neighbourhood after the closure of the Hoefkade and the dangerous behaviour of drivers. Policymakers must consider the possible increase in traffic crashes on alternative routes when planning a road closure. Additional measures to ensure traffic safety are essential. Examples of measures are better street lighting, narrower streets and the installation of speed bumps to limit traffic speed, warning signs at dangerous intersections, increased police presence and enforcement, and awareness campaigns on safe driving behaviour.

It is important for policymakers to conduct extensive traffic analyses both before and after the implementation of a road closure. Before implementing a road closure, policymakers should conduct a traffic analysis that consider not only the target area but also the surrounding streets. This way, they can predict the changes in traffic and address potential consequences. After closing a road, it is crucial for policymakers to continuously monitor traffic using tools like traffic cameras or inductive loops. This information can be used for traffic analyses to determine whether the road closure has been effective, how traffic has changed, and whether measures need to be taken based on the monitoring results. The traffic analyses should be taken place on a regular basis.

Finally, it is essential to involve the local community in traffic implementation. After the closure of the Hoefkade, there were multiple protests from the local community of the Schilderswijk, indicating a lack of involvement and communication. Policymakers can prevent this by involving the local community from the beginning of the process in any traffic decisions. This can be done by organizing meetings, surveys, and gathering their opinions. Using the community's input can help identify negative consequences, increasing the acceptance of the road closure by the community.

In summary, policymakers should use traffic models and simulations to predict traffic shifts and address possible measures, ensure traffic safety by implementing additional measures, conduct extensive traffic analyses before and after road closures, and involve the local community in the process of making a decision for future similar projects. The research into the closure of the Hoefkade has provided these lessons. Furthermore, this study has been the beginning of filling the research gap on permanent road closures and their effect on traffic, specifically on traffic flows and the number of traffic crashes.

Appendix A: Data for Traffic Flow

The numbering of the segments is assigned based on street names, which are listed in alphabetical order in the "Street" column. For streets divided into multiple segments, the "Between" and "And" columns are filled in to indicate the streets between which the segment is located.

Table X

Average motorised traffic flows of 41 segments in The Hague (Gemeente Den Haag, 2022)

Num-ber	Street	Between	And	Distance	Location Relative to Station Den Haag HS	Traffic Speed [km/h]	Traffic Flow Before [vehicles/ day]	Traffic Flow After [vehicles/ day]	Absolute difference [vehicles/ day]	Relative difference [%]
1	Binkhorst-laan			Far	South	50	25039	25113	74	0.30
2	Caland-straat	Parallel weg	Waldorp-straat	Far	South	50	34802	37989	3187	9.16
3	Caland-straat	Waldorp-straat	Neher-kade	Far	South	50	19089	20089	1000	5.24
4	Groene-wegje			Far	North	30	1164	221	-943	-81.01
5	Hoefkade	Stations-weg	Koning-straat	-	North	30	9564	396	-9168	-95.86
6	Hoefkade	Koning-straat	Pieter Lastman-straat	Close	North	30	7727	2353	-5374	-69.55
7	Hoefkade	Pieter Lastman-straat	Vaillant-laan	Close	North	50	8255	6162	-2093	-25.35
8	Hoefkade	Vaillantlaan	Parallel-weg	Close	North	50	8635	6954	-1681	-19.47
9	Hofwijck-straat			Far	North	30	4054	3884	-170	-4.19
10	Jacob Catsstraat	Parallel weg	Hoefkade	Close	North	30	996	1567	571	57.33
11	Jacob Catsstraat	Hoefkade	Hoofts-kade	Close	North	30	3274	2006	-1268	-38.73
12	Koning-straat	Parallel weg	Hoefkade	Close	North	30	6620	3070	-3550	-53.63
13	Koning-straat	Hoefkade	Groene-wegje	Close	North	30	3145	2089	-1056	-33.58
14	Neherkade	Stieltjes-straat	Slachthuis-laan	Far	South	50	20856	23643	2787	13.36
15	Neherkade	Slachthuis-laan	Rijswijk-seweg	Far	South	50	30075	34963	4888	16.25
16	Neherkade	Rijswijkse-weg	Binck-horstlaan	Far	South	50	19141	22841	3700	19.33
17	Oranjelaan			Close	North	30	7596	2964	-4632	-60.98

18	Parallelweg	Wolterbeek-straat	Koning-straat	Far	North	50	11547	2306	-9241	-80.03
19	Parallelweg	Koning-straat	Vaillant-laan	Far	North	50	10708	6501	-4207	-39.29
20	Parallelweg	Vaillantlaan	Wouwer-manstraat	Far	North	50	8635	4835	-3800	-44.01
21	Rijswijkse-weg	Rijswijkse-plein	Waldorp-straat	Far	South	50	22568	26284	3716	16.47
22	Rijswijkse-weg	Waldorp-straat	Neher-kade	Far	South	50	10934	10606	-328	-3.00
23	Schenk-viaduct	Binckhorst-laan	Utrechtse-baan	Far	North	50	29796	21840	-7956	-26.70
24	Schenk-viaduct	Rijswijkse-plein	Pletterij-kade	Far	North	50	15832	11471	-4361	-27.55
25	Slijpmolen			Far	North	30	2005	0	-2005	-100
26	Stations-plein			Far	North	30	8859	1842	-7017	-79.21
27	Stations-weg	Stations-plein	Hoefkade	Close	North	30	2365	4356	1991	84.19
28	Stations-weg	Hoefkade	Groene-wegje	Close	North	30	5505	3524	-1981	-35.99
29	Vaillantlaan	Parallelweg	David Blesstraat	Far	North	50	25746	26928	1182	4.59
30	Vaillantlaan	David Blesstraat	Hoefkade	Close	North	50	25468	25656	188	0.74
31	Vaillantlaan	Hoefkade	Van Ostade-straat	Close	North	50	29121	25799	-3322	-11.41
32	Vaillantlaan	Van Ostade-straat	Ruijsdael-straat	Far	North	50	17662	15163	-2499	-14.15
33	Van der Kunstraat	Waldorp-straat	Caland-straat	Far	South	50	2414	4380	1966	81.44
34	Van der Kunstraat	Caland-straat	Leeghwat-erplein	Far	South	50	5778	6256	478	8.27
35	Van der Vennestraat			Far	North	30	9169	6669	-2500	-27.27
36	Van Ostande-straat	Vaillantlaan	Jacob Catsstraat	Far	North	30	2290	1877	-413	-18.03
37	Waldorp-straat	Caland-straat	Leeghwat-erplein	Far	South	50	15713	19173	3460	22.02
38	Waldorp-straat	Leeghwater-plein	Rijswijk-seweg	Far	South	50	16082	21303	5221	32.46

39	Wetering-kade			Far	North	50	6749	2736	-4013	-59.46
40	Wolterbee k-straat			Close	North	30	1820	833	-987	-54.23
41	Zuyliche m-straat			Far	North	30	1891	446	-1445	-76.41

Appendix B: Data for Traffic Crashes

Table XI

Average number of traffic crashes for 41 segments in The Hague (Smart Traffic Accident Reporting, 2024)

Num-ber	Street	Between	And	Distance	Location Relative to Station Den Haag HS	Traffic Speed [km/h]	Traffic Crashes Before	Traffic Crashes After	Absolute difference	Relative difference [%]
1	Binkhorst-laan			Far	South	50	9	10	1	11.11
2	Caland-straat	Parallel weg	Waldorp-straat	Far	South	50	0	0	0	0
3	Caland-straat	Waldorp-straat	Neherkade	Far	South	50	5	11	6	120
4	Groene-wegje			Far	North	30	2	0	-2	-100
5	Hoefkade	Stations weg	Koning-straat	-	North	30	19	8	-11	-57.89
6	Hoefkade	Koningstraat	Pieter Lastman-straat	Close	North	30	18	19	1	5.56
7	Hoefkade	Pieter Lastman-straat	Vaillantlaan	Close	North	50	1	4	3	300
8	Hoefkade	Vaillantlaan	Parallelweg	Close	North	50	7	7	0	0
9	Hofwijck-straat			Far	North	30	0	1	1	Infinite integer
10	Jacob Catsstraat	Parallel weg	Hoefkade	Close	North	30	1	2	1	100
11	Jacob Catsstraat	Hoefkade	Hooftskade	Close	North	30	4	0	-4	-100
12	Koning-straat	Parallel weg	Hoefkade	Close	North	30	2	0	-2	-100
13	Koning-straat	Hoefkade	Groene-wegje	Close	North	30	10	4	-6	-60
14	Neherkade	Stieltjes-straat	Slachthuis-laan	Far	South	50	8	9	1	12.5
15	Neherkade	Slachthuis-laan	Rijswijkse-weg	Far	South	50	12	18	6	50
16	Neherkade	Rijswijkse-weg	Binckhorst-laan	Far	South	50	7	13	6	85.71
17	Oranjelaan			Close	North	30	7	6	-1	-14.29
18	Parallelweg	Wolterbeek-straat	Koning-straat	Far	North	50	8	6	-2	-25
19	Parallelweg	Koningstraat	Vaillantlaan	Far	North	50	17	8	-9	-52.94

20	Parallelweg	Vaillantlaan	Wouwer-manstraat	Far	North	50	2	1	-1	-50
21	Rijswijk-seweg	Rijswijkse-plein	Waldorp-straat	Far	South	50	2	6	4	200
22	Rijswijk-seweg	Waldorp-straat	Neherkade	Far	South	50	7	10	3	42.86
23	Schenk-viaduct	Binckhorst-laan	Utrechtse-baan	Far	North	50	13	6	-7	-53.85
24	Schenk-viaduct	Rijswijkse-plein	Pletterij-kade	Far	North	50	6	5	-1	-16.67
25	Slijp-molen			Far	North	30	0	1	1	Infinite integer
26	Stations-plein			Far	North	30	20	13	-7	-35
27	Stations-weg	Stations plein	Hoefkade	Close	North	30	2	3	1	50
28	Stations-weg	Hoefkade	Groene-wegje	Close	North	30	11	7	-4	-36.36
29	Vaillant-laan	Parallel weg	David Blesstraat	Far	North	50	11	17	6	54.55
30	Vaillantlaan	David Blesstraat	Hoefkade	Close	North	50	18	21	3	16.67
31	Vaillantlaan	Hoefkade	Van Ostade-straat	Close	North	50	8	8	0	0
32	Vaillantlaan	Van Ostade-straat	Ruijsdael-straat	Far	North	50	20	21	1	5
33	Van der Kunstraat	Waldorp-straat	Caland-straat	Far	South	50	6	8	2	33.33
34	Van der Kunstraat	Calandstraat	Leeghwater-plein	Far	South	50	7	11	4	57.14
35	Van der Vennestraat			Far	North	30	6	1	-5	-83.33
36	Van Ostande-straat	Vaillantlaan	Jacob Catsstraat	Far	North	30	0	2	2	Infinite integer
37	Waldorp-straat	Calandstraat	Leeghwater-plein	Far	South	50	13	14	1	7.69
38	Waldorp-straat	Leeghwater-plein	Rijswijkse-weg	Far	South	50	19	25	6	31.58
39	Wetering-kade			Far	North	50	9	4	-5	-55.56
40	Wolterbeek-straat			Close	North	30	2	1	-1	-50
41	Zuylichem-straat			Far	North	30	0	0	0	0

Appendix C: Python Code for Data Collection

```
import numpy as np
import scipy
from scipy import stats
import matplotlib.pyplot as plt
```

```
#Section 4.1 Data Collection for Traffic Flow
Traffic_Flow_Before = [25039, 34802, 19089, 1164, 9564, 7727, 8255, 8635,
                       4054, 996, 3274, 6620, 3145, 20856, 30075, 19141,
                       7596, 11547, 10708, 8635, 22568, 10934, 29796,
                       15832, 2005, 8859, 2365, 5505, 25746, 25468, 29121,
                       17662, 2414, 5778, 9169, 2290, 15713, 16082, 6749,
                       1820, 1891]
Traffic_Flow_After = [25113, 37989, 20089, 221, 396, 2353, 6162, 6954,
                      3884, 1567, 2006, 3070, 2089, 23643, 34963, 22841,
                      2964, 2306, 6501, 4835, 26284, 10606, 21840, 11471,
                      0, 1842, 4356, 3524, 26928, 25656, 25799, 15163,
                      4380, 6256, 6669, 1877, 19173, 21303,
                      2736, 833, 446]
```

```
Absolute_Difference_Flow = np.subtract(Traffic_Flow_After,
                                       Traffic_Flow_Before)
```

```
Relative_Difference_Flow = np.divide(Absolute_Difference_Flow,
                                     Traffic_Flow_Before) * 100
```

```
#Section 4.2 Data Collection for Traffic Accidents
Traffic_Accidents_Before = [9, 0, 5, 2, 19, 18, 1, 7, 0, 1, 4, 2, 10, 8, 12, 7,
                             7, 8, 17, 2, 2, 7, 13, 6, 0, 20, 2, 11, 11, 18, 8,
                             20, 6, 7, 6, 0, 13, 19, 9, 2, 0]
Traffic_Accidents_After = [10, 0, 11, 0, 8, 19, 4, 7, 1, 2, 0, 0, 4, 9, 18, 13,
                           6, 6, 8, 1, 6, 10, 6, 5, 1, 13, 3, 7, 17, 21, 8,
                           21, 8, 11, 1, 2, 14, 25, 4, 1, 0]
```

```
Absolute_Difference_Accidents = np.subtract(Traffic_Accidents_After,
                                            Traffic_Accidents_Before)
```

```
Relative_Difference_Accidents = np.divide(Absolute_Difference_Accidents,
                                          Traffic_Accidents_Before) * 100
```

```python
#Information for the Bar Chart for Traffic Flow
Traffic_Flow_Before = [25039, 34802, 19089, 1164, 7727, 8255, 8635,
                            4054, 996, 3274, 6620, 3145, 20856, 30075, 19141,
                            7596, 11547, 10708, 8635, 22568, 10934, 29796,
                            15832, 2005, 8859, 2365, 5505, 25746, 25468, 29121,
                            17662, 2414, 5778, 9169, 2290, 15713, 16082, 6749,
                            1820, 1891]
#This array corresponds to the "Traffic Flow Before [vehicles/day]" column ..
#.. in Table X, except for row 6 (Segement 5)
g_Flow_Before = np.mean(Traffic_Flow_Before)
Traffic_Flow_After = [25113, 37989, 20089, 221, 2353, 6162, 6954,
                           3884, 1567, 2006, 3070, 2089, 23643, 34963, 22841,
                           2964, 2306, 6501, 4835, 26284, 10606, 21840, 11471,
                           0, 1842, 4356, 3524, 26928, 25656, 25799, 15163,
                           4380, 6256, 6669, 1877, 19173, 21303,
                           2736, 833, 446]
#This array corresponds to the "Traffic Flow After [vehicles/day]" column ..
#.. in Table X, except for row 6 (Segement 5)
g_Flow_After = np.mean(Traffic_Flow_After)

Traffic_Flow_Before_30 = [1164, 7727, 4054, 996, 3274, 6620, 3145,
                              7596, 2005, 8859, 2365, 5505, 9169, 2290, 1820,
                               1891]
#This array corresponds to the "Traffic Flow Before [vehicles/day]" column ...
# ... in Table X for the segments with a maximum traffic speed of 30 km/h, ..
# ... except for row 6 (Segment 5)
g_Flow_Before_30 = np.mean(Traffic_Flow_Before_30)
Traffic_Flow_After_30 = [221, 2353, 3884, 1567, 2006, 3070, 2089,
                             2964, 0, 1842, 4356, 3524, 6669, 1877, 833, 446]
#This array corresponds to the "Traffic Flow After [vehicles/day]" column ...
# ... in Table X for the segments with a maximum traffic speed of 30 km/h, ..
# ... except for row 6 (Segment 5)
g_Flow_After_30 = np.mean(Traffic_Flow_After_30)

Traffic_Flow_Before_50 = [25039, 34802, 19089, 8255, 8635, 20856, 30075,
                               19141, 11547, 10708, 8635, 22568, 10934, 29796,
                               15832, 25746, 25468, 29121, 17662, 2414, 5778,
                               15713, 16082, 6749]
#This array corresponds to the "Traffic Flow Before [vehicles/day]" column ...
# ... in Table X for the segments with a maximum traffic speed of 50 km/h, ..
# ... except for row 6 (Segment 5)
g_Flow_Before_50 = np.mean(Traffic_Flow_Before_50)
Traffic_Flow_After_50 = [25113, 37989, 20089, 6162, 6954, 23643, 34963,
                              22841, 2306, 6501, 4835, 26284, 10606, 21840,
                              11741, 26928, 25656, 25799, 15163, 4380, 6256,
                              19173, 21303, 2736]
#This array corresponds to the "Traffic Flow After [vehicles/day]" column ...
# ... in Table X for the segments with a maximum traffic speed of 50 km/h, ..
# ... except for row 6 (Segment 5)
g_Flow_After_50 = np.mean(Traffic_Flow_After_50)
```

```
Traffic_Flow_Before_Close = [7727, 8255, 8635, 996, 3274, 6620, 3145, 7596,
                             2365, 5505, 25468, 29121, 1820]
#This array corresponds to the "Traffic Flow Before [vehicles/day]" column ...
# ... in Table X for the segments close to the Hoefkade, except for ..
# ... row 6 (Segment 5)
g_Flow_Before_Close = np.mean(Traffic_Flow_Before_Close)
Traffic_Flow_After_Close = [2353, 6162, 6954, 1567, 2006, 3070, 2089, 2964,
                            4356, 3524, 25656, 25799, 833]
#This array corresponds to the "Traffic Flow After [vehicles/day]" column ...
# ... in Table X for the segments close to the Hoefkade, except for ..
# ... row 6 (Segment 5)
g_Flow_After_Close = np.mean(Traffic_Flow_After_Close)

Traffic_Flow_Before_Far = [25039, 34802, 19089, 1164, 4054, 20856, 30075,
                            19141, 11547, 10708, 8635, 22568, 10934, 29796,
                            15832, 2005, 8859, 25746, 17662, 2414, 5778, 9169,
                           2290, 15713, 16082, 6749, 1891]
#This array corresponds to the "Traffic Flow Before [vehicles/day]" column ...
# ... in Table X for the segments far from the Hoefkade, except for ..
# ... row 6 (Segment 5)
g_Flow_Before_Far = np.mean(Traffic_Flow_Before_Far)
Traffic_Flow_After_Far = [25113, 37989, 20089, 221, 3884, 23643, 34963,
                           22841, 2306, 6501, 4835, 26284, 10606, 21840,
                           11471, 0, 1842, 26928, 15163, 4380, 6256, 6669,
                          1877, 19173, 21303, 2736, 446]
#This array corresponds to the "Traffic Flow After [vehicles/day]" column ...
# ... in Table X for the segments far from the Hoefkade, except for ..
# ... row 6 (Segment 5)
g_Flow_After_Far = np.mean(Traffic_Flow_After_Far)

Traffic_Flow_Before_North =[1164, 7727, 8255, 8635, 4054, 996, 3274, 6620,
                             3145, 7596, 11547, 10708, 8635, 29796, 15832,
                             2005, 8859, 2365, 5505, 25746, 25468, 29121,
                             17662, 9169, 2290, 6749, 1820, 1891]
#This array corresponds to the "Traffic Flow Before [vehicles/day]" column ...
# ... in Table X for the segments north from the station HS, except for ..
# ... row 6 (Segment 5)
g_Flow_After_North = np.mean(Traffic_Flow_After_North)

Traffic_Flow_Before_South = [25039, 34802, 19089, 20856, 30075, 19141, 22568,
                             10934, 2414, 5778, 15713, 16082]
#This array corresponds to the "Traffic Flow Before [vehicles/day]" column ...
# ... in Table X for the segments south from the station HS, except for ..
# ... row 6 (Segment 5)
g_Flow_Before_South = np.mean(Traffic_Flow_Before_South)
Traffic_Flow_After_South = [25113, 37989, 20089, 23643, 34963, 22841, 26284,
                            10606, 4380, 6256, 19173, 21303]
#This array corresponds to the "Traffic Flow After [vehicles/day]" column ...
# ... in Table X for the segments south from the station HS, except for ..
# ... row 6 (Segment 5)
g_Flow_After_South = np.mean(Traffic_Flow_After_South)
```

```
#Bar Chart for Traffic Flow
barWidth = 0.25
fig = plt.subplots(figsize=(12,8))

Flow_Before = [g_Flow_Before, g_Flow_Before_30, g_Flow_Before_50,
         g_Flow_Before_Close, g_Flow_Before_Far, g_Flow_Before_North,
              g_Flow_Before_South]
Flow_After = [g_Flow_After, g_Flow_After_30, g_Flow_After_50,
         g_Flow_After_Close, g_Flow_After_Far, g_Flow_After_North,
             g_Flow_After_South]

br_Flow_Before = np.arange(len(Flow_Before))
br_Flow_After = [x + barWidth for x in br_Flow_Before]

plt.bar(br_Flow_Before, Flow_Before, color = 'b', width = barWidth,
        edgecolor = 'grey', label = 'Before closure')
plt.bar(br_Flow_After, Flow_After, color = 'y', width = barWidth,
        edgecolor = 'grey', label = 'After closure')

plt.xlabel('Type of Surrounding Street', fontweight = 'bold', fontsize = 15)
plt.ylabel('Traffic Flow [vehicles/day]', fontweight = 'bold', fontsize = 15)
plt.xticks([r + barWidth for r in range(len(Flow_Before))],
           ['All streets', '30 km/h streets', '50 km/h streets', 'Close streets'
plt.title('Average Motorised Traffic Flows for the Streets Surrounding the Hoefk
plt.legend()
plt.show()
#Information for the Bar Chart for Traffic Accidents
Traffic_Accidents_Before = [9, 0, 5, 2, 18, 1,7, 0, 1, 4, 2, 10, 8, 12, 7,
                            7, 8, 17, 2, 2, 7, 13, 6, 0, 20, 2, 11, 11, 18,
                            8, 20, 6, 7, 6, 0, 13, 19, 9, 2, 0]
#This array corresponds to the "Traffic Accident Before" column in Table XI, ..
# ... except for row 6 (Segement 5)
g_Accidents_Before = np.mean(Traffic_Accidents_Before)
Traffic_Accidents_After = [10, 0, 11, 0, 19, 4, 7, 1, 2, 0, 0, 4, 9, 18, 13, 6,
                           6, 8, 1, 6, 10, 6, 5, 1, 13, 3, 7, 17, 21, 8,
                           21, 8, 11, 1, 2, 14, 25, 4, 1, 0]
#This array corresponds to the "Traffic Accident After" column in Table XI, ..
# ... except for row 6 (Segement 5)
g_Accidents_After = np.mean(Traffic_Accidents_After)

Traffic_Accidents_Before_30 = [2, 18, 0, 1, 4, 2, 10, 7, 0, 20, 2, 11,
                               6, 0, 2, 0]
#This array corresponds to the "Traffic Accident Before" column in Table XI
# ... for the segments with a maximum traffic speed of 30 km/h, except for ..
# ... row 6 (Segment 5)
g_Accidents_Before_30 = np.mean(Traffic_Accidents_Before_30)
Traffic_Accidents_After_30 = [0, 19, 1, 2, 0, 0, 4, 6, 1, 13, 3, 7, 1, 2,
                              1, 0]
#This array corresponds to the "Traffic Accident After" column in Table XI
# ... for the segments with a maximum traffic speed of 30 km/h, except for ..
# ... row 6 (Segment 5)
g_Accidents_After_30 = np.mean(Traffic_Accidents_After_30)
```

```python
Traffic_Accidents_Before_50 = [9, 0, 5, 1, 7, 8, 12, 7, 8, 17, 2, 2, 7, 13,
                               6, 11, 18, 8, 20, 6, 7, 13, 19, 9]
#This array corresponds to the "Traffic Accident Before" column in Table XI
# ... for the segments with a maximum traffic speed of 50 km/h, except for ..
# ... row 6 (Segment 5)
g_Accidents_Before_50 = np.mean(Traffic_Accidents_Before_50)
Traffic_Accidents_After_50 = [10, 0, 11, 4, 7, 9, 18, 13, 6, 8, 1, 6, 10, 6,
                              5, 17, 21, 8, 21, 8, 11, 14, 25, 4]
#This array corresponds to the "Traffic Accident After" column in Table XI
# ... for the segments with a maximum traffic speed of 50 km/h, except for ..
# ... row 6 (Segment 5)
g_Accidents_After_50 = np.mean(Traffic_Accidents_After_50)

Traffic_Accidents_Before_Close = [18, 1, 7, 1, 4, 2, 10, 7, 2, 11, 18, 8, 2]
#This array corresponds to the "Traffic Accident Before" column in Table XI ..
# ... for the segments close to the Hoefkade, except for row 6 (Segment 5)
g_Accidents_Before_Close = np.mean(Traffic_Accidents_Before_Close)
Traffic_Accidents_After_Close = [19, 4, 7, 2, 0, 0, 4, 6, 3, 7, 21, 8, 1, 0]
#This array corresponds to the "Traffic Accident After" column in Table XI ..
# ... for the segments close to the Hoefkade, except for row 6 (Segment 5)
g_Accidents_After_Close = np.mean(Traffic_Accidents_After_Close)

Traffic_Accidents_Before_Far = [9, 0, 5, 2, 0, 8, 12, 7, 8, 17, 2, 2, 7, 13,
                               6, 0, 20, 11, 20, 6, 7, 6, 0, 13, 19, 9, 0]
#This array corresponds to the "Traffic Accident Before" column in Table XI ..
# .. for the segments far from the Hoefkade, except for row 6 (Segment 5)
g_Accidents_Before_Far = np.mean(Traffic_Accidents_Before_Far)
Traffic_Accidents_After_Far = [10, 0, 11, 0, 1, 9, 18, 13, 6, 8, 1, 6, 10, 6,
                              5, 1, 13, 17, 21, 8, 11, 1, 2, 14, 25, 4, 0]
#This array corresponds to the "Traffic Accident After" column in Table XI ..
# .. for the segments far from the Hoefkade, except for row 6 (Segment 5)
g_Accidents_After_Far = np.mean(Traffic_Accidents_After_Far)

Traffic_Accidents_Before_North = [2, 18, 1,7, 0, 1, 4, 2, 10, 7, 8, 17, 2,
                                  13, 6, 0, 20, 2, 11, 11, 18, 8, 20, 6, 0,
                                  9, 2, 0]
#This array corresponds to the "Traffic Accidents Before" column ...
# ... in Table XI for the segments north from the station HS, except for ..
# ... row 6 (Segment 5)
g_Accidents_Before_North = np.mean(Traffic_Accidents_Before_North)
Traffic_Accidents_After_North = [0, 19, 4, 7, 1, 2, 0, 0, 4, 6, 6, 8, 1, 6,
                                 5, 1, 13, 3, 7, 17, 21, 8, 21, 1, 2, 4, 1, 0]
#This array corresponds to the "Traffic Accidents After" column ...
# ... in Table XI for the segments north from the station HS, except for ..
# ... row 6 (Segment 5)
g_Accidents_After_North = np.mean(Traffic_Accidents_After_North)
```

```
Traffic_Accidents_Before_South = [9, 0, 5, 8, 12, 7, 2, 7, 6, 7, 13, 19]
#This array corresponds to the "Traffic Accidents Before" column ...
# ... in Table XI for the segments south from the station HS, except for ..
# ... row 6 (Segment 5)
g_Accidents_Before_South = np.mean(Traffic_Accidents_Before_South)
Traffic_Accidents_After_South = [10, 0, 11, 9, 18, 13, 6, 10, 8, 11, 14, 25]
#This array corresponds to the "Traffic Accidents After" column ...
# ... in Table XI for the segments south from the station HS, except for ..
# ... row 6 (Segment 5)
g_Accidents_After_South = np.mean(Traffic_Accidents_After_South)
```

```
#Bar Chart for Traffic Accidents
barWidth = 0.25
fig = plt.subplots(figsize=(12,8))

Accidents_Before = [g_Accidents_Before, g_Accidents_Before_30,
                    g_Accidents_Before_50, g_Accidents_Before_Close,
                    g_Accidents_Before_Far, g_Accidents_Before_North,
                   g_Accidents_Before_South]
Accidents_After = [g_Accidents_After, g_Accidents_After_30,
                   g_Accidents_After_50, g_Accidents_After_Close,
                   g_Accidents_After_Far, g_Accidents_After_North,
                  g_Accidents_After_South]

br_Accidents_Before = np.arange(len(Accidents_Before))
br_Accidents_After = [x + barWidth for x in br_Accidents_Before]

plt.bar(br_Accidents_Before, Accidents_Before, color = 'b', width = barWidth,
        edgecolor = 'grey', label = 'Before closure')
plt.bar(br_Accidents_After, Accidents_After, color = 'y', width = barWidth,
        edgecolor = 'grey', label = 'After closure')

plt.xlabel('Type of Surrounding Street', fontweight = 'bold', fontsize = 15)
plt.ylabel('Number of Traffic Accidents', fontweight = 'bold', fontsize = 15)
plt.xticks([r + barWidth for r in range(len(Accidents_Before))],
           ['All streets', '30 km/h streets', '50 km/h streets', 'Close streets'
plt.title('Average Number of Traffic Accidents for the Streets Surrounding the H
plt.legend()
plt.show()
```

Appendix D: Python Code for Comparative Analysis

```
import numpy as np
import scipy
from scipy import stats
```

```
#Section 5.1.1 Statistical Test
Absolute_Difference_Flow = [74, 3187, 1000, -943, -5374, -2093, -1681, -170,
                            571, -1268, -3550, -1056, 2787, 4888, 3700, -4632,
                            -9241, -4207, -3800, 3716, -328, -7956, -4361,
                            -2005, -7017, 1991, -1981, 1182, 188, -3322,
                            -2499, 1966, 478, -2500, -413, 3460, 5221,
                            -4013, -987, -1445]
#This array corresponds to the "Absolute Difference" column in Table X,...
# .., except for row 6 (Segement 5)

stat_Flow, p_Flow = scipy.stats.shapiro(Absolute_Difference_Flow)
print(f'The p-value of the distribution of the differences in traffic flows is

if p_Flow > 0.05:
    print('This p-value is higher than 0.05, thus the distribution is normal.')
else:
    print('This p-value is lower than 0.05, thus the distribution is not normal
```

```
The p-value of the distribution of the differences in traffic flows is 0.851
This p-value is higher than 0.05, thus the distribution is normal.
```

```
Absolute_Difference_Accidents = [1, 0, 6, -2, 1, 3, 0, 1, 1, -4, -2, -6,
                                 1, 6, 6, -1, -2, -9, -1, 4, 3, -7, -1, 1, -7,
                                 1, -4, 6, 3, 0, 1, 2, 4, -5, 2, 1, 6, -5,
                                 -1, 0]
#This array corresponds to the "Absolute Difference" column in Table XI,...
# .., except for row 6 (Segement 5)

stat_Accidents, p_Accidents = scipy.stats.shapiro(Absolute_Difference_Accidents
print(f'The p-value of the distribution of the differences in traffic accidents

if p_Accidents > 0.05:
    print('This p-value is higher than 0.05, thus the distribution is normal.')
else:
    print('This p-value is lower than 0.05, thus the distribution is not normal
```

```
The p-value of the distribution of the differences in traffic accidents is 0.0
953
This p-value is higher than 0.05, thus the distribution is normal.
```

```
#Section 5.1.1.1 Statistical Test for Traffic Flow
#Statistical Tests for Entirety for Traffic Flow
D_Flow = Absolute_Difference_Flow
mean_D_Flow= np.mean(D_Flow)
std_D_Flow = np.std(D_Flow)
n = len(D_Flow)
T_Flow = mean_D_Flow / (std_D_Flow/(np.sqrt(n)))

print(f'The mean of D_Flow is {mean_D_Flow:.8}')
print(f'The standard deviation of D_Flow is {std_D_Flow:.7}')
print(f'The degree of freedom df is {n-1}')
print(f'The T-value for the traffic flows is {T_Flow:.4}')

if T_Flow > 2.023 or T_Flow < -2.023:
    print('This T-value does fall within the critical region, which means the nu
else:
    print('This T-value does not fall within the critial region, which means the
```

```
The mean of D_Flow is -1060.825
The standard deviation of D_Flow is 3347.193
The degree of freedom df is 39
The T-value for the traffic flows is -2.004
This T-value does not fall within the critial region, which means the alternati
ve hypothesis is rejected
```

```
#Statistical Tests for 30 km/h roads for Traffic Flow
Traffic_Flow_Before_30 = [1164, 7727, 4054, 996, 3274, 6620, 3145, 7596,
                          2005, 8859, 2365, 5505, 9169, 2290, 1820, 1891]
Traffic_Flow_After_30 = [221, 2353, 3884, 1567, 2006, 3070, 2089, 2964,
                         0, 1842, 4356, 3524, 6669, 1877, 833, 446]

stat_Flow_30, p_Flow_30 = scipy.stats.wilcoxon(Traffic_Flow_Before_30,
                                                Traffic_Flow_After_30)
print(f'The p value of the 30 km/h roads for traffic flow is {p_Flow_30:.3}')

if p_Flow_30 > 0.05:
    print('This p-value is higher than 0.05, thus there is no significant differ
else:
    print('This p-value is lower than 0.05, thus there is a significant differen
```

```
The p value of the 30 km/h roads for traffic flow is 0.00269
This p-value is lower than 0.05, thus there is a significant difference.
```

```
#Statistical Tests for 50 km/h roads for Traffic Flow
Traffic_Flow_Before_50 = [25039, 34802, 19089, 8255, 8635, 20856, 30075,
                          19141, 11547, 10708, 8635, 22568, 10934, 29796,
                          15832, 25746, 25468, 29121, 17662, 2414, 5778,
                          15713, 16082, 6749]
Traffic_Flow_After_50 = [25113, 37989, 20089, 6162, 6954, 23643, 34963,
                         22841, 2306, 6501, 4835, 26284, 10606, 21840,
                         11741, 26928, 25656, 25799, 15163, 4380, 6256,
                         19173, 21303, 2736]
```

```
stat_Flow_50, p_Flow_50 = scipy.stats.wilcoxon(Traffic_Flow_Before_50,
                                               Traffic_Flow_After_50)
print(f'The p value of the 50 km/h roads for traffic flow is {p_Flow_50:.3}' )

if p_Flow_50 > 0.05:
    print('This p-value is higher than 0.05, thus there is no significant differ
else:
    print('This p-value is lower than 0.05, thus there is a significant differer
```

```
The p value of the 50 km/h roads for traffic flow is 0.726
This p-value is higher than 0.05, thus there is no significant difference.
```

```
#Statistical Tests for Streets Close to the Hoefkade for Traffic Flow
Traffic_Flow_Before_Close = [7727, 8255, 8635, 996, 3274, 6620, 3145, 7596,
                             2365, 5505, 25468, 29121, 1820]
Traffic_Flow_After_Close = [2353, 6162, 6954, 1567, 2006, 3070, 2089, 2964,
                           4356, 3524, 25656, 25799, 833]

stat_Flow_Close, p_Flow_Close = scipy.stats.wilcoxon(Traffic_Flow_Before_Close,
                                               Traffic_Flow_After_Close)
print(f'The p value of the streets close to the Hoefkade for traffic flow is {p_

if p_Flow_Close > 0.05:
    print('This p-value is higher than 0.05, thus there is no significant differ
else:
    print('This p-value is lower than 0.05, thus there is a significant differer
```

```
The p value of the streets close to the Hoefkade for traffic flow is 0.0134
This p-value is lower than 0.05, thus there is a significant difference.
```

```
#Statistical Tests for Streets Far from the Hoefkade for Traffic Flow
Traffic_Flow_Before_Far = [25039, 34802, 19089, 1164, 4054, 20856, 30075,
                           19141, 11547, 10708, 8635, 22568, 10934, 29796,
                           15832, 2005, 8859, 25746, 17662, 2414, 5778, 9169,
                          2290, 15713, 16082, 6749, 1891]
Traffic_Flow_After_Far = [25113, 37989, 20089, 221, 3884, 23643, 34963,
                          22841, 2306, 6501, 4835, 26284, 10606, 21840,
                          11471, 0, 1842, 26928, 15163, 4380, 6256, 6669,
                         1877, 19173, 21303, 2736, 446]

stat_Flow_Far, p_Flow_Far = scipy.stats.wilcoxon(Traffic_Flow_Before_Far,
                                               Traffic_Flow_After_Far)
print(f'The p value of the streets far from the Hoefkade for traffic flow is {p_

if p_Flow_Far > 0.05:
    print('This p-value is higher than 0.05, thus there is no significant differ
else:
    print('This p-value is lower than 0.05, thus there is a significant differer
```

```
The p value of the streets far from the Hoefkade for traffic flow is 0.456
This p-value is higher than 0.05, thus there is no significant difference.
```

```python
#Statistical Tests for Streets North of the train tracks of The Hague HS Statior
Traffic_Flow_Before_North =[1164, 7727, 8255, 8635, 4054, 996, 3274, 6620,
                            3145, 7596, 11547, 10708, 8635, 29796, 15832,
                            2005, 8859, 2365, 5505, 25746, 25468, 29121,
                            17662, 9169, 2290, 6749, 1820, 1891]
Traffic_Flow_After_North = [221, 2353, 6162, 6954, 3884, 1567, 2006, 3070,
                            2089, 2964, 2306, 6501, 4835, 21840, 11471,
                           0, 1842, 4356, 3524, 26928, 25656, 25799, 15163,
                           6669, 1877, 2736, 833, 446]

stat_Flow_North, p_Flow_North = scipy.stats.wilcoxon(Traffic_Flow_Before_North,
                                                     Traffic_Flow_After_North)
print(f'The p value of the streets north of the train tracks of The Hague HS sta

if p_Flow_North > 0.05:
    print('This p-value is higher than 0.05, thus there is no significant differ
else:
    print('This p-value is lower than 0.05, thus there is a significant differer
```

```
The p value of the streets north of the train tracks of The Hague HS station fo
r traffic flow is 6.13e-05
This p-value is lower than 0.05, thus there is a significant difference.
```

```python
#Statistical Tests for Streets South of the train tracks of The Hague HS Statior
Traffic_Flow_Before_South = [25039, 34802, 19089, 20856, 30075, 19141, 22568,
                             10934, 2414, 5778, 15713, 16082]
Traffic_Flow_After_South = [25113, 37989, 20089, 23643, 34963, 22841, 26284,
                            10606, 4380, 6256, 19173, 21303]

stat_Flow_South, p_Flow_South = scipy.stats.wilcoxon(Traffic_Flow_Before_South,
                                                     Traffic_Flow_After_South)
print(f'The p value of the streets south of the train tracks of The Hague HS sta

if p_Flow_South > 0.05:
    print('This p-value is higher than 0.05, thus there is no significant differ
else:
    print('This p-value is lower than 0.05, thus there is a significant differer
```

```
The p value of the streets south of the train tracks of The Hague HS station fo
r traffic flow is 0.00146
This p-value is lower than 0.05, thus there is a significant difference.
```

```python
#Section 5.1.1.2 Statistical Test for Traffic Accidents
#Statistical Tests for Entirety
D_Accidents = Absolute_Difference_Accidents
mean_D_Accidents = np.mean(D_Accidents)
std_D_Accidents = np.std(D_Accidents)
n = len(D_Accidents)
T_Accidents = mean_D_Accidents / (std_D_Accidents/(np.sqrt(n)))
```

```
print(f'The mean of D_Accidents is {mean_D_Accidents:.3}')
print(f'The standard deviation of D_Accidents is {std_D_Accidents:.4}')
print(f'The degree of freedom df is {n-1}')
print(f'The T-value for the traffic accidents is {T_Accidents:.3}')

if T_Accidents > 2.023 or T_Accidents < -2.023:
    print('This T-value does fall within the critical region, which means the nu
else:
    print('This T-value does not fall within the critial region, which means the
```

```
The mean of D_Accidents is 0.075
The standard deviation of D_Accidents is 3.771
The degree of freedom df is 39
The T-value for the traffic accidents is 0.126
This T-value does not fall within the critial region, which means the alternati
ve hypothesis is rejected
```

```
#Statistical Tests for 30 km/h roads for Traffic Accidents
Traffic_Accidents_Before_30 = [2, 18, 0, 1, 4, 2, 10, 7, 0, 20, 2, 11,
                               6, 0, 2, 0]
Traffic_Accidents_After_30 = [0, 19, 1, 2, 0, 0, 4, 6, 1, 13, 3, 7, 1, 2,
                              1, 0]

stat_Accidents_30, p_Accidents_30 = scipy.stats.wilcoxon(Traffic_Accidents_Befor
                                                         Traffic_Accidents_After_30)
print(f'The p value of the 30 km/h roads for traffic flow is {p_Accidents_30:.3}

if p_Accidents_30 > 0.05:
    print('This p-value is higher than 0.05, thus there is no significant differ
else:
    print('This p-value is lower than 0.05, thus there is a significant differer
```

```
The p value of the 30 km/h roads for traffic flow is 0.0746
This p-value is higher than 0.05, thus there is no significant difference.
```

```
#Statistical Tests for 50 km/h roads for Traffic Accidents
Traffic_Accidents_Before_50 = [9, 0, 5, 1, 7, 8, 12, 7, 8, 17, 2, 2, 7, 13,
                               6, 11, 18, 8, 20, 6, 7, 13, 19, 9]
Traffic_Accidents_After_50 = [10, 0, 11, 4, 7, 9, 18, 13, 6, 8, 1, 6, 10, 6,
                              5, 17, 21, 8, 21, 8, 11, 14, 25, 4]
stat_Accidents_50, p_Accidents_50 = scipy.stats.wilcoxon(Traffic_Accidents_Befor
                                                         Traffic_Accidents_After_50)
print(f'The p value of the 50 km/h roads for traffic flow is {p_Accidents_50:.3}

if p_Accidents_50 > 0.05:
    print('This p-value is higher than 0.05, thus there is no significant differ
else:
    print('This p-value is lower than 0.05, thus there is a significant differer
```

```
The p value of the 50 km/h roads for traffic flow is 0.108
This p-value is higher than 0.05, thus there is no significant difference.
```

```
#Statistical Tests for Streets Close to the Hoefkade for Traffic Accidents
Traffic_Accidents_Before_Close = [18, 1, 7, 1, 4, 2, 10, 7, 2, 11, 18, 8, 2]
Traffic_Accidents_After_Close = [19, 4, 7, 2, 0, 0, 4, 6, 3, 7, 21, 8, 1]

stat_Accidents_Close, p_Accidents_Close = scipy.stats.wilcoxon(Traffic_Accidents
                                                   Traffic_Accidents_After_Close)
print(f'The p value of the streets close to the Hoefkade for traffic accidents i

if p_Accidents_Close > 0.05:
    print('This p-value is higher than 0.05, thus there is no significant differ
else:
    print('This p-value is lower than 0.05, thus there is a significant differen
```

```
The p value of the streets close to the Hoefkade for traffic accidents is 0.418
This p-value is higher than 0.05, thus there is no significant difference.
```

```
#Statistical Tests for Streets Far from the Hoefkade for Traffic Accidents
Traffic_Accidents_Before_Far = [9, 0, 5, 2, 0, 8, 12, 7, 8, 17, 2, 2, 7, 13,
                               6, 0, 20, 11, 20, 6, 7, 6, 0, 13, 19, 9, 0]
Traffic_Accidents_After_Far = [10, 0, 11, 0, 1, 9, 18, 13, 6, 8, 1, 6, 10, 6,
                              5, 1, 13, 17, 21, 8, 11, 1, 2, 14, 25, 4, 0]

stat_Accidents_Far, p_Accidents_Far = scipy.stats.wilcoxon(Traffic_Accidents_Bef
                                                   Traffic_Accidents_After_Far)
print(f'The p value of the streets far from the Hoefkade for traffic accidents i

if p_Accidents_Far > 0.05:
    print('This p-value is higher than 0.05, thus there is no significant differ
else:
    print('This p-value is lower than 0.05, thus there is a significant differen
```

```
The p value of the streets far from the Hoefkade for traffic accidents is 0.457
This p-value is higher than 0.05, thus there is no significant difference.
```

```
#Statistical Tests for Streets North of the train tracks of The Hague HS Station
Traffic_Accidents_Before_North = [2, 18, 1,7, 0, 1, 4, 2, 10, 7, 8, 17, 2,
                                 13, 6, 0, 20, 2, 11, 11, 18, 8, 20, 6, 0,
                                 9, 2, 0]
Traffic_Accidents_After_North = [0, 19, 4, 7, 1, 2, 0, 0, 4, 6, 6, 8, 1, 6,
                                5, 1, 13, 3, 7, 17, 21, 8, 21, 1, 2, 4, 1, 0]

stat_Accidents_North, p_Accidents_North = scipy.stats.wilcoxon(Traffic_Accidents
                                                   Traffic_Accidents_After_North)
print(f'The p value of the streets north of the train tracks of The Hague HS sta

if p_Accidents_North > 0.05:
    print('This p-value is higher than 0.05, thus there is no significant differ
else:
    print('This p-value is lower than 0.05, thus there is a significant differen
```

```
The p value of the streets north of the train tracks of The Hague HS station fo
r traffic accidents is 0.0802
This p-value is higher than 0.05, thus there is no significant difference.
```

```
#Statistical Tests for Streets South of the train tracks of The Hague HS Station
Traffic_Accidents_Before_South = [9, 0, 5, 8, 12, 7, 2, 7, 6, 7, 13, 19]
Traffic_Accidents_After_South = [10, 0, 11, 9, 18, 13, 6, 10, 8, 11, 14, 25]

stat_Accidents_South, p_Accidents_South = scipy.stats.wilcoxon(Traffic_Accidents
                                                               Traffic_Accidents_After_South)
print(f'The p value of the streets south of the train tracks of The Hague HS sta

if p_Accidents_South > 0.05:
    print('This p-value is higher than 0.05, thus there is no significant differ
else:
    print('This p-value is lower than 0.05, thus there is a significant differen
```

```
The p value of the streets south of the train tracks of The Hague HS station fo
r traffic accidents is 0.00312
This p-value is lower than 0.05, thus there is a significant difference.
```

```
#Section 5.1.2.1 Effect Size for Traffic Flow
#Effect Size for Entirety for Traffic Flow
Traffic_Flow_Before = [25039, 34802, 19089, 1164, 7727, 8255, 8635,
                       4054, 996, 3274, 6620, 3145, 20856, 30075, 19141,
                       7596, 11547, 10708, 8635, 22568, 10934, 29796,
                       15832, 2005, 8859, 2365, 5505, 25746, 25468, 29121,
                       17662, 2414, 5778, 9169, 2290, 15713, 16082, 6749,
                       1820, 1891]
Traffic_Flow_After = [25113, 37989, 20089, 221, 2353, 6162, 6954,
                      3884, 1567, 2006, 3070, 2089, 23643, 34963, 22841,
                      2964, 2306, 6501, 4835, 26284, 10606, 21840, 11471,
                      0, 1842, 4356, 3524, 26928, 25656, 25799, 15163,
                      4380, 6256, 6669, 1877, 19173, 21303,
                      2736, 833, 446]

M1_Flow = np.mean(Traffic_Flow_Before)
std1_Flow = np.std(Traffic_Flow_Before)
M2_Flow = np.mean(Traffic_Flow_After)
std2_Flow = np.std(Traffic_Flow_After)
std_pooled_Flow = np.sqrt((std1_Flow**2 + std2_Flow**2)/2)
d_Flow = (M1_Flow - M2_Flow)/ std_pooled_Flow

print(f'The standard deviation of group 1 is {std1_Flow:.7}')
print(f'The standard deviation of group 2 is {std2_Flow:.8}')
print(f'The pooled standard deviation is {std_pooled_Flow:.9}')
print(f'The mean of group 1 is {M1_Flow:.8}')
print(f'The mean of group 2 is {M2_Flow:.9}')
print(f'The Cohens d-value is {d_Flow:.3}')
```

```
The standard deviation of group 1 is 9535.267
The standard deviation of group 2 is 10794.491
The pooled standard deviation is 10184.359
The mean of group 1 is 12228.125
The mean of group 2 is 11167.3
The Cohens d-value is 0.104
```

```
#Effect Size for 30 km/h roads for Traffic Flow
Traffic_Flow_Before_30 = [1164, 7727, 4054, 996, 3274, 6620, 3145,
                              7596, 2005, 8859, 2365, 5505, 9169, 2290, 1820,
                               1891]
Traffic_Flow_After_30 = [221, 2353, 3884, 1567, 2006, 3070, 2089,
                             2964, 0, 1842, 4356, 3524, 6669, 1877, 833, 446]

M1_Flow_30 = np.mean(Traffic_Flow_Before_30)
std1_Flow_30 = np.std(Traffic_Flow_Before_30)
M2_Flow_30 = np.mean(Traffic_Flow_After_30)
std2_Flow_30 = np.std(Traffic_Flow_After_30)
std_pooled_Flow_30 = np.sqrt((std1_Flow_30**2 + std2_Flow_30**2)/2)
d_Flow_30 = (M1_Flow_30 - M2_Flow_30)/ std_pooled_Flow_30

print(f'The Cohens d-value for 30 km/h roads for traffic flow is {d_Flow_30:.3}
```

```
The Cohens d-value for 30 km/h roads for traffic flow is 0.843
```

```
#Effect Size for 50 km/h roads for Traffic Flow
Traffic_Flow_Before_50 = [25039, 34802, 19089, 8255, 8635, 20856, 30075,
                               19141, 11547, 10708, 8635, 22568, 10934, 29796,
                               15832, 25746, 25468, 29121, 17662, 2414, 5778,
                               15713, 16082, 6749]
Traffic_Flow_After_50 = [25113, 37989, 20089, 6162, 6954, 23643, 34963,
                              22841, 2306, 6501, 4835, 26284, 10606, 21840,
                              11741, 26928, 25656, 25799, 15163, 4380, 6256,
                              19173, 21303, 2736]

M1_Flow_50 = np.mean(Traffic_Flow_Before_50)
std1_Flow_50 = np.std(Traffic_Flow_Before_50)
M2_Flow_50 = np.mean(Traffic_Flow_After_50)
std2_Flow_50 = np.std(Traffic_Flow_After_50)
std_pooled_Flow_50 = np.sqrt((std1_Flow_50**2 + std2_Flow_50**2)/2)
d_Flow_50 = (M1_Flow_50 - M2_Flow_50)/ std_pooled_Flow_50

print(f'The Cohens d-value for 50 km/h roads for traffic flow is {d_Flow_50:.3}
```

```
The Cohens d-value for 50 km/h roads for traffic flow is 0.0497
```

```
#Effect Size for streets close to the Hoefkade for Traffic Flow
Traffic_Flow_Before_Close = [7727, 8255, 8635, 996, 3274, 6620, 3145, 7596,
                             2365, 5505, 25468, 29121, 1820]
Traffic_Flow_After_Close = [2353, 6162, 6954, 1567, 2006, 3070, 2089, 2964,
                           4356, 3524, 25656, 25799, 833]

M1_Flow_Close = np.mean(Traffic_Flow_Before_Close)
std1_Flow_Close = np.std(Traffic_Flow_Before_Close)
M2_Flow_Close = np.mean(Traffic_Flow_After_Close)
std2_Flow_Close = np.std(Traffic_Flow_After_Close)
std_pooled_Flow_Close = np.sqrt((std1_Flow_Close**2 + std2_Flow_Close**2)/2)
d_Flow_Close = (M1_Flow_Close - M2_Flow_Close)/ std_pooled_Flow_Close

print(f'The Cohens d-value for the streets close to the Hoefkade for traffic flo
```

```
The Cohens d-value for the streets close to the Hoefkade for traffic flow is
0.214
```

```
#Effect Size streets far from the Hoefkade for Traffic Flow
Traffic_Flow_Before_Far = [25039, 34802, 19089, 1164, 4054, 20856, 30075,
                           19141, 11547, 10708, 8635, 22568, 10934, 29796,
                           15832, 2005, 8859, 25746, 17662, 2414, 5778, 9169,
                          2290, 15713, 16082, 6749, 1891]
Traffic_Flow_After_Far = [25113, 37989, 20089, 221, 3884, 23643, 34963,
                          22841, 2306, 6501, 4835, 26284, 10606, 21840,
                          11471, 0, 1842, 26928, 15163, 4380, 6256, 6669,
                         1877, 19173, 21303, 2736, 446]

M1_Flow_Far = np.mean(Traffic_Flow_Before_Far)
std1_Flow_Far = np.std(Traffic_Flow_Before_Far)
M2_Flow_Far = np.mean(Traffic_Flow_After_Far)
std2_Flow_Far = np.std(Traffic_Flow_After_Far)
std_pooled_Flow_Far = np.sqrt((std1_Flow_Far**2 + std2_Flow_Far**2)/2)
d_Flow_Far = (M1_Flow_Far - M2_Flow_Far)/ std_pooled_Flow_Far

print(f'The Cohens d-value for the streets far from the Hoefkade for traffic flo
```

```
The Cohens d-value for the streets far from the Hoefkade for traffic flow is
0.0685
```

```
#Effect Size for Streets North of the train tracks of The Hague HS Station for T
Traffic_Flow_Before_North =[1164, 7727, 8255, 8635, 4054, 996, 3274, 6620,
                            3145, 7596, 11547, 10708, 8635, 29796, 15832,
                            2005, 8859, 2365, 5505, 25746, 25468, 29121,
                            17662, 9169, 2290, 6749, 1820, 1891]
Traffic_Flow_After_North = [221, 2353, 6162, 6954, 3884, 1567, 2006, 3070,
                            2089, 2964, 2306, 6501, 4835, 21840, 11471,
                           0, 1842, 4356, 3524, 26928, 25656, 25799, 15163,
                           6669, 1877, 2736, 833, 446]

M1_Flow_North = np.mean(Traffic_Flow_Before_North)
std1_Flow_North = np.std(Traffic_Flow_Before_North)
M2_Flow_North = np.mean(Traffic_Flow_After_North)
std2_Flow_North = np.std(Traffic_Flow_After_North)
std_pooled_Flow_North = np.sqrt((std1_Flow_North**2 + std2_Flow_North**2)/2)
d_Flow_North = (M1_Flow_North - M2_Flow_North)/ std_pooled_Flow_North

print(f'The Cohens d-value for the streets north of the HS station for traffic f
```

```
The Cohens d-value for the streets north of the HS station for traffic flow is
0.313
```

```
#Effect Size for Streets South of the train tracks of The Hague HS Station for T
Traffic_Flow_Before_South = [25039, 34802, 19089, 20856, 30075, 19141, 22568,
                             10934, 2414, 5778, 15713, 16082]
Traffic_Flow_After_South = [25113, 37989, 20089, 23643, 34963, 22841, 26284,
                            10606, 4380, 6256, 19173, 21303]

M1_Flow_South = np.mean(Traffic_Flow_Before_South)
std1_Flow_South = np.std(Traffic_Flow_Before_South)
M2_Flow_South = np.mean(Traffic_Flow_After_South)
std2_Flow_South = np.std(Traffic_Flow_After_South)
std_pooled_Flow_South = np.sqrt((std1_Flow_South**2 + std2_Flow_South**2)/2)
d_Flow_South = (M1_Flow_South - M2_Flow_South)/ std_pooled_Flow_South

print(f'The Cohens d-value for the streets south of the HS station for traffic f
```

```
The Cohens d-value for the streets south of the HS station for traffic flow is
-0.268
```

```python
#Section 5.1.2.2 Effect Size for Traffic Accidents
#Effect Size for Entirety for Traffic Accidents
Traffic_Accidents_Before = [9, 0, 5, 2, 18, 1,7, 0, 1, 4, 2, 10, 8, 12, 7,
                            7, 8, 17, 2, 2, 7, 13, 6, 0, 20, 2, 11, 11, 18,
                            8, 20, 6, 7, 6, 0, 13, 19, 9, 2, 0]
Traffic_Accidents_After = [10, 0, 11, 0, 19, 4, 7, 1, 2, 0, 0, 4, 9, 18, 13, 6,
                           6, 8, 1, 6, 10, 6, 5, 1, 13, 3, 7, 17, 21, 8,
                           21, 8, 11, 1, 2, 14, 25, 4, 1, 0]

M1_Accidents = np.mean(Traffic_Accidents_Before)
std1_Accidents = np.std(Traffic_Accidents_Before)
M2_Accidents = np.mean(Traffic_Accidents_After)
std2_Accidents = np.std(Traffic_Accidents_After)
std_pooled_Accidents = np.sqrt((std1_Accidents**2 + std2_Accidents**2)/2)
d_Accidents = (M1_Accidents - M2_Accidents)/ std_pooled_Accidents

print(f'The standard deviation of group 1 is {std1_Accidents:.5}')
print(f'The standard deviation of group 2 is {std2_Accidents:.4}')
print(f'The pooled standard deviation is {std_pooled_Accidents:.4}')
print(f'The mean of group 1 is {M1_Accidents:.4}')
print(f'The mean of group 2 is {M2_Accidents:.4}')
print(f'The Cohens d-value is {d_Accidents:.3}')
```

```
The standard deviation of group 1 is 6.0125
The standard deviation of group 2 is 6.655
The pooled standard deviation is 6.342
The mean of group 1 is 7.5
The mean of group 2 is 7.575
The Cohens d-value is -0.0118
```

```python
#Effect Size for 30 km/h roads for Traffic Accidents
Traffic_Accidents_Before_30 = [2, 18, 0, 1, 4, 2, 10, 7, 0, 20, 2, 11,
                               6, 0, 2, 0]
Traffic_Accidents_After_30 = [0, 19, 1, 2, 0, 0, 4, 6, 1, 13, 3, 7, 1, 2,
                              1, 0]

M1_Accidents_30 = np.mean(Traffic_Accidents_Before_30)
std1_Accidents_30 = np.std(Traffic_Accidents_Before_30)
M2_Accidents_30 = np.mean(Traffic_Accidents_After_30)
std2_Accidents_30 = np.std(Traffic_Accidents_After_30)
std_pooled_Accidents_30 = np.sqrt((std1_Accidents_30**2 + std2_Accidents_30**2)/
d_Accidents_30 = (M1_Accidents_30 - M2_Accidents_30)/ std_pooled_Accidents_30

print(f'The Cohens d-value for 30 km/h roads for traffic accidents is {d_Acciden
```

```
The Cohens d-value for 30 km/h roads for traffic accidents is 0.274
```

```python
#Effect Size for 50 km/h roads for Traffic Accidents
Traffic_Accidents_Before_50 = [9, 0, 5, 1, 7, 8, 12, 7, 8, 17, 2, 2, 7, 13,
                               6, 11, 18, 8, 20, 6, 7, 13, 19, 9]
Traffic_Accidents_After_50 = [10, 0, 11, 4, 7, 9, 18, 13, 6, 8, 1, 6, 10, 6,
                              5, 17, 21, 8, 21, 8, 11, 14, 25, 4]
```

```
M1_Accidents_50 = np.mean(Traffic_Accidents_Before_50)
std1_Accidents_50 = np.std(Traffic_Accidents_Before_50)
M2_Accidents_50 = np.mean(Traffic_Accidents_After_50)
std2_Accidents_50 = np.std(Traffic_Accidents_After_50)
std_pooled_Accidents_50 = np.sqrt((std1_Accidents_50**2 + std2_Accidents_50**2)/
d_Accidents_50 = (M1_Accidents_50 - M2_Accidents_50)/ std_pooled_Accidents_50

print(f'The Cohens d-value for 50 km/h roads for traffic accidents is {d_Accider
```

```
The Cohens d-value for 50 km/h roads for traffic accidents is -0.198
```

```
the Hoefkade for Traffic Accidents
18, 1, 7, 1, 4, 2, 10, 7, 2, 11, 18, 8, 2]
9, 4, 7, 2, 0, 0, 4, 6, 3, 7, 21, 8, 1, 0]

ic_Accidents_Before_Close)
fic_Accidents_Before_Close)
ic_Accidents_After_Close)
fic_Accidents_After_Close)
rt((std1_Accidents_Close**2 + std2_Accidents_Close**2)/2)
Close - M2_Accidents_Close)/ std_pooled_Accidents_Close

streets close to the Hoefkade for traffic accidents is {d_Accidents_Close:.3}')
```

```
The Cohens d-value for the streets close to the Hoefkade for traffic accidents
is 0.189
```

```
#Effect Size streets far from the Hoefkade for Traffic Accidents
Traffic_Accidents_Before_Far = [9, 0, 5, 2, 0, 8, 12, 7, 8, 17, 2, 2, 7, 13,
                                6, 0, 20, 11, 20, 6, 7, 6, 0, 13, 19, 9, 0]
Traffic_Accidents_After_Far = [10, 0, 11, 0, 1, 9, 18, 13, 6, 8, 1, 6, 10, 6,
                               5, 1, 13, 17, 21, 8, 11, 1, 2, 14, 25, 4, 0]

M1_Accidents_Far = np.mean(Traffic_Accidents_Before_Far)
std1_Accidents_Far = np.std(Traffic_Accidents_Before_Far)
M2_Accidents_Far = np.mean(Traffic_Accidents_After_Far)
std2_Accidents_Far = np.std(Traffic_Accidents_After_Far)
std_pooled_Accidents_Far = np.sqrt((std1_Accidents_Far**2 + std2_Accidents_Far*
d_Accidents_Far = (M1_Accidents_Far - M2_Accidents_Far)/ std_pooled_Accidents_Fa

print(f'The Cohens d-value for the streets far from the Hoefkade for traffic acc
```

```
The Cohens d-value for the streets far from the Hoefkade for traffic accidents
is -0.0692
```

```
#Effect Size for Streets North of the train tracks of The Hague HS Station for T
Traffic_Accidents_Before_North = [2, 18, 1,7, 0, 1, 4, 2, 10, 7, 8, 17, 2,
                                  13, 6, 0, 20, 2, 11, 11, 18, 8, 20, 6, 0,
                                  9, 2, 0]
Traffic_Accidents_After_North = [0, 19, 4, 7, 1, 2, 0, 0, 4, 6, 6, 8, 1, 6,
                                 5, 1, 13, 3, 7, 17, 21, 8, 21, 1, 2, 4, 1, 0]
```

```
M1_Accidents_North = np.mean(Traffic_Accidents_Before_North)
std1_Accidents_North = np.std(Traffic_Accidents_Before_North)
M2_Accidents_North = np.mean(Traffic_Accidents_After_North)
std2_Accidents_North = np.std(Traffic_Accidents_After_North)
std_pooled_Accidents_North = np.sqrt((std1_Accidents_North**2 + std2_Accidents_N
d_Accidents_North = (M1_Accidents_North - M2_Accidents_North)/ std_pooled_Accide

print(f'The Cohens d-value for the streets north of the HS station for traffic a
```

```
The Cohens d-value for the streets north of the HS station for traffic accident
s is 0.207
```

```
#Effect Size for Streets South of the train tracks of The Hague HS Station for T
Traffic_Accidents_Before_South = [9, 0, 5, 8, 12, 7, 2, 7, 6, 7, 13, 19]
Traffic_Accidents_After_South = [10, 0, 11, 9, 18, 13, 6, 10, 8, 11, 14, 25]

M1_Accidents_South = np.mean(Traffic_Accidents_Before_South)
std1_Accidents_South = np.std(Traffic_Accidents_Before_South)
M2_Accidents_South = np.mean(Traffic_Accidents_After_South)
std2_Accidents_South = np.std(Traffic_Accidents_After_South)
std_pooled_Accidents_South = np.sqrt((std1_Accidents_South**2 + std2_Accidents_S
d_Accidents_South = (M1_Accidents_South - M2_Accidents_South)/ std_pooled_Accide

print(f'The Cohens d-value for the streets south of the HS station for traffic a
```

```
The Cohens d-value for the streets south of the HS station for traffic accident
s is -0.618
```

Appendix E: Python Code for Correlation Analysis

```
import numpy as np
import scipy
from scipy import stats
```

```
#Section 5.2 Correlation Analysis
#Correlation coefficient for Entirety
Traffic_Flow_Before = [25039, 34802, 19089, 1164, 7727, 8255, 8635,
                       4054, 996, 3274, 6620, 3145, 20856, 30075, 19141,
                       7596, 11547, 10708, 8635, 22568, 10934, 29796,
                       15832, 2005, 8859, 2365, 5505, 25746, 25468, 29121,
                       17662, 2414, 5778, 9169, 2290, 15713, 16082, 6749,
                       1820, 1891]
Traffic_Accidents_Before = [9, 0, 5, 2, 18, 1,7, 0, 1, 4, 2, 10, 8, 12, 7,
                       7, 8, 17, 2, 2, 7, 13, 6, 0, 20, 2, 11, 11, 18,
                       8, 20, 6, 7, 6, 0, 13, 19, 9, 2, 0]

Traffic_Flow_After = [25113, 37989, 20089, 221, 2353, 6162, 6954,
                      3884, 1567, 2006, 3070, 2089, 23643, 34963, 22841,
                      2964, 2306, 6501, 4835, 26284, 10606, 21840, 11471,
                      0, 1842, 4356, 3524, 26928, 25656, 25799, 15163,
                      4380, 6256, 6669, 1877, 19173, 21303,
                      2736, 833, 446]
Traffic_Accidents_After = [10, 0, 11, 0, 19, 4, 7, 1, 2, 0, 0, 4, 9, 18, 13, 6,
                      6, 8, 1, 6, 10, 6, 5, 1, 13, 3, 7, 17, 21, 8,
                      21, 8, 11, 1, 2, 14, 25, 4, 1, 0]

correlation_before, p_before = scipy.stats.spearmanr(Traffic_Flow_Before,
                                          Traffic_Accidents_Before)
correlation_after, p_after = scipy.stats.spearmanr(Traffic_Flow_After,
                                          Traffic_Accidents_After)

print(f'The Spearmans rank correlation coefficient before the closure of the Hoe
print(f'The Spearmans rank correlation coefficient after the closure of the Hoef
```

```
The Spearmans rank correlation coefficient before the closure of the Hoefkade i
s 0.495 with a p-value of 0.00118
The Spearmans rank correlation coefficient after the closure of the Hoefkade is
0.541 with a p-value of 0.000312
```

```
#Fisher's z-transformation for Entirety
N1 = len(Traffic_Flow_Before)
z1 = 0.5*np.log((1+correlation_before)/(1-correlation_before))
std_z1 = 1/np.sqrt(N1-1)
N2 = len(Traffic_Flow_After)
z2 = 0.5*np.log((1+correlation_after)/(1-correlation_after))
std_z2 = 1/np.sqrt(N2-1)
Z = (z1-z2)/np.sqrt(std_z1**2+std_z2**2)
```

```
print(f'The z-value of the first coefficient is {z1:.3}')
print(f'The z-value of the second coefficient is {z2:.3}')
print(f'The standard deviation of z1 is {std_z1:.3}')
print(f'The standard deviation of z2 is {std_z2:.3}')
print(f'The Z-value is {Z:.3}')
```

```
The z-value of the first coefficient is 0.542
The z-value of the second coefficient is 0.606
The standard deviation of z1 is 0.16
The standard deviation of z2 is 0.16
The Z-value is -0.281
```

```
#Correlation Coefficient for 30 km/h roads
Traffic_Flow_Before_30 = [1164, 7727, 4054, 996, 3274, 6620, 3145,
                          7596, 2005, 8859, 2365, 5505, 9169, 2290, 1820,
                          1891]
Traffic_Accidents_Before_30 = [2, 18, 0, 1, 4, 2, 10, 7, 0, 20, 2, 11,
                               6, 0, 2, 0]

Traffic_Flow_After_30 = [221, 2353, 3884, 1567, 2006, 3070, 2089,
                         2964, 0, 1842, 4356, 3524, 6669, 1877, 833, 446]
Traffic_Accidents_After_30 = [0, 19, 1, 2, 0, 0, 4, 6, 1, 13, 3, 7, 1, 2,
                              1, 0]

correlation_before_30, p_before_30 = scipy.stats.spearmanr(Traffic_Flow_Before_3
                                         Traffic_Accidents_Before_30)
correlation_after_30, p_after_30 = scipy.stats.spearmanr(Traffic_Flow_After_30,
                                         Traffic_Accidents_After_30)

print(f'The Spearmans rank correlation coefficient before the closure of the Hoe
print(f'The Spearmans rank correlation coefficient after the closure of the Hoef
```

```
The Spearmans rank correlation coefficient before the closure of the Hoefkade f
or 30 km/h roads is 0.661 with a p-value of 0.00528
The Spearmans rank correlation coefficient after the closure of the Hoefkade fo
r 30 km/h roads is 0.287 with a p-value of 0.281
```

```
#Fisher's z-transformation for 30 km/h roads
N1_30 = len(Traffic_Flow_Before_30)
z1_30 = 0.5*np.log((1+correlation_before_30)/(1-correlation_before_30))
std_z1_30 = 1/np.sqrt(N1_30-1)
N2_30 = len(Traffic_Flow_After_30)
z2_30 = 0.5*np.log((1+correlation_after_30)/(1-correlation_after_30))
std_z2_30 = 1/np.sqrt(N2_30-1)
Z_30 = (z1_30-z2_30)/np.sqrt(std_z1_30**2+std_z2_30**2)

print(f'The z-value of the first coefficient for 30 km/h roads is {z1_30:.3}')
print(f'The z-value of the second coefficient for 30 km/h roads is {z2_30:.3}')
print(f'The standard deviation of z1 for 30 km/h roads is {std_z1_30:.3}')
print(f'The standard deviation of z2 for 30 km/h roads is {std_z2_30:.3}')
print(f'The Z-value for 30 km/h roads is {Z_30:.4}')
```

```
The z-value of the first coefficient for 30 km/h roads is 0.795
The z-value of the second coefficient for 30 km/h roads is 0.295
The standard deviation of z1 for 30 km/h roads is 0.258
The standard deviation of z2 for 30 km/h roads is 0.258
The Z-value for 30 km/h roads is 1.369
```

```
#Correlation Coefficient for 50 km/h roads
Traffic_Flow_Before_50 = [25039, 34802, 19089, 8255, 8635, 20856, 30075,
                          19141, 11547, 10708, 8635, 22568, 10934, 29796,
                          15832, 25746, 25468, 29121, 17662, 2414, 5778,
                          15713, 16082, 6749]
Traffic_Accidents_Before_50 = [9, 0, 5, 1, 7, 8, 12, 7, 8, 17, 2, 2, 7, 13,
                          6, 11, 18, 8, 20, 6, 7, 13, 19, 9]

Traffic_Flow_After_50 = [25113, 37989, 20089, 6162, 6954, 23643, 34963,
                         22841, 2306, 6501, 4835, 26284, 10606, 21840,
                         11741, 26928, 25656, 25799, 15163, 4380, 6256,
                         19173, 21303, 2736]
Traffic_Accidents_After_50 = [10, 0, 11, 4, 7, 9, 18, 13, 6, 8, 1, 6, 10, 6,
                         5, 17, 21, 8, 21, 8, 11, 14, 25, 4]

correlation_before_50, p_before_50 = scipy.stats.spearmanr(Traffic_Flow_Before_5
                                     Traffic_Accidents_Before_50)
correlation_after_50, p_after_50 = scipy.stats.spearmanr(Traffic_Flow_After_50,
                                     Traffic_Accidents_After_50)
print(f'The Spearmans rank correlation coefficient before the closure of the Hoe
print(f'The Spearmans rank correlation coefficient after the closure of the Hoef
```

```
The Spearmans rank correlation coefficient before the closure of the Hoefkade f
or 50 km/h roads is 0.221 with a p-value of 0.3
The Spearmans rank correlation coefficient after the closure of the Hoefkade fo
r 50 km/h roads is 0.343 with a p-value of 0.101
```

```
#Fisher's z-transformation for 50 km/h roads
N1_50 = len(Traffic_Flow_Before_50)
z1_50 = 0.5*np.log((1+correlation_before_50)/(1-correlation_before_50))
std_z1_50 = 1/np.sqrt(N1_50-1)
N2_50 = len(Traffic_Flow_After_50)
z2_50 = 0.5*np.log((1+correlation_after_50)/(1-correlation_after_50))
std_z2_50 = 1/np.sqrt(N2_50-1)
Z_50 = (z1_50-z2_50)/np.sqrt(std_z1_50**2+std_z2_50**2)

print(f'The z-value of the first coefficient for 50 km/h roads is {z1_50:.3}')
print(f'The z-value of the second coefficient for 50 km/h roads is {z2_50:.3}')
print(f'The standard deviation of z1 for 50 km/h roads is {std_z1_50:.3}')
print(f'The standard deviation of z2 for 50 km/h roads is {std_z2_50:.3}')
print(f'The Z-value for 50 km/h roads is {Z_50:.3}')
```

```
The z-value of the first coefficient for 50 km/h roads is 0.225
The z-value of the second coefficient for 50 km/h roads is 0.358
The standard deviation of z1 for 50 km/h roads is 0.209
The standard deviation of z2 for 50 km/h roads is 0.209
The Z-value for 50 km/h roads is -0.451
```

```
#Correlation Coefficient for the streets close to the Hoefkade
Traffic_Flow_Before_Close = [7727, 8255, 8635, 996, 3274, 6620, 3145, 7596,
                             2365, 5505, 25468, 29121, 1820]
Traffic_Accidents_Before_Close = [18, 1, 7, 1, 4, 2, 10, 7, 2, 11, 18, 8,2]

Traffic_Flow_After_Close = [2353, 6162, 6954, 1567, 2006, 3070, 2089, 2964,
                           4356, 3524, 25656, 25799, 833]
Traffic_Accidents_After_Close = [19, 4, 7, 2, 0, 0, 4, 6, 3, 7, 21, 8, 1]

correlation_before_Close, p_before_Close = scipy.stats.spearmanr(Traffic_Flow_Be
                                             Traffic_Accidents_Before_Close)
correlation_after_Close, p_after_Close = scipy.stats.spearmanr(Traffic_Flow_Afte
                                            Traffic_Accidents_After_Close)
print(f'The Spearmans rank correlation coefficient before the closure of the Hoe
print(f'The Spearmans rank correlation coefficient after the closure of the Hoef
```

```
The Spearmans rank correlation coefficient before the closure of the Hoefkade f
or the streets close to the Hoefkade is 0.474 with a p-value of 0.101
The Spearmans rank correlation coefficient after the closure of the Hoefkade fo
r the streets close to the Hoefkade is 0.621 with a p-value of 0.0236
```

```
#Fisher's z-transformation for the streets close to the Hoefkade
N1_Close = len(Traffic_Flow_Before_Close)
z1_Close = 0.5*np.log((1+correlation_before_Close)/(1-correlation_before_Close))
std_z1_Close = 1/np.sqrt(N1_Close-1)
N2_Close = len(Traffic_Flow_After_Close)
z2_Close = 0.5*np.log((1+correlation_after_Close)/(1-correlation_after_Close))
std_z2_Close = 1/np.sqrt(N2_Close-1)
Z_Close = (z1_Close-z2_Close)/np.sqrt(std_z1_Close**2+std_z2_Close**2)

print(f'The z-value of the first coefficient for the streets close to the Hoefka
print(f'The z-value of the second coefficient for the streets close to the Hoefk
print(f'The standard deviation of z1 for the streets close to the Hoefkade  is {
print(f'The standard deviation of z2 for the streets close to the Hoefkade  is {
print(f'The Z-value for the streets close to the Hoefkade  is {Z_Close:.3}')
```

```
The z-value of the first coefficient for the streets close to the Hoefkade is
0.516
The z-value of the second coefficient for the streets close to the Hoefkade  is
0.726
The standard deviation of z1 for the streets close to the Hoefkade  is 0.289
The standard deviation of z2 for the streets close to the Hoefkade  is 0.289
The Z-value for the streets close to the Hoefkade  is -0.515
```

```
#Correlation Coefficient for the streets far from the Hoefkade
Traffic_Flow_Before_Far = [25039, 34802, 19089, 1164, 4054, 20856, 30075,
                           19141, 11547, 10708, 8635, 22568, 10934, 29796,
                           15832, 2005, 8859, 25746, 17662, 2414, 5778, 9169,
                          2290, 15713, 16082, 6749, 1891]
Traffic_Accidents_Before_Far = [9, 0, 5, 2, 0, 8, 12, 7, 8, 17, 2, 2, 7, 13,
                                6, 0, 20, 11, 20, 6, 7, 6, 0, 13, 19, 9, 0]
```

```
Traffic_Flow_After_Far = [25113, 37989, 20089, 221, 3884, 23643, 34963,
                          22841, 2306, 6501, 4835, 26284, 10606, 21840,
                          11471, 0, 1842, 26928, 15163, 4380, 6256, 6669,
                         1877, 19173, 21303, 2736, 446]
Traffic_Accidents_After_Far = [10, 0, 11, 0, 1, 9, 18, 13, 6, 8, 1, 6, 10, 6,
                              5, 1, 13, 17, 21, 8, 11, 1, 2, 14, 25, 4, 0]

correlation_before_Far, p_before_Far = scipy.stats.spearmanr(Traffic_Flow_Before
                                             Traffic_Accidents_Before_Far)
correlation_after_Far, p_after_Far = scipy.stats.spearmanr(Traffic_Flow_After_Fa
                                            Traffic_Accidents_After_Far)
print(f'The Spearmans rank correlation coefficient before the closure of the Hoe
print(f'The Spearmans rank correlation coefficient after the closure of the Hoef
```

```
The Spearmans rank correlation coefficient before the closure of the Hoefkade f
or the streets far from the Hoefkade is 0.413 with a p-value of 0.0322
The Spearmans rank correlation coefficient after the closure of the Hoefkade fo
r the streets far from the Hoefkade is 0.477 with a p-value of 0.012
```

```
#Fisher's z-transformation for the streets far from the Hoefkade
N1_Far = len(Traffic_Flow_Before_Far)
z1_Far = 0.5*np.log((1+correlation_before_Far)/(1-correlation_before_Far))
std_z1_Far = 1/np.sqrt(N1_Far-1)
N2_Far = len(Traffic_Flow_After_Far)
z2_Far = 0.5*np.log((1+correlation_after_Far)/(1-correlation_after_Far))
std_z2_Far = 1/np.sqrt(N2_Far-1)
Z_Far = (z1_Far-z2_Far)/np.sqrt(std_z1_Far**2+std_z2_Far**2)

print(f'The z-value of the first coefficient for the streets far from the Hoefka
print(f'The z-value of the second coefficient for the streets far from the Hoefk
print(f'The standard deviation of z1 for the streets far from the Hoefkade  is {
print(f'The standard deviation of z2 for the streets far from the Hoefkade  is {
print(f'The Z-value for the streets far from the Hoefkade  is {Z_Far:.3}')
```

```
The z-value of the first coefficient for the streets far from the Hoefkade is
0.439
The z-value of the second coefficient for the streets far from the Hoefkade  is
0.519
The standard deviation of z1 for the streets far from the Hoefkade  is 0.196
The standard deviation of z2 for the streets far from the Hoefkade  is 0.196
The Z-value for the streets far from the Hoefkade  is -0.285
```

```
#Correlation Coefficient for the streets north of the HS station
Traffic_Flow_Before_North =[1164, 7727, 8255, 8635, 4054, 996, 3274, 6620,
                            3145, 7596, 11547, 10708, 8635, 29796, 15832,
                            2005, 8859, 2365, 5505, 25746, 25468, 29121,
                            17662, 9169, 2290, 6749, 1820, 1891]
Traffic_Accidents_Before_North = [2, 18, 1,7, 0, 1, 4, 2, 10, 7, 8, 17, 2,
                                  13, 6, 0, 20, 2, 11, 11, 18, 8, 20, 6, 0,
                                  9, 2, 0]
```

```
Traffic_Flow_After_North = [221, 2353, 6162, 6954, 3884, 1567, 2006, 3070,
                            2089, 2964, 2306, 6501, 4835, 21840, 11471,
                           0, 1842, 4356, 3524, 26928, 25656, 25799, 15163,
                           6669, 1877, 2736, 833, 446]
Traffic_Accidents_After_North = [0, 19, 4, 7, 1, 2, 0, 0, 4, 6, 6, 8, 1, 6,
                                 5, 1, 13, 3, 7, 17, 21, 8, 21, 1, 2, 4, 1, 0]

correlation_before_North, p_before_North = scipy.stats.spearmanr(Traffic_Flow_Be
                                             Traffic_Accidents_Before_North)
correlation_after_North, p_after_North = scipy.stats.spearmanr(Traffic_Flow_Afte
                                            Traffic_Accidents_After_North)
print(f'The Spearmans rank correlation coefficient before the closure of the Hoe
print(f'The Spearmans rank correlation coefficient after the closure of the Hoef
```

```
The Spearmans rank correlation coefficient before the closure of the Hoefkade f
or the streets north of the station is 0.677 with a p-value of 7.71e-05
The Spearmans rank correlation coefficient after the closure of the Hoefkade fo
r the streets north of the station is 0.574 with a p-value of 0.00139
```

```
#Fisher's z-transformation for the streets north of the HS station
N1_North = len(Traffic_Flow_Before_North)
z1_North = 0.5*np.log((1+correlation_before_North)/(1-correlation_before_North))
std_z1_North = 1/np.sqrt(N1_North-1)
N2_North = len(Traffic_Flow_After_North)
z2_North = 0.5*np.log((1+correlation_after_North)/(1-correlation_after_North))
std_z2_North = 1/np.sqrt(N2_North-1)
Z_North = (z1_North-z2_North)/np.sqrt(std_z1_North**2+std_z2_North**2)

print(f'The z-value of the first coefficient for the streets north of the static
print(f'The z-value of the second coefficient for the streets north of the stati
print(f'The standard deviation of z1 for the streets north of the station is {st
print(f'The standard deviation of z2 for the streets north of the station  is {s
print(f'The Z-value for the streets north of the station is {Z_North:.3}')
```

```
The z-value of the first coefficient for the streets north of the station is
0.823
The z-value of the second coefficient for the streets north of the station is
0.654
The standard deviation of z1 for the streets north of the station is 0.192
The standard deviation of z2 for the streets north of the station  is 0.192
The Z-value for the streets north of the station is 0.62
```

```
#Correlation Coefficient for the streets south of the HS station
Traffic_Flow_Before_South = [25039, 34802, 19089, 20856, 30075, 19141, 22568,
                             10934, 2414, 5778, 15713, 16082]
Traffic_Accidents_Before_South = [9, 0, 5, 8, 12, 7, 2, 7, 6, 7, 13, 19]
```

```
Traffic_Flow_After_South = [25113, 37989, 20089, 23643, 34963, 22841, 26284,
                            10606, 4380, 6256, 19173, 21303]
Traffic_Accidents_After_South = [10, 0, 11, 9, 18, 13, 6, 10, 8, 11, 14, 25]
```

```
correlation_before_South, p_before_South = scipy.stats.spearmanr(Traffic_Flow_Be
                                            Traffic_Accidents_Before_South)
correlation_after_South, p_after_South = scipy.stats.spearmanr(Traffic_Flow_Afte
                                           Traffic_Accidents_After_South)
print(f'The Spearmans rank correlation coefficient before the closure of the Hoe
print(f'The Spearmans rank correlation coefficient after the closure of the Hoef
```

```
The Spearmans rank correlation coefficient before the closure of the Hoefkade f
or the streets south of the station is -0.106 with a p-value of 0.744
The Spearmans rank correlation coefficient after the closure of the Hoefkade fo
r the streets south of the station is -0.179 with a p-value of 0.578
```

```
#Fisher's z-transformation for the streets south of the HS station
N1_South = len(Traffic_Flow_Before_South)
z1_South = 0.5*np.log((1+correlation_before_South)/(1-correlation_before_South))
std_z1_South = 1/np.sqrt(N1_South-1)
N2_South = len(Traffic_Flow_After_South)
z2_South = 0.5*np.log((1+correlation_after_South)/(1-correlation_after_South))
std_z2_South = 1/np.sqrt(N2_South-1)
Z_South = (z1_South-z2_South)/np.sqrt(std_z1_South**2+std_z2_South**2)

print(f'The z-value of the first coefficient for the streets south of the statio
print(f'The z-value of the second coefficient for the streets south of the stati
print(f'The standard deviation of z1 for the streets south of the station is {st
print(f'The standard deviation of z2 for the streets south of the station  is {s
print(f'The Z-value for the streets south of the station is {Z_South:.3}')
```

```
The z-value of the first coefficient for the streets south of the station is
-0.106
The z-value of the second coefficient for the streets south of the station is
-0.181
The standard deviation of z1 for the streets south of the station is 0.302
The standard deviation of z2 for the streets south of the station  is 0.302
The Z-value for the streets south of the station is 0.176
```

Appendix F: Figure 6 Enlarged

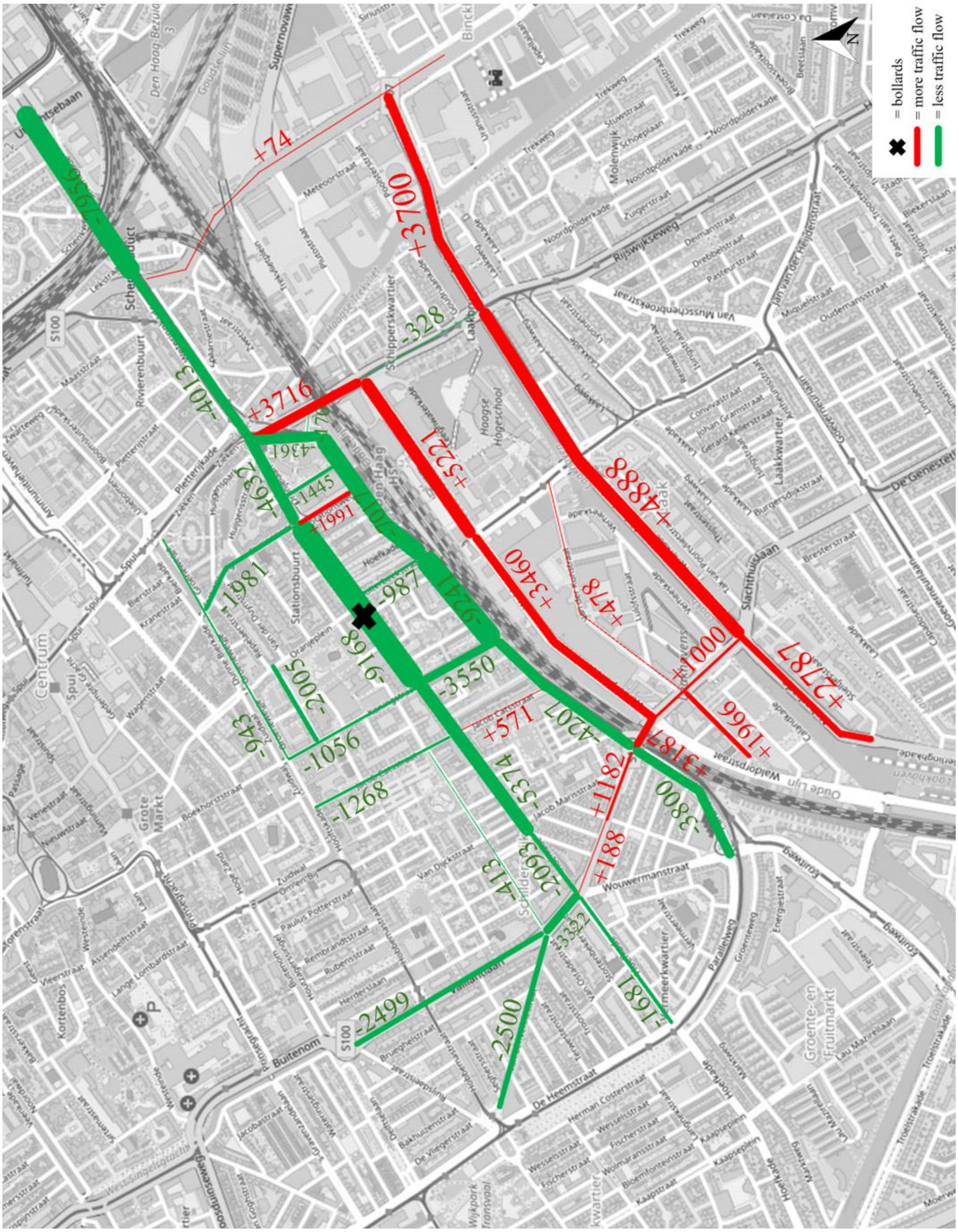

Figure 8. An enlarged version of Figure 6 (OpenStreetMap, 2024)

Appendix G: Figure 7 Enlarged

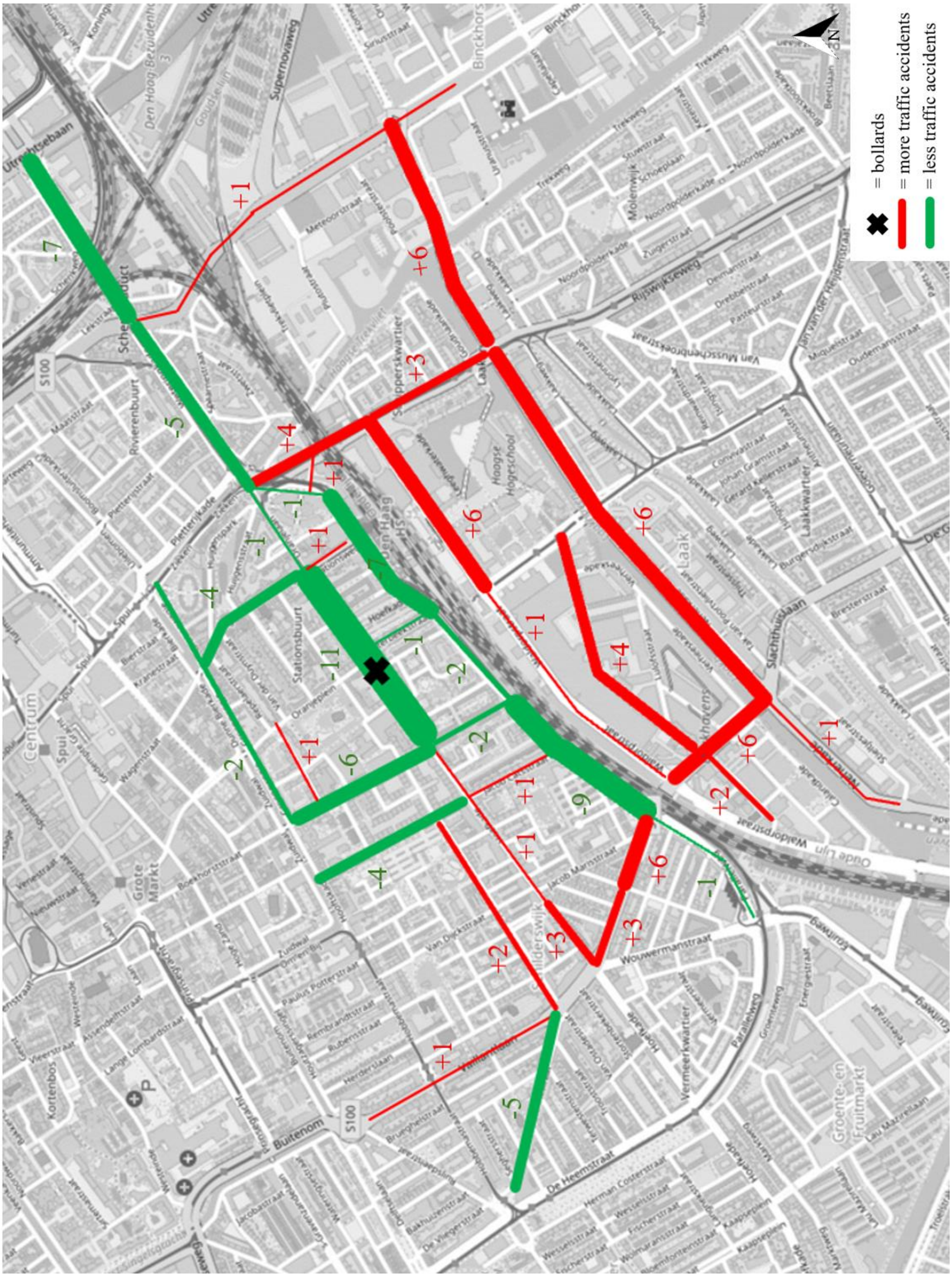

Figure 9. An enlarged version of Figure 7 (OpenStreetMap, 2024)

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