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Benefits of Partial Road Closures

An Analysis of the Effects on Quality of Life from the Nørrebrogade Road Closures

An Interactive Qualifying Project Report completed in partial fulfillment of the Bachelor of Science degree at Worcester Polytechnic Institute, Worcester, MA.

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Abstract

Nørrebrogade was a busy street in Copenhagen, Denmark that suffered from excessive traffic congestion, air and noise pollution. In October 2008 the City of Copenhagen began several experimental road segment closures on Nørrebrogade. The goal of this project, sponsored by Miljøpunkt Nørrebro (Agenda 21), was to investigate changes in quality of life that have resulted from the trial closures on Nørrebrogade and was accomplished through a traffic flow analysis, motor vehicle emissions calculations, noise level calculations, and surveying and interviewing stakeholders. The team determined that traffic had been reduced on Nørrebrogade by 50-80%, traffic-related pollution emissions were reduced by 35-80%, and noise levels were lowered by 3-6dB (50–75%)along Nørrebrogade. Additionally, surveys revealed an increase in perceived safety and a calmer atmosphere on Nørrebrogade, though some businesses claimed to be suffering due to the closure. Overall, the closure has positively affected the health-related quality of life of people on Nørrebrogade.

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Authorship Page

Each team member listed on the cover page contributed equally by writing and reviewing all sections of the report as well as performing calculations and conducting surveys.

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Executive Summary

Agenda 21 is a program created by the United Nations to promote sustainability in urban areas throughout the world. The Municipality of Copenhagen funds several Agenda 21 centers including the Agenda 21 center located in Nørrebro, Copenhagen. Now called Miljøpunkt Nørrebro, this Agenda 21 center has been dedicated to promote sustainability and environmentalism in the densely populated and multicultural Nørrebro neighborhood. Running through Nørrebro, Nørrebrogade is a narrow and well-traveled road that links Northwest Copenhagen to the city centre. Before October 2008, approximately 11,000 motor vehicles traveled daily along Nørrebrogade during business and rush hours, plaguing the neighborhood with traffic congestion and excess noise and air pollution. As an attempt to improve the conditions in Nørrebro, experimental plans were created to reduce private motor traffic along Nørrebrogade, while increasing the speed and use of public transportation, and better conditions for cyclists on Nørrebrogade.

The experimental plans consisted of various restrictions on private motor traffic, preventing vehicles from entering certain segments of Nørrebrogade, and controlling the types of turns these vehicles could make at particular intersections. The first trial began in October of 2008 and the third trial was underway at the time of this study. Figure 1 displays the chaotic atmosphere along Nørrebrogade before the closures and the relaxed atmosphere after the closures.

Figure 1: Nørrebrogade before and after the road closures (EcosistemaUrbano, 2009 and Dr. Politiken, 2008, respectively).

Placing these restrictions on a well-traveled, residential and commercial road generated many positive and negative effects on the surrounding neighborhood. In accordance with Miljøpunkt Nørrebro, we have investigated the changes in quality of life along Nørrebrogade that have resulted from the road closure trials. The primary focus was to investigate the reductions in traffic-related noise and air pollution, and their possible effects on the health of residents and employees of Nørrebrogade. In addition, anecdotal opinions of the local residents, shoppers, and business owners were obtained to gain additional insights regarding changes in safety, business, and the atmosphere along Nørrebrogade. The investigation began with research into the meaning of quality of life, case studies of similar road closures, and how traffic-related noise and air pollution affect the human body.

While there are many definitions of quality of life, the health-related quality of life (HRQoL) presented by the Centers for Disease Control and Prevention is divided into two main categories: mental and physical. In terms of our project, stress is the most important aspect of mental health, while the effects of air pollution and some effects of noise pollution can be associated with physical health. In addition to these health needs, safety needs and financial needs are also parts of quality of life that are important to this project.

Numerous long-term studies have shown that noise pollution as well as air pollutants from road traffic, such as carbon monoxide (CO), nitrous oxides (NO_x), hydrocarbons (HC), and particulate matter (PM), cause many adverse health effects. Health effects from air pollution are typically respiratory in nature, including well-known ailments like asthma and bronchitis. Noise pollution is usually associated with increased stress, sleep disturbance, and elevated blood pressure. Studies on these health effects must be conducted over a long period of time because the adverse effects of these pollutants usually take several years to occur in any significant or measurable way. Since the road closure trials began only a year and half before this study was conducted, most health changes cannot be observed yet.

In order to determine the change in noise and air pollution on Nørrebrogade, detailed information regarding the change in traffic on Nørrebrogade was needed. As such, the first objective of the project was to calculate the change in traffic in the Nørrebro area, particularly for Nørrebrogade. Traffic data were obtained from the City of Copenhagen for various reading locations on and around Nørrebrogade. The traffic readings contained counts for different vehicle categories during each hour of the day between 7:00 and 18:00. The team created an organizational system for the traffic data and a mathematical model to calculate the change in traffic at selected reading locations. Nørrebrogade itself was divided into four segments composed of multiple reading locations with similar vehicle counts. The results of our calculations indicated that traffic decreased between 50% and 80% along the segments of Nørrebrogade when compared to data from before the closure. Many additional streets in the Nørrebro area also experienced varying degrees of reduction in motor traffic, though some reading locations did increase in traffic. The experimental road closures have enabled public transportation to traverse Nørrebrogade more efficiently and have increased safety for cyclists.

To estimate changes in air quality along Nørrebrogade and assess the impact of these changes on peoples' health, the relative change in traffic-related pollution emitted on each of the four segments was calculated. The average number of vehicles in each of several vehicle categories, fuel consumption, fuel type, and emission factors were used to find the change in several traffic-related air pollutants: carbon monoxide, nitrous oxides, hydrocarbons, and particulate matter. We calculated varying reductions in traffic-related air pollution depending on the pollutant and segment of Nørrebrogade. Nitrous oxides experienced the smallest reduction. On the south end of Nørrebrogade, NO_x was only reduced by approximately 35%. Carbon monoxide was reduced the most along Nørrebrogade. In the mid-south section of Nørrebrogade, which contains the segment closed during all trials, CO was reduced by approximately 80%. All other reductions in pollution were in between these two extreme values.

A reduction in pollution of this magnitude will most likely result in several long-term health benefits. The pollutants studied are known to cause damage to Clara cells in the lungs, increase the chance of asthma onset in children, cause bodily damage due to benzene metabolites, increase the risk of childhood cancers, and cause dangerous clots in the lungs and brain, in addition to many other known or hypothesized health concerns. Lowered pollution levels for an extended period of time will reduce the detrimental health effects of these pollutants.

The team also analyzed the effects of changes in noise levels on Nørrebrogade on peoples' health. The Danish Environmental Protection Agency (Miljøministeriet) estimated the noise levels on Nørrebrogade to be over 75dB during the day, and 65-

70dB at night. These values result in a weighted average noise level that is significantly higher than the recommended 58dB L_{den} noise level for an urban residential road like Nørrebrogade. For each of the four Nørrebrogade road segments, we were able to estimate the reduction in road traffic noise levels based on the percent reduction in road traffic. We estimate that noise levels on Nørrebrogade have been reduced by approximately 3-6dB, or 50-75%, depending on which part of Nørrebrogade is considered. Though the reduction in noise does not reduce noise levels below the recommended values, a reduction of this magnitude still may have a positive impact on peoples' health. Noise pollution has been associated with many increases in physiological and socio-psychological ailments. Physiological problems include myocardial infarction, ischemic heart disease, systolic blood pressure, and poor sleep quality. Socio-psychological problems include stress and aggressive behavior. Since Nørrebrogade's noise levels were estimated to be over 75dB, these harmful effects were most likely present amongst those exposed. A reduction of 3-6dB is likely to reduce the percentage of people who suffer from these problems. Furthermore, since noise pollution reduces property values, a decrease in noise along Nørrebrogade can increase the property value of apartments, bringing economic growth to Nørrebro.

Finally, we surveyed and interviewed 75 people along Nørrebrogade, 27 of which were shop owners or employees, in order to collect anecdotal evidence regarding other impacts on quality of life from the segment closures. Questions on topics such as transportation, safety, health, shopping, and business were asked. Based on these surveys, we concluded that the road segment closures had mixed effects on stakeholders. According to our surveys and interviews, the reduction in traffic on Nørrebrogade created a calmer and safer environment for many. Respondents who reported that Nørrebrogade felt calm or very calm increased from 25% to 39% and the number of respondents who classified Nørrebrogade as somewhat or totally chaotic decreased from 41% to 32%. The percentage of respondents who reported that Nørrebrogade became safer after the road closures was 63%. Since safety is a major factor in quality of life, those who feel safer since the road closure may have experience an increase in quality of life.

Many shopkeepers along Nørrebrogade believed that their businesses were suffering from the closures. Some losses in business could also be attributed to the global economic recession, although it was clear that businesses whose patrons used private vehicles to transport purchased items were negatively impacted. On the other hand, some businesses such as cafés or bicycle shops reported either improvements or no change in their businesses. Decrease in business causes both stress and a decrease in financial security, both of which lead to a decrease in quality of life for the owners and employees of the effected establishments. Businesses that are suffering from the road closures will have to adapt to the road closures, close, or move to a different location. The businesses that permanently close or move off Nørrebrogade will be replaced with businesses more suited for Nørrebrogade's new environment. Also, residents and shoppers who are dependent on their private motor vehicles and who do not want to change their transportation will move and potentially be replaced with residents who wish to live in areas with restrictions on private motor vehicles.

In order to increase the likelihood of seeing continual improvements in quality of life, we recommend keeping the road segments closed. If traffic levels remain lowered, then we expect that benefits will continue to increase. Additionally, we recommended that local health establishments and researchers initiate cohort studies that observe the relationship between reducing traffic and traffic-related health problems such as asthma and poor sleep quality in the residents of Nørrebro. Although Nørrebrogade's population size may be too small to support significant statistics for the cohort studies, the information obtained may still be of interest to many organizations, including Miljøpunkt Nørrebro. Furthermore, should the City of Copenhagen plan additional road closures in Copenhagen, we recommend establishing a stronger baseline of information before any of the changes begin, so more statistically sound conclusions can be made regarding traffic, air pollution, noise levels, and health concerns.

Overall, we believe that the road closures have had a positive effect on the quality of life along Nørrebrogade for the vast majority of stakeholders. The negative effects of the closures should be taken into consideration when planning future projects; however, in an experimental project such as this, it is impossible to eliminate all negative side effects. Since the road closures greatly reduced traffic, noise, and air pollution while increasing the efficiency of public transportation and safety for cyclists, we deem the road closures a great success and hope that other cities across the globe utilize the Nørrebrogade road closures as an urban planning model.

Chapter 1: Introduction

For the past several decades, countries around the world have been faced with increasing motor vehicle congestion, resulting in cities plagued with both air and noise pollution creating inconvenient and harmful conditions for residents, employees, patrons, and travelers. Traffic-related air and noise pollution can have detrimental effects on the quality of life of those who live, work, or frequent areas with traffic congestion. The health-related quality of life may be at the greatest risk for those experiencing excessive traffic-related air and noise pollution. Even the best-planned cities can witness heavy traffic congestion, face air pollution problems, or have to deal with unnecessarily loud noise levels.

Urban planners have developed many strategies in order to alleviate traffic congestion and pollution in attempt to improve an area's quality of life, which can include health, safety, and happiness. These methods include traffic calming, urban traffic control, rerouting traffic, banning traffic, increasing public transportation options and availability, urban road pricing, developing priority routes, and establishing parking controls (Crabbe & Elsom, 1998). In 2008, city officials and organizations in Copenhagen, Denmark launched a project aimed at alleviating traffic congestion and improve conditions for public transportation and cyclists in the densely populated urban neighborhood of Nørrebro. The project planned to close sections of Nørrebrogade, a 2.2km road that connects the northwest neighborhoods to the city center. Multiple trials experimented with closing different sections of Nørrebrogade to personal motor vehicle traffic beginning in October 2008. Although Nørrebrogade is a well traveled road with many businesses and residents, the Municipality of Copenhagen lacks extensive research on how the closures have impacted the Nørrebro.

Researchers around the world have studied the effects of traffic-related pollution on human health extensively. Studies have found possible links between traffic-related air pollution and the following health problems: increased asthma symptoms (Chen et. al., 2008), increased hospital visits for respiratory problems (Buckeridge et. al, 2002), lung cancer (Cohen, 2000), rheumatoid arthritis (Hart et. al, 2009) and many others. A World Health Organization publication links noise pollution to hearing impairment, sleep disturbance, ischemic heart disease and hypertension, mental illnesses, impaired cognitive skills, annoyance, and aggressive behavior (Berglund et. al, 1999).

Additionally, engineers have designed several forms of pollution-reduction equipment to install in motor vehicles including particle filters and selective catalytic reduction (Press-Kristensen, 2009).

Despite the large amount of research that has gone into developing traffic control systems to reduce air pollution in cities, little direct research has been done to link street closures to quality of life. In 2009, a team from Worcester Polytechnic Institute measured the reduction in traffic around Nørrebrogade as a result of trial road closures; however, this study focused mainly on traffic flow and did not include an analysis of pollution levels due to the reduction in motor traffic. Another study analyzing air pollution on Nørrebrogade was commissioned and the researchers discovered that ultrafine particles (UFP), a component of air pollution, decreased linearly with the traffic reduction from the road closure (Olsen, A. et. al, 2009). The project, however, did not link the decrease in UFP to quality of life of the area residents, employees, shop owners, and commuters. Since this study only investigated UFP, a reduction in other air pollutants and noise levels and their impact on the quality of life has still not been researched. Furthermore, there has been little research on other aspects of quality of life that the road closures may have affected, including safety and ambiance.

This project was designed to help Agenda 21 investigate the impact on quality of life for local residents, employees, commuters, shoppers, and establishments due to the Nørrebrogade road closures. This was accomplished by researching changes in air quality and noise levels and surveying stakeholders. The team calculated the change in traffic on and around Nørrebrogade due to the road closures. These data were used to estimate differences in air and noise pollution levels on Nørrebrogade. The team then investigated potential changes in health that might occur from the calculated differences in air quality, and determined probable health and economic consequences that may result from changes in noise levels. In order to obtain additional perspectives on the road closures, the team surveyed stakeholders regarding their expectations and thoughts on the closing of Nørrebrogade. At the conclusion of the project, the team was able to provide Agenda 21 Nørrebro with quantitative evidence that shows the road closures reduced air and noise pollution and qualitative evidence that shows that the road closures have positively affected the atmosphere and safety along Nørrebrogade and the lives of many in the Nørrebro area, resulting in an increase in quality of life.

Chapter 2: Background

This chapter will discuss many of the topics that are relevant to the affects of a road closure. Many factors relate quality of life to road closures. The topics discussed in the background will include a detailed investigation into the meaning of quality of life, motor vehicle pollutants, traffic variables that affect air and noise pollution, and other methods of reducing traffic and their affects on an area.

An analysis of the concepts in our background is critical in order to understand how air and noise pollution can affect the health of people who reside, work, or use busy streets. The phrase "quality of life" is broad and can consist of many different concepts so it is important that all aspects are covered, including the way we define "quality of life" in this project. Additionally, other methods of traffic alleviation and road closure case studies will be discussed in order demonstrate that the project presented in this report is a new concept. Our research will help us identify the benefits or concerns regarding quality of life from closing a section of a busy street in Copenhagen.

2.1 A Brief Description of Nørrebrogade

Located in Nørrebro, Nørrebrogade is a busy street in northwestern Copenhagen. Nørrebrogade begins at the Dronning Louises Bro, one of four bridges that extend across Pedlingesø, a body of water in central Copenhagen. The road goes straight north and west until it turns into Frederikssundsvej. The stretch called Nørrebrogade is about 2.2km long, and is highlighted in blue in Figure 2.

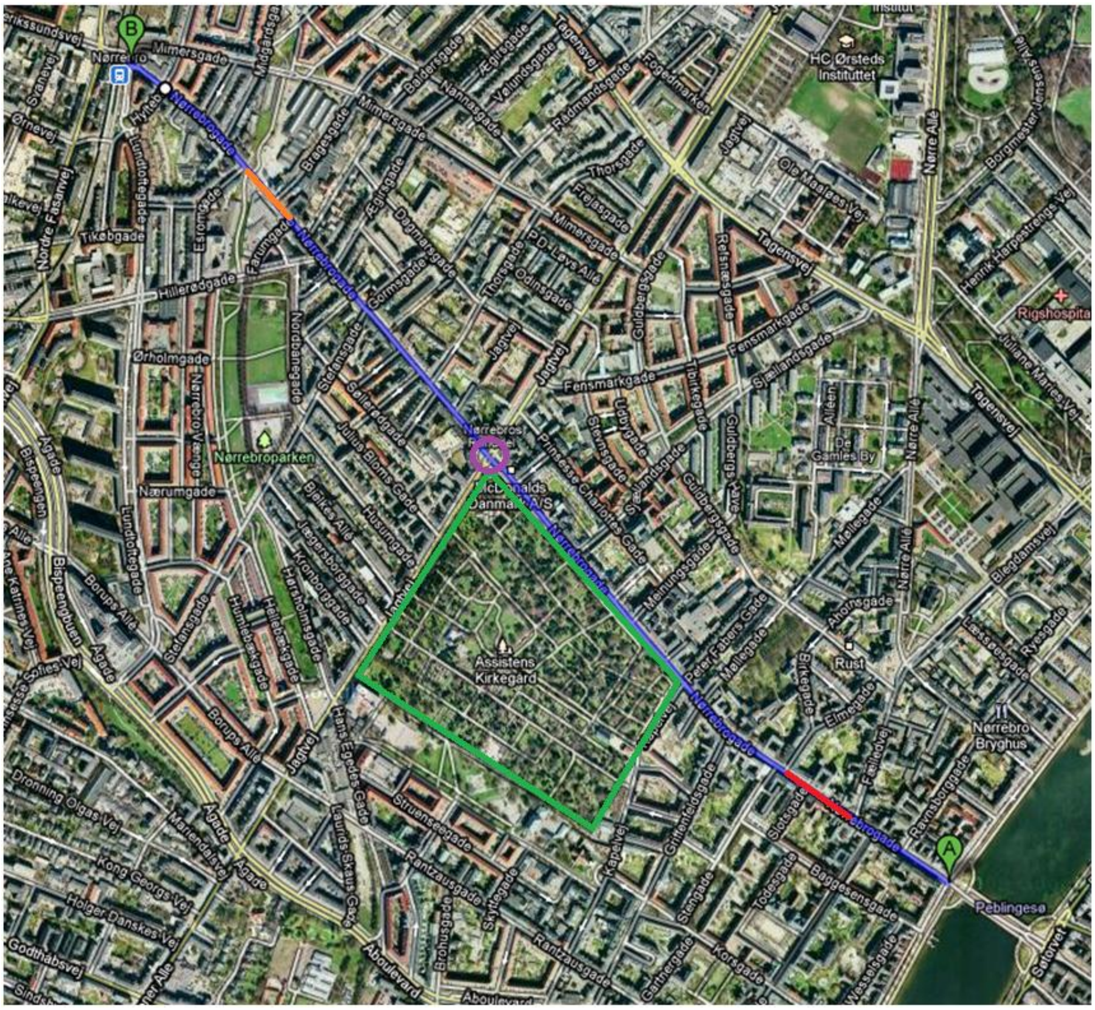

Figure 2: Nørrebrogade Satellite Image. Original image from Google Maps.

As can be seen in Figure 2, there is a large cemetery along part of Nørrebrogade, which is outlined in green. Around the midpoint of Nørrebrogade, there is a large rotary, outlined in purple. On October 1st, 2008 the first trial closure began and two road segments were closed to private motor vehicles. Only bicycles and public transportation were allowed in these areas. The two road segments are highlighted in orange and red in Figure 2. Also during trial 1, private motor vehicles could not pass straight through the rotary, highlighted in purple on the map, and had to turn off of Nørrebrogade. Furthermore, private motor vehicles traveling down Søtorvet, a road segment perpendicular to the south end of Nørrebrogade across the bridge, could not turn onto Nørrebrogade.

On May 17, 2009, Trial 1 ended and a second trial began. This trial allowed private motor vehicles to pass straight through the rotary and continue on Nørrebrogade. During trial 2, the orange and red sections were still closed off to private motor vehicles and private motor vehicles traveling down Søtorvet could not turn down Nørrebrogade.

Trial 2 ended and Trial 3 began on March 11, 2010. Trial 3will continue until sometime in the summer of 2010. The section in red remained closed while the orange section was opened up to private motor vehicle traffic. Vehicles are once again not allowed to pass through the rotary and remain straight on Nørrebrogade and cars traveling down Søtorvet can still not turn down Nørrebrogade (Københavns Kommune, 2010). A three-way comparison of Trials 1-3 is displayed in Figure 3. The red arrows in Figure 3 indicate where private motor vehicles are not allowed to pass.

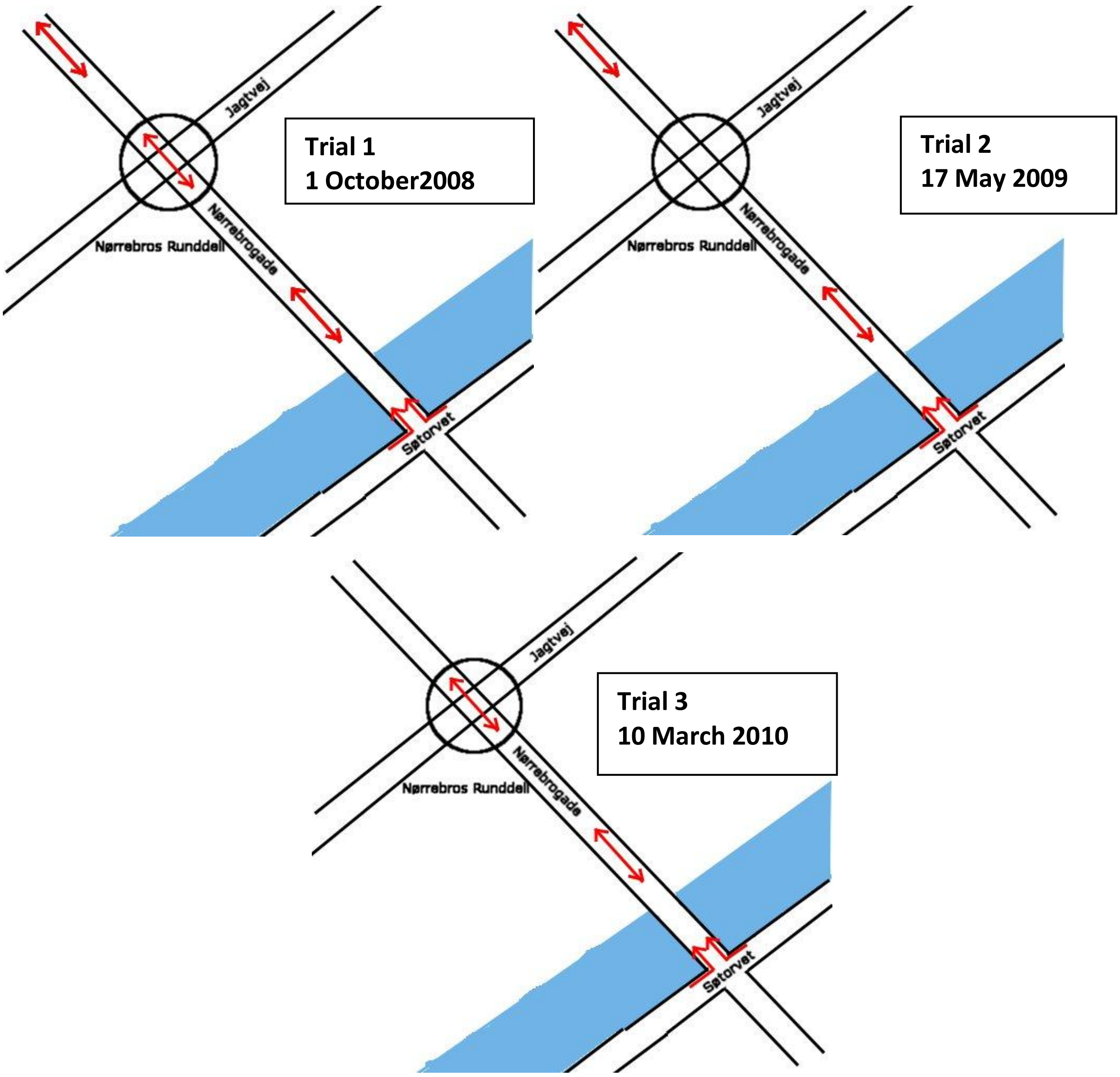

Figure 3: The Nørrebrogade Road Closing Trials 1-3 comparison.

Along the road there are many small shops, various restaurants, pastry shops, and apartments. In particular, there are many Middle-Eastern restaurants, clothing shops, and bike shops. Buildings along Nørrebrogade are typically around five stories tall. Ground floors are often commercial, while the upper floors are typically residential.

Nørrebrogade has two lanes for motor traffic, one moving in each direction. There is a lane for bicycles on each side of the road, and sidewalks for pedestrians. Before the trial road closures, traffic on Nørrebrogade was typically heavy, especially during peak rush hour traffic. This was part of the motivation for the Traffic Study Interactive Qualifying Project from 2009. The trial road closure reduced traffic on Nørrebrogade, as the Traffic Study IQP explains (see Appendix B).

2.2 Quality of Life

Philosophers for centuries have contemplated the meaning of "quality of life". Aristotle once said, "The quality of life is determined by its activities." Defining and categorizing the elusiveness behind quality of life has gained momentum over the last century and became the center of much research. The following section explores several different theories of quality of life. Also, the relationship between owning a motor vehicle and quality of life is explored and how the desire to own a motor vehicle can create an imbalance in our needs and wants.

2.2.1 What is Quality of Life?

Abraham Maslow, a humanist physiologist from the early mid 20th century, believed that quality of life is defined by eight categories of needs. These needs are physiological, safety, belonging, esteem, understanding, self-actualization, and transcendence. Maslow entitled these eight needs as the Hierarchy of Needs that contributes to the happiness of an individual, which according Maslow is the outcome when all needs are satisfied (Boeree, 2006). As seen in Figure 4 below, physiological needs are the foundation of the quality of life. Directly above physiological needs are safety needs, which include health, security, and protection (Boeree, 2006). Using the Maslow hierarchy of needs can help determine the quality of life.

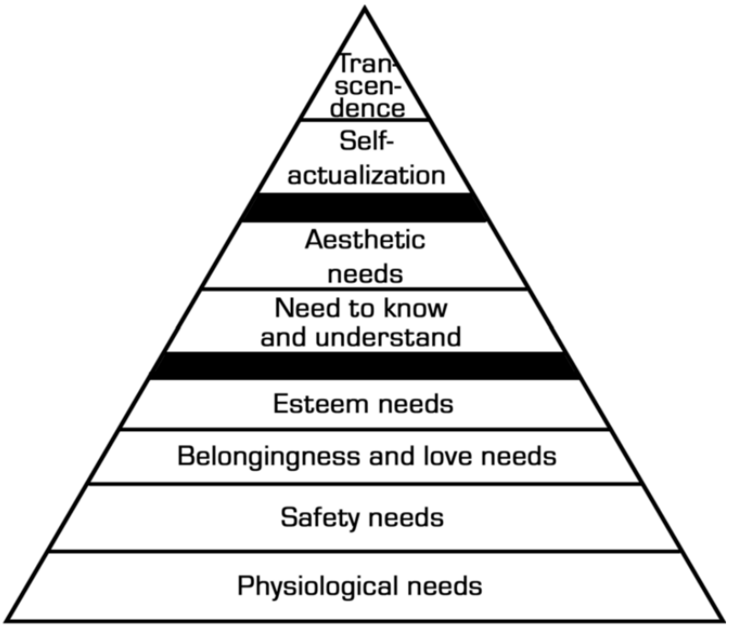

Figure 4: Hierarchy of Needs (Ventegodt et. al, 2003)

Additionally, The Economist Intelligence Unit (EIU) developed a system to determine the quality of life called the quality of life index. The EIU is a global research and advisory firm that investigates countries to provide businesses with information for making informed decisions. In 2005, the EIU divided the quality of life into nine areas for their quality of life index system. The EIU quality of life index areas are material wellbeing, health, political stability and security, family life, community life, climate and geography, job security, political freedom, and gender equality. In order to provide clients with information on different countries, the EIU ranks countries according to the nine areas and provides reasons why the country ranked accordingly.

Ferrans and Powers also developed a quality of life model, which describes quality of life as the sense of well being one feels based on satisfaction by personal factors. The Quality of Life Index developed by Ferrans and Powers is divided into four main domains that include health, psychology and spirituality, social and economics, and family. Many surveys based on these domains exist in order to quantify an individual's quality of life. In addition, this model stresses that diseases significantly lower the quality of life index for an individual (Ferrans& Powers, 1987).

Despite the differences in the Maslow, EIU, and Ferrans& Powers quality of life models, they have several aspects in common, including health. Since health appears in the three models above, it is an important aspect in determining the quality of life. The Center for Disease Control and Prevention (CDC) has performed extensive research in the field of health-related quality of life (HRQoL). HRQoL is divided into two main categories, mental and physical. An individual's HRQoL can be determined by examining the number of mentally and physically healthy or unhealthy days the individual had in a 30 day period. In 2009, the CDC reported that diseases increase the number of unhealthy days an individual has in a month. Furthermore, the CDC reported that stress negatively affects mental and physical HRQoL.

Many factors contribute to the quality of life as demonstrated by the Maslow, EIU, and Ferrans& Powers models. When our basic physiological and safety needs are filled, our aspirations and wants begin to drive us. When our wants and aspirations are filled, the higher levels of the Maslow Hierarchy of Needs pyramid are satisfied; however, the higher levels of the pyramid can be in conflict with the basic levels. An example of a want from the higher levels of the pyramid that can affect our basic needs is to own a motor vehicle.

2.2.2 Motor Vehicles, Traffic, and Quality of Life

Motor vehicles were originally invented for convenience. As years passed and inventions improved, the automobile, obsessions with speed, beauty, prestige, and danger began to drive the want for automobiles. Obtaining an automobile, whether it is for independence, power, prestige, or a combination, can greatly increase the individual quality of life (Gärling and Steg, 2007). Many societies have been built around the convenience of owning of motor vehicles such as the United States. In modern times, it is commonplace for households in many countries to have more than one car. In the US, the number of vehicles per household has dramatically increased since 1969, yet the number of persons per household has decreased (US Federal Highway Administration, 2003). This trend is displayed in Figure 5 below.

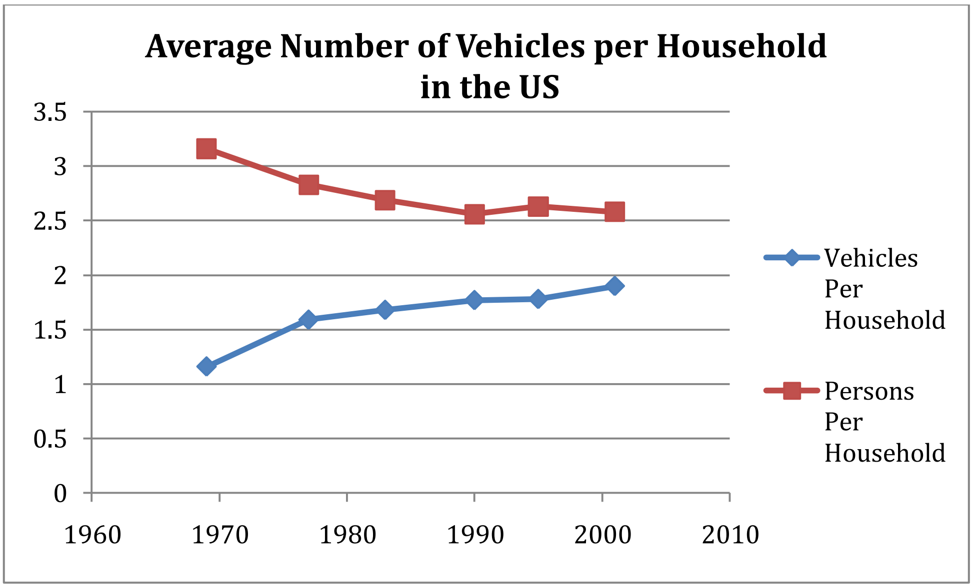

Figure 5: Number of Vehicles per Household in the US and how many people per household (Adapted from US Federal Highway Administration, 2003).

The spiraling number of motor vehicles has caused a severe problem in cities across the world, namely traffic congestion. There are many factors that produce traffic congestion. In the book, *Threats from Car Traffic to the Quality of Urban Life*, authors Tommy Gärling and Linda Steg examine the relationship between humans, car ownership, traffic, and quality of life in urban areas. Gärling and Steg explain that air and noise pollution created by motor vehicle traffic can have a detrimental impact on the quality of life in cities. Many researchers have investigated the negative affects traffic has on quality of life.

According to 2005 The Environmental Health Committee Ontario College of Family Physicians reported that traffic can have detrimental effects on the quality of life of residents and commuters. Traffic congestion increases the length of commutes, which detracts from leisure. As a result, stress accumulates, which overall has adverse effects on people's well being. Furthermore, The Environmental Health Committee reported that aggressive driving known as "Road Rage" is more prominent in urban traffic congestion.

In addition, Swiss researchers studied the effects of traffic noise on health related of quality of life. A group of 5,021 Swiss adults ranging from 28-72 years of age from the Swiss Cohort Study of Air Pollution and Lung Disease in Adults (SAPALDIA) filled out a survey regarding traffic noise and their HRQOL. Members of SAPALDIA reside in a variety of environments including rural and urban areas. The surveys investigated mental and physical health, living conditions, lifestyle, and social-economics of the participants. Each participant scored the areas between 0 and 100 where 0 was the worst and 100 the best. The participants were specifically asked, "How annoying is the noise from traffic in your home when the windows are open?" which was scored on a scale 0-10, where 0 represented no annoyance and 10 unbearable annoyance. After a statistical analysis, the researchers determined that 13% or 652 of the 5021 participants scored traffic annoyance above or equal to 7. The participants who scored traffic annoyance above or equal to 7 had lower average health quality of life scores than the participants who were less annoyed with traffic noise levels. A correlation between factors such as gender, age, education, and number of years living in current location affected the traffic noise annoyance levels. Older residents and women were more likely to report traffic annoyance as greater than or equal to 7 (Dratva*et. al*, 2009).

Traffic-related air pollution and quality of life have also been extensively researched. Since 2005, a large group of European researchers called ALPNAP, collaborated to investigate traffic pollution and its effects on health and well being in the Swiss Alps. At the end of 2007, ALPANP reported that traffic related air pollution lowers the overall health and quality of life for residents in the Alps. The report also suggested that traffic-related air pollution aggravates respiratory illnesses such as asthma and bronchitis, which again, according to the Ferrans and Powers Quality of Life Index is detrimental to an individual's well being. Additionally, the ALPANP study discovered that individuals who were unaware of traffic emissions' effects on health were less likely to consider air pollution when determining their own quality of life. Figure 6 below displays the links ALPNAP discovered between quality of life and traffic. According to this figure, the surrounding landscape and weather influence traffic emissions that include both noise and air pollution. Noise and air pollution then affect the quality of life of residents. Though ALPNAP's model shows links between traffic-related air and noise pollution, it does not include other factors such as safety and aesthetics.

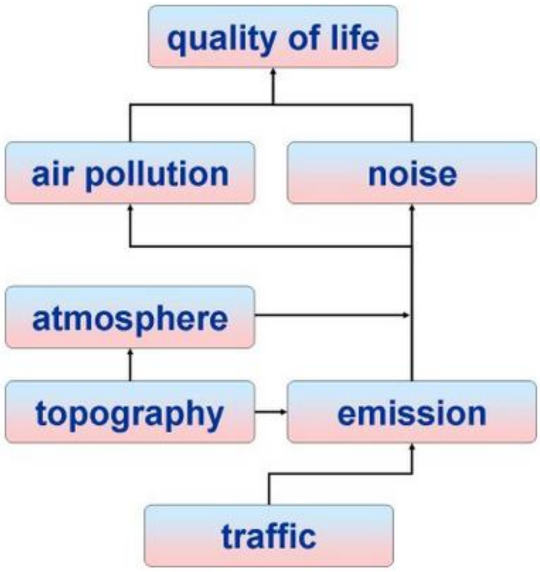

Figure 6: Possible links between traffic and quality of life (ALPNAP, 2008)

Many cities across the world have attempted to combat traffic congestion. Urban planning, public transportation, and advocating for alternative methods of transportation such as cycling, are ways cities are fighting to alleviate traffic congestion. Copenhagen, Denmark has been efficiently utilizing these methods of traffic alleviation and was voted as the top city to live in by Monocle Magazine in 2008. Monocle's annual survey searches worldwide to find the 25 top cities to live in by researching the quality of life in hundreds of cities. The survey takes into account areas such transport, public health, education, security, and environment, which may affect the quality of life. The editor in chief of Monocle, Tyler Brûlé, expressed in a video interview that urban design improves quality of life for citizens (Wonderful Copenhagen, 2008). He also suggested that bicycles give the Danish a sense of freedom and coziness. According to the Cycling Embassy of Denmark, approximately 83% of Danes own bicycles. With a 200% luxury tax on new cars (Perry, 2009), it appears that the lack of motor vehicle ownership does not necessary affect the quality of life in Denmark negatively. Though Copenhagen has done a tremendous job in battling traffic congestion, the city still has traffic issues and continues to implement innovative methods such as road closings in the fight against traffic.

2.3 Road Closure Case Studies

Opportunities to get true empirical evidence regards the effects of road closures are rare, but some do exist. Some of the following case studies focus on the impact of road closures on traffic, while others focus on air quality, noise levels, or other results.

2.3.1 Boston, MA, United States

In 2004 an opportunity to measure and analyze the effects of short-term road closures in Boston, Massachusetts became available. Several large highways were closed during certain hours due to the Democratic National Convention, which was taking place in Boston at that time. A team of investigators took the necessary steps to capture data regarding the overall air pollution levels and distribution across the city of Boston. By measuring traffic volume, nitrogen dioxide levels, and elemental carbon before, during, and after the highway closures, the team was able to gather significant data that indicated that air pollution was reduced near the closed highways. Figure 7, below, shows the closed roads and the location of air pollution monitoring sites. The investigators chose sites where they hypothesized concentration decreases, increases, no change, and sites where the impact was initially unclear. Though traffic increased on auxiliary roads, the study concluded that there was a "small but measurable" reduction in citywide air quality patterns from the road closures (Levy et al., 2006).

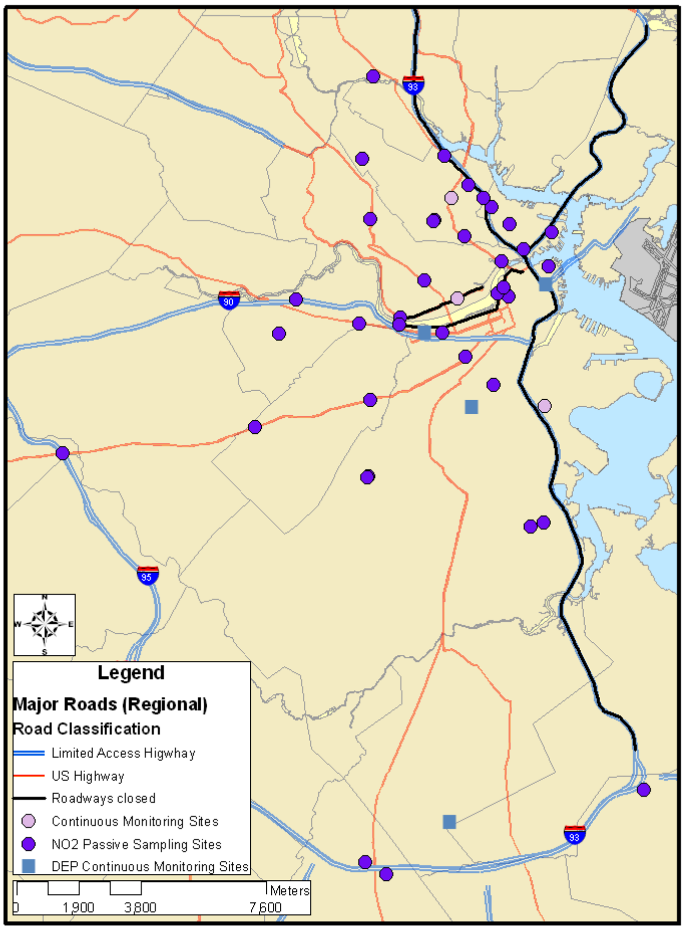

Figure 7: Road Closures and Sampling Sites in Boston, MA due to the Democratic National Convention (Levy, et al., 2006).

2.3.2 Kajaani, Finland

During early 1990s, Kajaani's central city square was declining economically and socially due to various issues, including traffic congestion. A strategy was implemented in1996 to re-stimulate the city center though the pedestrianization of part of the main high street and the city square. A repaved city center with new benches, lighting, trees, a stage, and a fountain now exists, with new shopping centers and apartments above the shops. As is typical with road closures, initially there was an upsurge in traffic volume in the surrounding area, but this did not last very long, and the 13,000 cars that once passed through the city center daily transferred to adjacent streets, and in part evaporated. Pedestrian trips through the city square increased, and a poll established that the local residents felt the square was "prettier, more comfortable, and safer than it was before" (Wallstrom, 2004).

2.3.3 New York City, NY, United States

In February of 2009, plans to close Times Square and Herald Square in New York City were presented to improve traffic flow in midtown NYC. After an 8-month trial period, the Mayor's office analyzed traffic flow data and responses from residents and local employees. The majority of the residents and local employees agreed that the street closures improved the aesthetic value of the area, and were generally satisfied by the project. Also, many merchants in the Squares expressed that the road closure should become permanent. The traffic data did not meet expectations, but was still successful in several ways. First there was a reduction in both pedestrian and driver injuries in the area by 35% and 63%, respectively. Furthermore, the traffic flow along a major road, Seventh Avenue, sped up by 7%. Improvements in travel times were also seen along Avenue of the Americas and throughout Midtown by 37% and 15%, respectively. After a long analysis by the NYC Mayor's office, both Times and Herald Squares were permanently closed to traffic (Grynbaum, 2010).

2.3.4 Wolverhampton, England

In Wolverhampton, England, intense traffic congestion, worsening environmental conditions and declining economic activity led local authorities to implement a four-phase plan to improve the city. The plan had goals to solve traffic issues and promote Wolverhampton as a "sub-regional center." First, by closing important central roads, private car traffic was slowly removed. Only buses, taxis, pedestrians and cyclists were allowed to access the city center, with some exceptions. Traffic flow inside the city center fell by 14% between 1990 and 1996, public transport gained reliability, and the people who initially felt negative about the arrangements became more approving as the center became cleaner, safer, more attractive and easier to access (Wallstrom, 2004).

2.3.5 Brighton, England

In 1991, traffic restrictions were placed during peak times during the day in Brighton, England. These restrictions included new one-way streets, turning bans, and restricting private vehicles from a busy shopping street. For one month before the traffic restrictions were put into place, hourly air pollution data were recorded. The same was done for the month following the restrictions. Reductions in nitrogen dioxide were not found; however, it is believed that this is due to the lack of recorded data. Nitrogen dioxide fluctuation patterns were noticed, which corresponded to the reduction of traffic flow during the daily bans. Hourly averages of carbon monoxide increased from 8 to 18 parts per million. Strong final conclusions could not be made from this study due to the short monitoring period. Also, since weather was constantly changing throughout the experiment, it possibly affected the pollution monitoring. From the study performed in Brighton, one can see that changes in traffic and corresponding air pollution rely on time, and future studies need to allow for longer study periods (Crabbe &Elsom, 1998).

2.3.6 Vauxhall Cross, London, England

Vauxhall Cross was a highly congested interchange, which provided no accommodations for cyclists, and inconvenient methods of crossing for pedestrians, even though local residents had one of the lowest car ownership rates in all of London. The Vauxhall Cross Project's primary objective was to make travelling into the central London easier by other methods of travel: bus, underground, and rail. The project includes "a new covered bus station with direct pedestrian access to the railway and underground stations." The plan also involved the creation of facilities dedicated for cyclists and surface level pedestrian crossings. Though initial computer modeling predicted terrible results for the motor vehicle traffic in the area, the concept of traffic evaporation was used to win support for the scheme. Although the plan was opposed by the public, it began in 1999. The predicted traffic chaos did not occur and the traffic flow initially reduced approximately by 10%, then by 15% over several stop lines. Furthermore, a 2-8% reduction in peak time traffic was observed; traffic evaporation numbers were too difficult to accurately calculate. All things considered, the final outcome was successful (Wallstrom, 2004).

2.3.7 Nuremberg, Germany

Traffic-related air pollution, the decay of historic buildings, health concerns, and excessive traffic congestion caused Nuremberg, Germany to begin a movement towards pedestrianization. In phases, authorities removed car traffic from the city center by closing various roads off from private motor traffic. During the first two months after the major closures, traffic congestion increased, and strong opposition was met. After this, however, traffic adjusted itself and the problems were resolved, and support grew in the spring as people realized they could enjoy urban street life. Extensive traffic counts generated statistics that indicated that traffic flow not entirely displaced to the surrounding area, but was actually removed. The air quality for the first two months after the closure was initially worse, but after one year air pollution decreased significantly in the area immediately around the road closure. It was speculated that other factors probably caused some of the air pollution decrease, but a direct correlation clearly exists between the closure of roads in the Nuremberg city center and a reduction in air pollution.

2.4 Air Pollution and Health

This section will discuss how air pollution can affect humans' health based on scholarly articles and experimental studies. The contents of air pollution will be described based on their chemical components and how they can be toxic to the human body. Also, an analysis of air pollution models will be provided in order to create an understanding of the important factors that can affect the dispersion and concentration of traffic-related air pollution in an urban setting.

2.4.1 What is Traffic-Related Air Pollution?

The United States' Environment Protection Agency (US EPA) defines air pollution as gases, dust, fumes, particulate matter, or odor in harmful amounts that affect the health of humans and animals (US EPA, 1993). Factories, power plants, and transportation, especially personal motor vehicles, are main contributors to air pollution. When an internal combustion engine converts gasoline into energy, incomplete combustion occurs, expelling various pollutants into the atmosphere. Incomplete combustions release carbon monoxide (CO), nitrogen dioxide (NO_2), hydrocarbons (HC), and particulate matter (PM) into the air (Toyota Motors). Figure 8displays incomplete combustion.

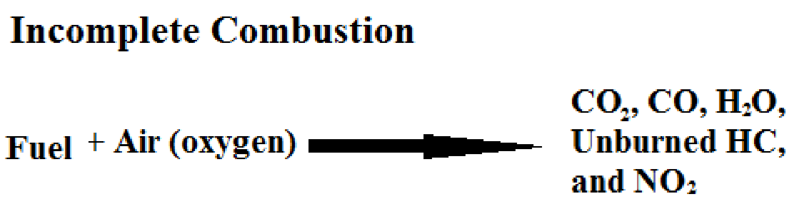

Figure 8: Incomplete combustion equation with reactants and products (adapted from Toyota Motors p.5).

Different types of motor vehicles release CO, NO_2, HC, and PM in different amounts. Table 1 displays highway emissions data from the US EPA on passenger cars, light trucks, and motorcycles. Furthermore, the age of the car affects the amount of emissions released. According to the US EPA, an older car releases more pollutants while a newer car releases fewer emissions. Passenger cars include sedans and taxis and light trucks include pickup trucks, sports utility vehicles, and mini vans.

Table 1: Highway Emissions Data for passenger vehicles, light trucks, and motorcycles (US EPA, 2000)

Type of Motor Vehicle	**Component**	**Emission Rate Per mi and km**	
Passenger		g/mi	g/km
	Hydrocarbons	2.80	1.74
	Carbon Monoxide	20.90	12.99
	Oxides of Nitrogen	1.39	0.86
Light Truck			
	Hydrocarbons	3.51	2.18
	Carbon Monoxide	27.70	17.21
	Oxides of Nitrogen	1.81	1.12
Motorcycle			
	Hydrocarbons	1.16	0.72
	Carbon Monoxide	39.14	24.32
	Oxides of Nitrogen	0.82	0.51

Carbon monoxide (CO) is a highly toxic gas, known as the silent killer, because it is odorless, colorless, and tasteless (SilentShadow, 2004). According to the US EPA, vehicles emit CO in exhaust during times of low air-to-fuel ratios, like ignition. In addition, the US EPA reported that cold weather causes CO emissions from vehicles to greatly increase because they need more fuel to start and the onboard CO control computers and catalytic converters work less efficiently.

Nitrogen dioxide (NO_2) is also is a product of incomplete combustion. While in the gaseous state NO_2 is clear to reddish brown and is highly toxic, reactive and corrosive (US EPA). According to the World Health Organization (WHO) in 2003, the majority of NO_2 present in urban areas results from motor vehicle emissions. Additionally, the WHO reported that NO_2 mixes with other gases and particles in the air and forms secondary particles such as ozone (O_3), acid rain, PM, and ammonium nitrate (NH_4NO_3). Many sources including the WHO (2003) and the US EPA (2009)indicate that NO_2 is a lung irritant and leads to respiratory problems such as asthma and bronchitis.

Hydrocarbons are organic compounds consisting only of hydrogen and carbon. Benzene (C_6H_8) is one type hydrocarbon released from incomplete gasoline combustion and is highly carcinogenetic. Researchers in Copenhagen, Denmark discovered that high exposure to benzene occurs during rush hour when people walk near high traffic roads. Additionally, the researchers discovered that traffic contributes to indoor benzene levels (Skov et. al, 2001). When released during incomplete combustion, benzene has the potential to mix with NO_2 and form ozone. O_3 is a component of smog that plagues urban areas and contributes to respiratory problems (US EPA, 1993).

Particulate matter (PM) is a suspension of solids, liquids, and gases in the air. For example, dust, pollen, soot, metals, smoke, organic matter, toxins, NO_2, CO_2, CO, and O_3 are components of PM. Figure 9displays what a typical PM molecule consists of. Particulate matter is measured by the aerodynamic diameter in pg/m^3 (Bayer-Oglesby et. al, 2005) and is displayed as $PM_{(\text{diameter in micro meters})}$. PM is separated into three categories based on diameter: coarse, fine and ultrafine. Ultrafine PM is more harmful than coarse PM because it is extremely tiny and it can enter the lungs where it can interfere with biological processes. Additionally, the physical and chemical characteristics of PM also affect how harmful PM is to the body (Lambré et. al, 2009). Many sources release PM components including motor vehicles. Motor vehicles release $PM_{0.1}$, $PM_{2.5}$, and PM_{10}, in addition to stirring up road dust, which can combine with other PM (Press-Kristensen, 2009). $PM_{0.1}$, $PM_{2.5}$and PM_{10} are known to cause adverse health effects.

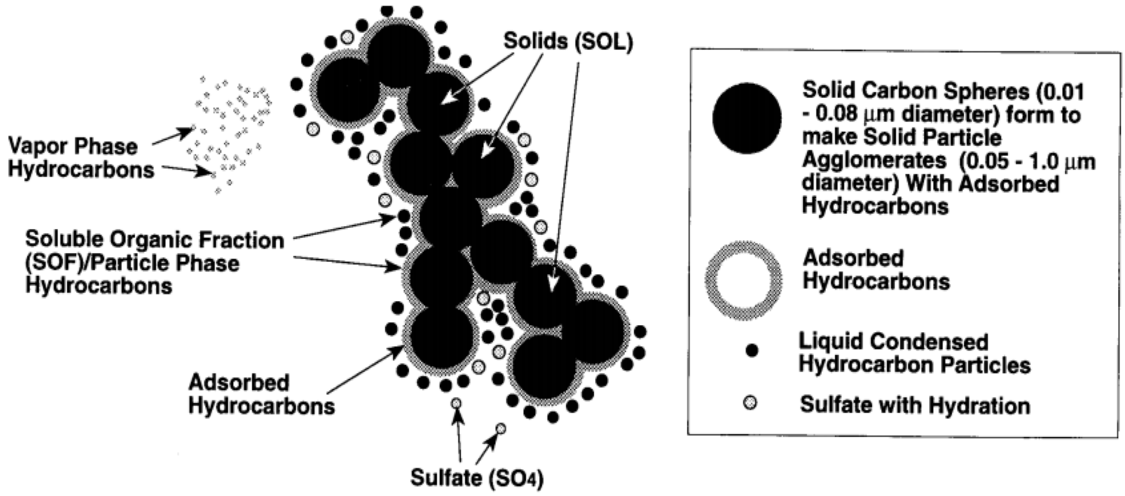

Figure 9: Composition of Particulate Matter: Many molecules collide together and form PM. (Olsen et al, 2009)

2.4.2 Factors Contributing to Air Pollution

Various models have been developed in order to predict air pollution in an area. Modeling these changes in air pollution is important because traffic is the main source of air pollution in cities. Also, continuously running air pollution measurements is expensive, so predicting through models is preferred (den Boeft et al, 1996). It is necessary to have updated air pollution data in order to caution local inhabitants if these levels become elevated enough to affect their health (Berkowicz et al, 1996). Many models take into account the traffic flow, traffic speed, and the numbers of light and heavy vehicles. Traffic-related pollution models are also needed to assess what factors are most important in contributing to problems with air pollution.

Air dispersion is an important concept to consider when analyzing air pollution concentrations. Gases in the atmosphere, like other substances, flow from high concentrations to low concentrations. "Certain atmospheric conditions and/or substance properties may result in peculiar gas behavior that makes the forecasting difficult" (Helsinki Commission, 2003). In Figure 10below, one can visualize the dispersion of a gas through the atmosphere at calm conditions, which is the easiest to predict and analyze. Also, this shows how meteorological conditions play a role in air pollution dispersion, which will be discussed later in this section (Helsinki Commission, 2003). In Figure 11, one can visualize the change in concentration of gases in the atmosphere from high concentration to low concentration through an area with many obstacles. The red color is the highest concentration, while the blue shows the lowest concentration (HazRes, 2010).

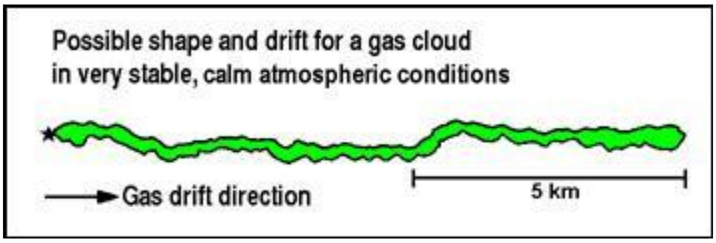

Figure 10: Dispersion of a gas in calm conditions (Helsinki Commission, 2003)

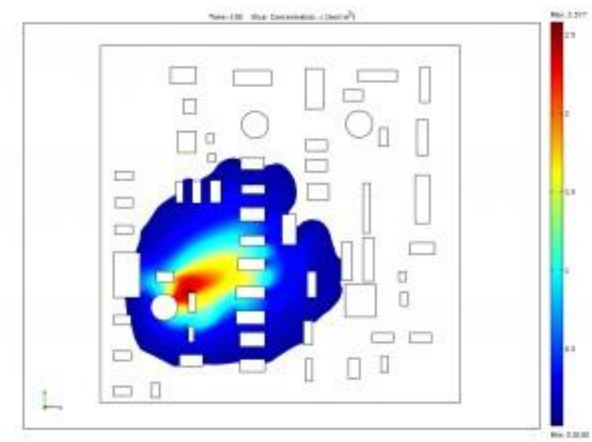

Figure 11: The dispersion of a toxic gas through an area with many barriers (HazRes, 2010)

A crucial factor in traffic-related air pollution is the presence of barriers. Barriers can either be topographical, such as valleys or hills, or man-made, such as buildings. When buildings serve as topographic barriers, the road may be described as a street canyon. A street canyon is defined as "a relatively narrow street with buildings lined up continuously along both sides" (Vardoulakis et al, 2003). High buildings on both sides cause the pollution to build up in these areas because the wind that would disperse the pollutants to other areas is blocked. The buildings or obstacles can be of varying heights, which cause differences in the turbulence of the wind carrying pollutants. Dispersion of gaseous pollutants also depends on the angle of the wind to the street (Vardoulakis et al, 2003). However, barriers such as buildings do not have a large effect on long-term measurements of pollutants even though they do have a short term effect in the area. Regardless, results from wind tunnel experiments have shown that direct rising of pollutants and recirculation of pollutants, by being trapped near buildings, were the two main factors affecting the concentration of pollutants (den Boeft et al, 1996).

The height and spacing of the buildings have an effect on how the wind flows and whether vortexes are formed (den Boeft et al, 1996). Vortexes are created when wind blows perpendicularly to the direction of the street, such that "the wind flow at street level is opposite to the flow above roof level" (Berkowicz et al, 1996). Below in Figure 12, a typical schematic of wind flow and vortex formation within a street canyon can be seen.

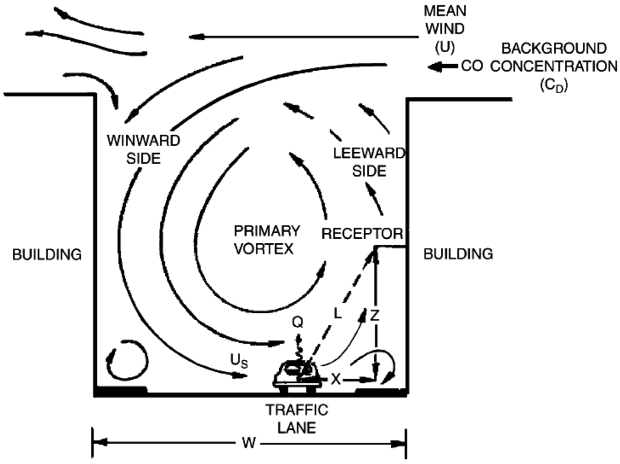

Figure 12: Pollution flow through a street canyon (Vardoulakis et al, 2003)

Pollutant concentrations on each side of the street canyon can be calculated in many ways depending on the size of the wind vortex, the direction of the wind, and the recirculation of pollutants. For example, the pollution concentrations throughout a street canyon are equal when there is no wind or when the wind blows along the same direction of the road (Vardoulakis et al, 2003). The concentration of pollution is much higher on leeward sides of street canyons while windward sides have a low concentration of pollutants. However, if the wind is very low (around 1 m/s) the wind vortex disappears and only the turbulence produced by vehicles' movement disperses the pollutants (Berkowicz et al, 1996).

Other meteorological factors besides wind are considered in the analysis of air pollution dispersion. Temperature, solar radiation, and relative humidity also have an effect on air pollution (Kukkonen et al, 2001). Starting a motor vehicle's engine in cold weather is called a cold start. Cold starts require more oxygen and fuel to ignite the engine, therefore releases more emissions (US EPA, 1993). Solar radiation and temperature play a role in how chemicals in pollutants react with one another (Karppinen et al, 2000).

Another topic to consider when analyzing traffic-related air pollution is the presence of background pollution. Pollution comes from other sources in addition to vehicles. Other mobile sources of pollutants are airplanes and boats. Examples of stationary points that may expel pollution are power plants and heating systems (Karppinen et al, 2000). "Measurements showed that background concentrations contributed on the average 26% and 45% on the total measured concentrations of NO_x [nitrous oxides] and NO_2, respectively" on a major road (Kukkonen et al, 2001).

Finally, the road and traffic conditions play a huge role in traffic-related air pollution. The length of the road being analyzed should be taken into account. Usually the length is taken between two intersections (Vardoulakis et al, 2003). Also, traffic flow, traffic volume, and traffic speed, all of which are related, play a large role. Areas with higher traffic speed and traffic volumes have higher measured concentrations of NO_2 and NO_x (Karppinen et al, 2000). The makeup of the traffic is also important. The percentage of heavy vehicles should be accounted for because larger vehicles typically release a larger amount of emissions (Vardoulakis et al, 2003).

All of the aspects mentioned above should be considered when analyzing a road such as Nørrebrogade. When comparing streets in the same area important factors such as climate and wind speed can be disregarded since they should be the same, though relative wind direction may vary between streets. A summary of this section is displayed in Figure 13.

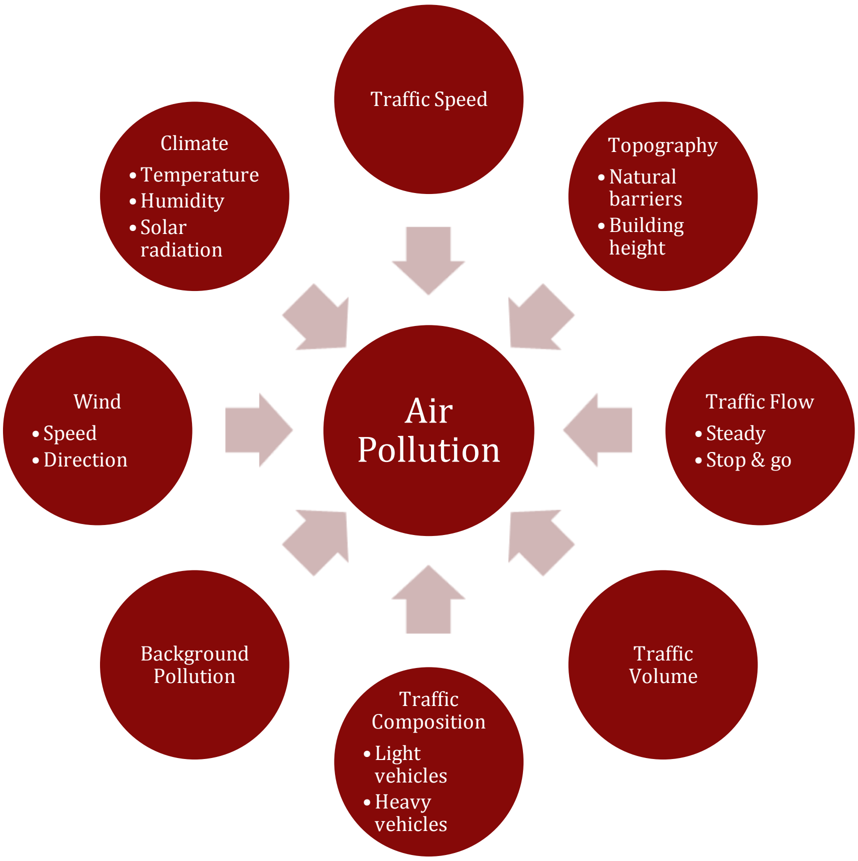

Figure 13: Contributing factors to urban air pollution

2.4.3 Traffic-Related Air Pollution and Health

Over the past several decades, researchers have studied air pollution and its effects on health. In particular, traffic-related air pollutants and their effect on human health have been extensively researched. The following sections describe the general and specific health problems that have been linked to traffic-related air pollution by health organizations and scholarly research.

2.4.3.1 General Health Issues and Traffic-Related Air Pollutants

CO, NO_2, HC, and PM have many different effects on the human body. Each of these pollutants has suggested exposure limits to prevent the body from harm. Research from institutions such as the United States Department of Labor and the WHO indicates that levels of pollutants below the exposure limit are not hazardous to health, but any levels above can cause harm to the human body. The time one is exposed to the pollutant also affects the exposure limit. The exposure limits for CO, NO_2, HC, and PM are listed in Table 2.

Table 2: Exposure Limits for Traffic-Related Air Pollutants. (US Department of Labor and the WHO, 2003)

Pollutant	**Exposure Limits**			
	Annual(A) or Lifetime (LT)	**1 Hour**	**8 Hour**	**24 Hour**
Nitrogen Dioxide NO2	100 μg/m^3	0.203mg/m^3	N/A	0.09971mg/m^3
Carbon Monoxide CO	N/A	40mg/m^3	10mg/m^3	N/A
Hydrocarbon -Benzene (C6H6)	0.17 gm/m^3 (LT)	N/A	0.319 mg/m^3	N/A
Particulate Matter	10μg/m^3 (A)	23-311 μg/m^3	N/A	N/A
PM0.1	N/A			
PM2.5	15.0 μg/m^3 (A)	N/A		35 μg/m^3
PM10	0.05 mg/m^3 (A)			150μg/m^3

Many institutions have extensively researched carbon monoxide and human health. The information from the organization SilentShadow (2004) reveals that when one is exposed to CO, the gas enters the blood stream and begins to displace the oxygen (O_2) carried by hemoglobin on red blood cells because they have a higher binding affinity for CO than O_2. As a result, the body's organs are starved of O_2 and shut down, leading to different issues depending on the percentage of CO in the blood. Health issues caused by CO poisoning are displayed below in

Table 3. Though most of these health effects are unlikely to occur outdoors, urban areas have higher levels of CO in the air due to the higher amounts of traffic (US EPA, 1993).

Table 3: Levels of CO in human blood and the health effects associated with those levels. Information gathered from silentshawdow.org

Levels of CO in Blood	**Health Effects**
10-30%	headaches, dizziness, fatigue
30-50%	nausea, vomiting, headaches, breathing difficulties
50% and up	loss of consciousness, seizures, convulsions, death

Nitrogen dioxide exposure causes many respiratory health issues. Research from Philipps University discovered that NO_2can affect the proliferation and morphology of Clara cells in the respiratory tract by exposing the cells to increasing levels of NO_2. Clara cells are found in the lungs and protect air passageways by secreting a variety of proteins (Atkinson et. al, 2008). The Clara cells affected by the NO_2 had rapid cell division unlike cells not exposed to NO_2 (Barth & Muller, 1999). Another experiment discovered that NO_2 exposure lowers hemoglobin, hematocrit, and acetyecholinesterase levels in human blood (Posin et. al, 1978). The American Lung Association reported that NO_2 causes lung inflammation, coughing and wheezing, increased number of asthma attacks, and susceptibility to respiratory illnesses (ALA, 2010).

Exposure to benzene also causes harm to the body. Benzene is metabolized first by the liver then bone marrow (Snyder &Hedli, 1996). These metabolites, including toluene, benzaldehyde, aniline and benzoic acid, interact with the body in various harmful ways (Philips et. al, 2004). Observable health effects from benzene exposure include drowsiness, dizziness and possible death (CDC, 2005). Research has shown that benzene metabolites can cause DNA damage and bone marrow deformation (Snyder &Hedli, 1996).

Particulate matter has been thoroughly researched by many institutions including the WHO and the Center for Disease Control and Prevention (CDC). Larger PM can be coughed up, but ultrafine PM is too minute to be trapped by respiratory system. Instead of leaving the body, ultrafine PM can be absorbed via alveolar, where they circulate through the body to the heart and brain (Olsen et. al, 2009). Figure 14shows the chance of different diameters of particulate matter affecting the different regions of the respiratory track in humans. The chance of a certain PM appearing in a region of the respiratory tract is the deposition (WHO, 2004).

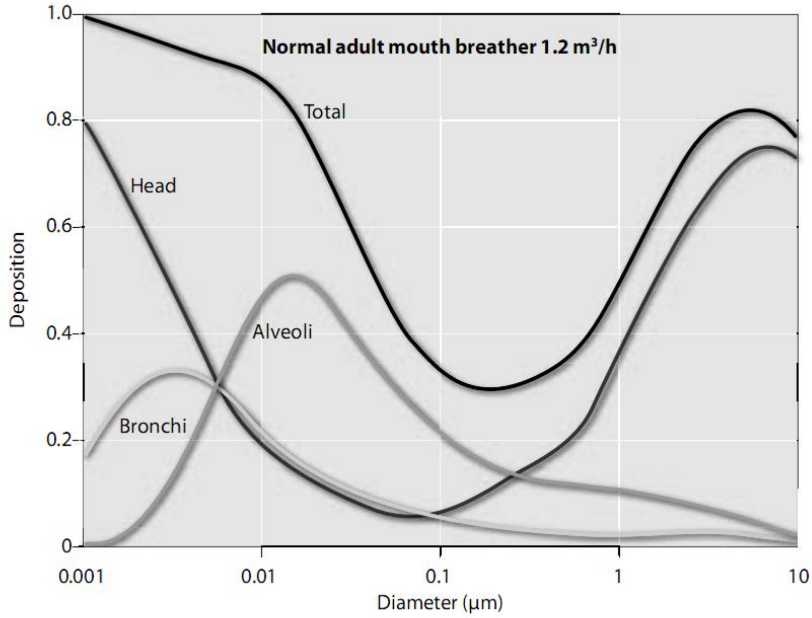

Figure 14: Diameters of Particulate Matter that effect different regions of the respiratory track (WHO, 2004)

2.4.3.2 Respiratory Problems

Chen et. al and a group of researchers from British Columbia University studied the relationship between chronic traffic-related air pollution and asthma symptoms in children living near high volume traffic. Seventy-three children diagnosed with asthma ranging from 9-18 years of age were surveyed about their stress level, asthma symptoms, and NO_2 levels near their homes. The participants wrote about their stress and asthma symptoms every day for six months, and their peak expiratory flow rate (PEFR) was recorded twice a day at their homes. Additionally, the researchers interviewed the children and their parents about their lives and asthmas symptoms at the beginning and end of the study to learn about the stresses in each participant's life. The data collected from the study displayed a direct correlation between the levels of NO_2 and asthma symptoms. According to the data, when air pollution levels were high, the PEFR of participants was lower and their chronic stress levels higher. This study shows that cleaner air helps reduce asthma symptoms, and as a result, decreases in traffic can improve the lives of the residents near high volume traffic roads (Chen E. et. al, 2008).

A correlation between an increase in particulate matter levels ($PM_{2.5}$) and an increase in respiratory related hospital visits and diagnosis was discovered in a study performed in Southeast Toronto, Canada. Researchers studied hospital codes and $PM_{2.5}$ levels from 1990-1992. The hospital codes used for the study included the following respiratory problems: asthma, bronchitis, chronic obstructive pulmonary disease, pneumonia, and upper respiratory tract infection. The researchers determined from their PM data that $PM_{2.5}$ is highest in close proximity to busy streets. The hospital codes data revealed that residents living the closest to busy streets were admitted to hospitals due to respiratory problems more often than those who live further from busy streets. Therefore, the researchers concluded that $PM_{2.5}$ from traffic could cause respiratory issues (Buckeridge et. al, 2002). This study shows a direct relationship between car emissions and respiratory problems.

Researchers in Switzerland found a direct link between decreasing air pollution and increasing respiratory health. Various studies across the globe concerning air pollution harming children's health prompted this study on ambient air pollution and respiratory health. Since there has been increase in air pollution awareness, Switzerland claims that air pollution has decreased across the country. As a result, from 1992-2001, several Swiss health institutes studied the affect of reduced air pollution in 10,397 Swiss children ranging from the ages of 6-15 living in urban communities. Over the course of the study, the parents completed a health survey describing their children's health pertaining to respiratory issues. In addition, air quality monitors were placed in neighborhoods where the children lived. From the survey and air quality data, the researchers determined a link between decreasing air pollution and improved respiratory health in the children (Bayer-Oglesby et. al, 2005).

Health facilities in California found a link between asthma onset and traffic related air pollution. During this study, 217 children ranging from the ages of 10-18 were observed for a course of 8 years according to where they lived and if they develop asthma. A nitrogen dioxide (NO_2) monitor was placed outside every child's home and each child was categorized by the amount of traffic his/hers house was located near. By the end of the study, the researchers found a correlation between the onset of asthma and NO_2 levels. Thus, this study shows that higher NO_2 levels increases the chance of children developing asthma (Jerrett, et. al, 2008).

Despite the successful research linking traffic-related air pollution and respiratory problems, some research has suggested that there is no connection. Researchers in Oslo, Norway attempted to find a link between asthma onset in schoolchildren and long term traffic-related air pollution. In Oslo, 5,279 schoolchildren born during 1992 and1993 were studied between 2001and 2002. These children lived near varying road conditions, ranging from busy streets to over 500 meters from a road. Since NO_2 is a traffic-generated pollutant, hourly NO_2 concentrations near the children's homes were taken in 1992 and 2001. The children answered a questionnaire in 2001 regarding doctor-diagnosed asthma. When the researchers compared the pre asthma onset NO_2 concentrations to current NO_2 concentrations, no positive relationship between long-term traffic exposure and asthma onset surfaced (Oftedal et al, 2009). This study only focused on asthma onset, not on the effects of traffic-related air pollution on existing asthmatic children.

2.4.3.3 Cancer, Rheumatoid Arthritis, Atherosclerosis

In 2002, a study from the Health Effects Institute in Cambridge, Massachusetts released an article aimed at investigating a link between air pollution and lung cancer. The researchers gathered data that suggests approximately 1% of future lung cancer cases in large cities would be caused by air pollution (Cohen, 2009). Though the percentage of future lung cancer cases caused by air pollution is small, air pollution can still be considered detrimental to health if individuals are excessively exposed.

Researchers from Colorado, USA used data from a previous childhood cancer study to suggest a link between traffic and childhood cancers. Each case of childhood cancer in Denver, CO from the 1980s was organized according to the neighborhood the child lived in. The study showed that childhood leukemia and other cancers are linked to traffic density. The researchers discovered that childhood cancers were more prevalent in neighborhoods with at least 20,000 vehicles per day (Pearson et. al, 2000). Additionally, researchers from Sweden studied cancer incidences for 11 years and discovered that as traffic density increases near homes, the diagnosis of childhood non-Hodgkin's lymphoma, acute lymphocytic leukemia (ALL), chronic myeloid leukemia (CML), and acute myeloid leukemia (AML) increase. The researchers indicate that benzene released by cars was the main cause of cancer development in the participants since higher levels of traffic burn more gasoline and emit larger amounts of benzene into the air than areas with lower traffic density (Nordlinder et. al, 1997).

American researchers also discovered a connection between traffic-related air pollution and rheumatoid arthritis in women. The researchers studied a cohort of American female nurses ranging between 30-55 years of age, who live near high traffic roads. All nurses received a questionnaire inquiring about their proximity to high traffic roads and their health problems. A 31% increase of rheumatoid arthritis was discovered amongst the cohort, thus linking traffic-related air pollution to rheumatoid arthritis (Hart et. al, 2009).

A possible link between atherosclerosis and traffic exposure was also found in America. From 1987 to 1989, Americans living in four different communities with various traffic densities were observed by several research institutes. The coronary health of 15,792 middle age Americans were recorded during the study, and after 13 years, 976 participants developed atherosclerosis. Many participants who developed atherosclerosis lived in high traffic density communities. The data showed participants living 300 meters or closer to high traffic densities increased their chance of atherosclerosis. This study found no correlation between gender, and race in developing atherosclerosis, only between the distances from high-density traffic (Kan et. al, 2008).

2.5 Noise and Health

Noisy streets are common in major cities. Therefore, being able to measure and predict noise levels is an important part of urban planning (Gowda&Rajakumara, 2008) and assessing the population's exposure to potential health problems (Fyhri&Klæboe, 2009). Noise levels in high traffic situations can either be collected by using measurement equipment or be calculated from traffic flow data by the use of model equations. In fact, taking measurements is necessary to create models and to verify that these models are realistic.

This section will discuss the relationship between noise and health as well as how noise levels are obtained through measurement. Noise levels that people in urban areas are exposed to on a daily basis will be described alongside examples of noise levels from certain sources and their likelihood to lead to permanent hearing loss. Also, studies that either support or reject the idea that noise has health effects on people will also be presented. Finally, traffic-related noise prediction models are analyzed and their important factors described in order to give the reader an understanding of what contributes to the creation of noise in an urban setting.

2.5.1 What is Traffic-Related Noise Pollution?

In recent decades the issue of community noise has surfaced and demanded attention from citizens and lawmakers. The World Health Organization (WHO, 1999) defines community noise, also known as environmental noise, residential noise or domestic noise, as noise emitted from all sources, except noise at the industrial workplace. According to the United States Environmental Protection Agency (US EPA, 1974), a level of 55 decibels outdoors and 45 decibels indoors hinders normal human activity and causes annoyance. Outside community noise sources are traffic, parks, restaurants, businesses, sporting events, and/or recorded music. Community noise has spiraled out of control in many countries due to the lack of enforcement and measuring protocols as well as an increase in sources including motor vehicle traffic.

WHO found shocking community noise statistics in the European Union: 40% of the population is exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dBA and 20% is exposed to levels exceeding 65 dBA during the day. Additionally, 30% of individuals are exposed to sound pressure levels exceeding 55 dBA at night. Noise pollution experiments by WHO, which recorded sound pressure levels near high traffic density roads, discovered some residents are exposed to 75–80 dBA continually for 24 hours. According to the US EPA this amount is detrimental to hearing and causes permanent hearing loss. Figure 15 displays various sources of noise pollution and their average sound levels.

Sound Levels (decibels)		
Harmful to hearing	140	Jet engine (25 m distance)
	130	Jet takeoff (100 m away) Threshold of pain
	120	Propeller aircraft
Risk hearing loss	110	Live rock band
	100	Jackhammer/Pneumatic chipper
	90	Heavy-duty truck Los Angeles, 3rd floor apartment next to freeway Average street traffic
Very noisy	80	Harlem, 2nd floor apartment
Urban	70	Private car Boston row house on major avenue Business office Watts — 8 mi. from touch down at major airport
	60	Conversational speech or old residential area in L.A.
Suburban & small town	50	San Diego — wooded residential area California tomato field
	40	Soft music from radio
	30	Quiet whisper
	20	Quiet urban dwelling
	10	Rustle of leaf
	0	Threshold of hearing

Figure 15: This table shows sources of noise pollution. (Raloff, 1982)

2.5.2 Noise Level Measurements

In order to collect noise level measurements, integrated sound level meters (ISLM) are usually set on each side of the road about a meter away from the traffic lane and 1.5 meters above the street (Abo-Qudais&Alhiary, 2005). Sound level meters change sound into electrical signals. Sound level is measured in either decibels (dB) or a-weighted decibels (dB(A)). Both decibels and a-weighted decibels are logarithmic measurements of how intense a sound is (sound-level meter, 2010). A-weighted decibels are decibel units that are adjusted to the frequency scale of the average human ear. This type of reading is typically used to measure if a noise source has intensity high enough to cause hearing damage (Noise pollution-Glossary, 2007).

2.5.3 Contributing Factors in Noise Pollution

Noise models are important because noise levels need to be considered when creating new transportation systems. Noise models can also be used to assess the level of noise that residents are exposed to, and if this noise level could be detrimental their health (Abo-Qudais&Alhiary, 2005). Predicting noise is necessary in designing highways and also in ensuring that government standards are being met (Steele, 2000).

Different types of noise models exist. Models have been developed in order to predict the noise levels in an intersection (Abo-Qudais&Alhiary, 2005) as well as uninterrupted and interrupted flow at intersections (Gowda&Rajakumara, 2008). There are also models that predict noise along a road with no intersection (Skarlatos&Zakinthinos, 2007). These models vary in complexity and in what variables they take into account. Even if the models are not used to predict noise levels, they still provide knowledge on what factors should be taken into consideration when assessing what causes noise pollution in an urban area.

Before discussing the factors that contribute to noise levels, a brief understanding on diffraction and reflection of sound is needed. Diffraction is defined as "the bending of waves around small obstacles and the spreading out of waves beyond small openings" (Nave, 2005). The image in Figure 16 demonstrates the concept of sound diffraction by using the example of a music concert. Nave (2005) uses this image to show how sound can penetrate through openings and travel around corners.

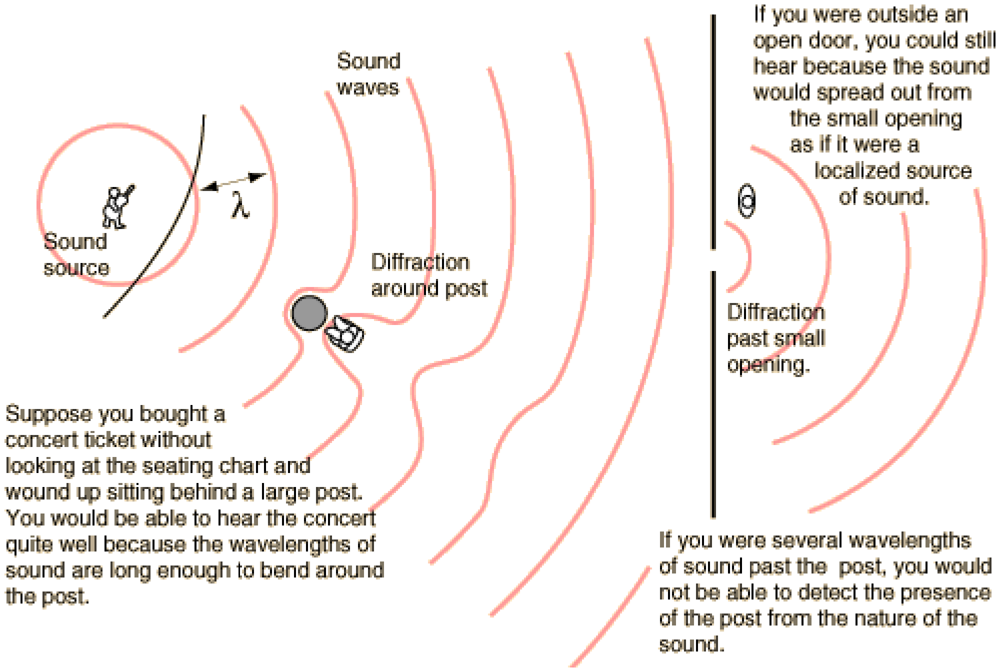

Figure 16: An example of noise diffraction presented with useful explanations (Nave, 2005)

Noise reflected from hard surfaces can amplify sound. Incident waves are sound waves that are emitted by the source and reflected waves are those that bounce off of a hard surface. "The reflected waves can interfere with incident waves, producing patterns of constructive and destructive interference" (Nave, 2005a). The patterns increase the intensity of the sound and double the pressure amplitude because the reflected waves add to the incident waves within the same pressure zone near the hard surface (Nave, 2005a).

Early noise models assessed the noise made by individual vehicles with no acceleration. However, today's models seek to find L_{eq}, which is the equivalent noise of a continuous flow for a given amount of time, usually presented in dB(A). Models that are used today usually use vehicles as point sources while some use traffic lanes as line sources. Sometimes the geography of the area is taken into consideration because the change in terrain can act as sound barriers or reflectors. This can also include buildings along the street that is being analyzed (Steele, 2000).

Traffic flow can vary from street to street. Vehicles traveling along a straight road without intersections are generally assumed to be at a constant flow rate and a constant speed (Steele, 2001). On the other hand, traffic that travels through streets with intersections create free-flow situations that have dynamics. In this case, dynamics are dependent on time since acceleration and deceleration are important variables when considering braking and starting at intersections. Considering dynamics is important in noise assessment because it takes into account situations which create higher noise levels such as congestion at intersections, acceleration from a complete stop at an intersection, and deceleration when approaching an intersection (Can et al, 2009).

The volume of traffic into an area, or vehicles entering an area in a specified segment of time, is an essential factor in generating noise. Traffic volume has been shown to be highly significant in predicting noise levels through statistical testing. It plays a larger role in noise than the percentage of heavy vehicles, road texture, and road slope combined (Abo-Qudais&Alhiary, 2007).

Vehicle types are a crucial factor to consider in traffic-related noise. Vehicles of different classes (automobile, motorcycle, trucks, and buses) all emit different levels of noise. Counts of vehicles in these categories are crucial in determining the contribution of noise (Abo-Qudais&Alhiary, 2007). Normally, a percentage of "heavy vehicles", which tend to be anything greater than 1500 kg (Skarlatos&Zakinthinos, 2007), and light vehicles which are usually cars and motorcycles (Skarlatos&Zakinthinos, 2007), are taken into account when predicting noise pollution because if all vehicles were given one emission value, the result would either be overestimated or underestimated (Steele, 2001).

Sound barriers and the area's topography can affect noise diffraction and reflection. Artificial and natural barriers such as hills, valleys, trees, high buildings, bridges, and overpasses can reflect or block noise from scattering through an area. The topographic data from a road should be considered when characterizing noise levels (Steele, 2001).

Road geometry is a category that can be broken down into road surface texture, number of lanes, and gradient or slope of the road. Vehicles driving on surfaces made out of dense materials make more noise than those driving on porous materials. Tires travelling over finer textures usually lead to lower noise emissions. The slope of the street plays a role in noise level because on a downhill vehicles use the brakes and on an uphill they accelerate. “The influence of gradient on the measured level is up to 8 dB(A) for heavy vehicles moving upwards and up to 3 dB(A) for passenger’s cars” (Skarlatos&Zakinthinos, 2007). Finally, the number of lanes (Skarlatos&Zakinthinos, 2007) and the width of the lanes (Abo-Qudais&Alhiary, 2007) also contribute to noise on a road.

In conclusion, factors that need to be considered in assessing noise in an urban area may vary. However, the following factors should be taken into account to some degree: traffic volume, traffic flow type, traffic speed, traffic composition, topography, road texture, road width, and road slope. All of these variables are relevant when analyzing a street such as Nørrebrogade. To accurately compare streets, all of the previously mentioned factors should be considered. A summary of these factors can be seen below in Figure 17.

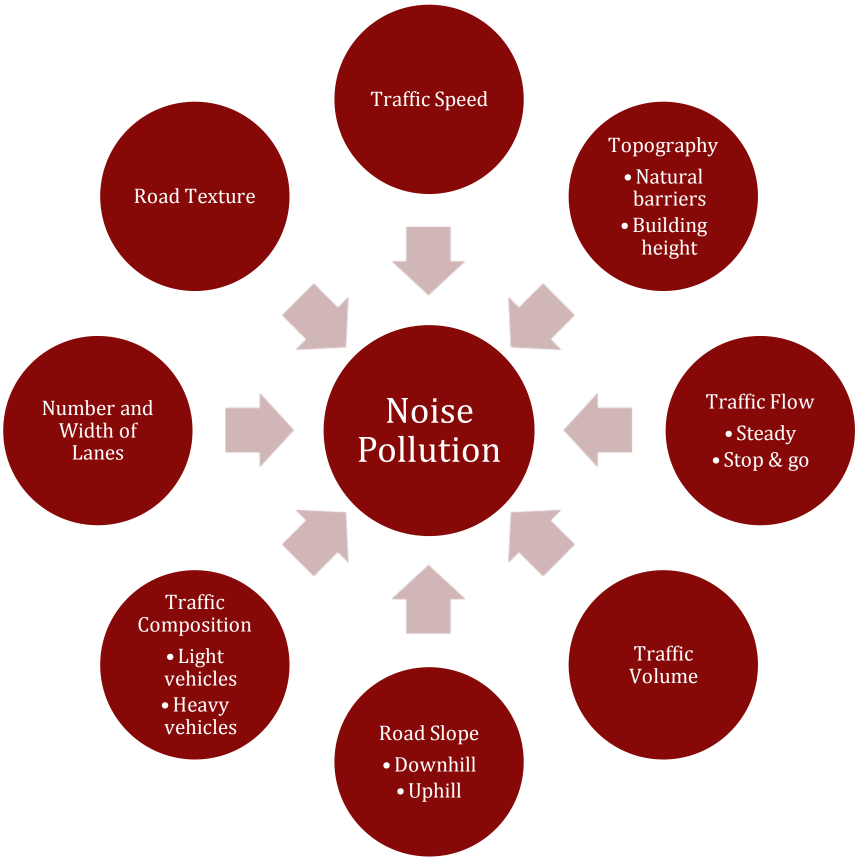

Figure 17: Contributing factors to urban noise pollution

2.5.4 Noise Pollution and Health

Studies from around the world have linked many health issues with noise pollution. According to the Institute for Stress Research in Germany, nighttime noise pollution can have detrimental effects on the body. Residents who are exposed to higher than normal traffic noise at night are at greater risks of having their sleep cycle interrupted. Interrupted sleep cycles is associated with higher levels of cortisol, the stress hormone. Constant high levels of cortisol can lead of a plethora of other health problems such as hyperglycemia, weight gain, idiopathic hypertonia, adipositas or diabetes mellitus (Maschke *et. al*, 1999).

Researchers from National Institute of Public Health and the Environment in Bilthoven, The Netherlands performed a meta-study on the effects noise pollution has on health. The researchers gathered 43 epidemiological studies regarding noise exposure, blood pressure, and/or ischemic heart disease from 1970-1999. Each study's methodology, results, and conclusion were carefully studied. The meta-study discovered participants in several studies exposed to occupational noise had a significant increase in systolic blood pressure. Furthermore, some participants in the studies exposed to road traffic noise showed an increase in the risk of myocardial infarction and ischemic heart disease. The studies also showed that participants exposed to noise for a short period of time can trigger a stress response, which has its own detrimental effect on the body such as changes in biochemistry and cardiovascular health (Kempen et.al, 2002).

Researchers from Göteborg University in Sweden launched a study in 2000 that examined the availability of quiet areas for residents that live in dwellings exposed to various sound levels and traffic composition. The dwellings selected for the study fell into one of the following categories according to their most exposed side of the house, either 45-65dB(A) or 35-45dB(A). The 956 residents were given surveys that focused on their health and well being associated with noise such as annoyance and sleep quality. Then the noise levels of the residents' dwellings were measured. After three years of collecting data, the researchers analyzed the data. The data showed that having access to both indoor and outdoor quiet areas in a dwelling decreases noise disturbances 30-50% in residents when the quiet area is 5db(A) lower than the more exposed side of the dwelling. Furthermore, the researchers found that residents who lacked access to quiet areas on their property were more likely to be tired, stressed, unsociable, irritable, and angry. Access to quiet areas reduced the number of annoyed residents in the study between 11-19%. Overall, the Swedish researchers discovered that the optimal noise in an residential environment is 48dB(A) or lower. The researchers recommended that residents should not be exposed to traffic noise louder than 60dB(A) in order to prevent negative health effects like stress and sleep disturbance (Öhrström et. al, 2005).

In 1997, Japanese researchers discovered a correlation between high levels of traffic noise and decreased health in women living near a main road in Tokyo. Five hundred women living on both sides of the main road were surveyed regarding annoyance, sleep disturbances, interference with activities, health problems, and disease history. These problems increased in women who were exposed to 70dB(A) of noise or higher. Prevalence of deafness, heart disease and hypercholesterolemia increased in women exposed to 65dB(A) or higher of noise. This study suggests the physical symptoms from traffic noise manifest at 70dB(A) and disease onset is more likely to occur at 65 dB(A) (Yoshida, T. *et. al*, 1997).

Contrary to the findings above, there have been studies that have shown that noise pollution is not linked to health problems. In the article written by Fyhri and Klæboe (2009), the correlation between noise exposure and hypertension and ischemic heart disease was the focus because there has not been much evidence in explaining the relationship between them. People in Oslo, Norway were interviewed on what types of health complaints they had, whether they were annoyed by certain levels of noise, and whether they considered themselves sensitive to noise. Noise levels and air pollution levels were calculated for each participant. Using all of the above data, this study resulted in no relationships between noise and hypertension and ischemic heart disease, or any health complaints for that matter. Some small correlations were found between noise annoyance and issues such as tiredness, headache, and sore throat. The authors suggest that a person's sensitivity to noise may make them more vulnerable to some health problems. Figure 18, below, is a visual interpretation of what the authors of this paper concluded.

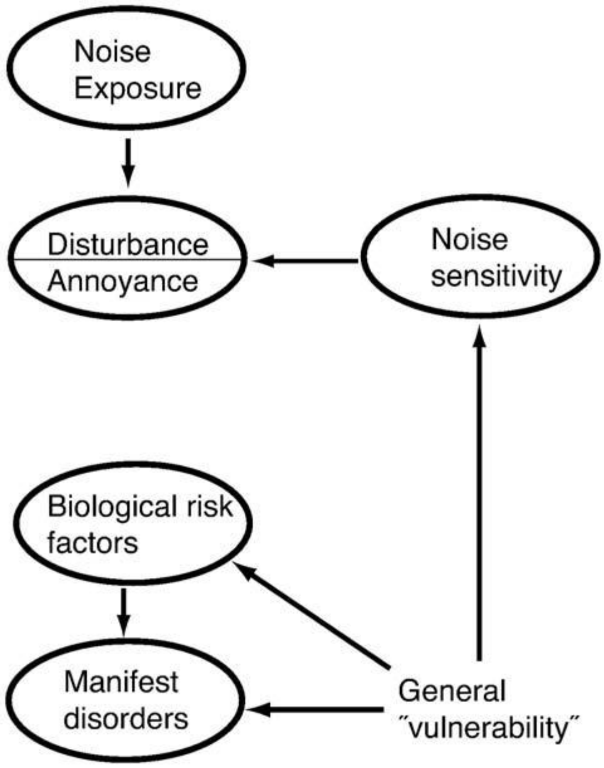

Figure 18: Fyhri and Klæboe's (2009) interpretation of how noise and health problems relate

2.5.5 Noise Pollution in Denmark

The Miljøministeriet, or the Danish equivalent of the United States' Environmental Protection Agency, recognizes the effects of noise pollution on peoples' health. They reported that exposure to excessive noise levels for a prolonged period of time can contribute to mental illnesses, anxiety, stress, and learning disabilities. Due to the negative effects of noise pollution both the European Union and the Miljøministeriet created many noise exposure limits for industrial sources, various types of traffic, and other sources. Figure 19shows the percent of highly annoyed people versus the noise level from various forms of traffic. The Miljøministeriet recommended noise limit for road traffic for residential areas in a city is 58 dB L_{den}, where L_{den} is a weighted average of the day, evening and nighttime noise. This level of motor vehicle traffic is estimated by the Miljøministeriet to be highly annoying to less than 10% of people. The percent of highly annoyed people versus the noise level is shown in Figure 19. Figure 19 shows that when the noise level from road traffic increases, the percent of annoyed individuals increases.

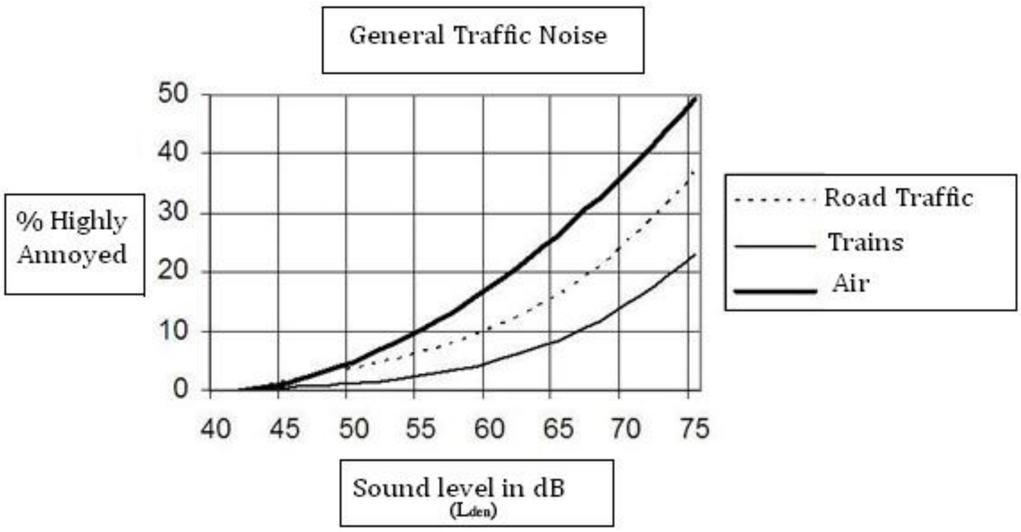

Figure 19: Percent of Highly Annoyed Persons vs. the Noise Level (Adapted from Miljøministeriet, 2010).

Naturally, comparing the actual noise levels on roads in Copenhagen to the recommended levels would be ideal. However, noise level measurements are complicated and time consuming to complete, so using a reliable noise model to calculate noise levels is more realistic. In the Nordic countries, the Nordic prediction method has dominated noise models for several decades. The Nordic prediction method was originally developed in 1981(Bendtsen, 1999). This model has undergone several revisions, and a major overhaul in 2001. This major overhaul created the Nord2000, which is significantly better than the old model (Kragh et. al, 2006).

Using traffic information provided by various municipalities from 2007 to 2009, the Miljøministeriet created a tool called the Støjkortlægning, which uses the Nord2000 noise modeling system to calculate the noise levels for virtually all of Copenhagen ("Støj-Danmarkskortet", 2010). Currently, this tool can be used to estimate both daytime and nighttime noise levels in Copenhagen both at 1.5m off the ground, and 4.0m off the ground. The 1.5m calculations represent street levels, and the 4.0m calculations represent 1st floor apartments. With the Støjkortlægning it becomes possible to compare the noise levels of many roads to the Miljøministeriet's guidelines.

2.6 Improving Safety Through Urban Planning

The safety of cyclists, pedestrians, and drivers is a very important aspect of traffic engineering. As cities worldwide move towards pedestrianization and cycling, the safety of these groups must be always examined because mixing cyclists and pedestrians with motorists can be lethal.

A study from 2000 by John Pucher and Lewis Dijkstra analyzes data collected regarding accidents, injuries, and fatalities in the United States, as well as in Germany and the Netherlands, which were two leaders in bicycle and pedestrian safety at the time of the research. The study suggests reasons why Germany and the Netherlands have had success in improving pedestrian and cyclist safety. The authors recognize that the exact effects of each of the suggestions is difficult to determine, since "data limitations make it impossible to undertake rigorous statistical analysis" for each individual measure (Pucher and Dijkstra, 2000). Nonetheless, these suggestions provide insight into cyclist and pedestrian safety.

There are several simple ways to increase pedestrian safety and convenience that should be consistently implemented. Pucher reports that virtually every Dutch and German city has pedestrian-only zones, allowing pedestrians, and often cyclists, to move uninhibited in area that can often be quite large (Pucher and Dijkstra, 2000). Other enhancements include raised and extra wide crosswalks, with "highly visible striping" and "overhead illumination," as well as "pedestrian-activated crossing signals, both at intersections and at mid-block crosswalks" (Pucher and Dijkstra, 2000). Islands where pedestrians can find refuge when crossing particularly wide streets and wide, well-lit sidewalks with benches are also helpful (Pucher and Dijkstra, 2000).

Bicycle safety and convenience can be enhanced greatly with lanes designed specifically for cyclists as well as fully integrated and planned bike paths (Pucher and Dijkstra, 2000). Beyond these important fundamental techniques, there are many other ways of enhancing cyclist safety. Certain streets can be designed to give cyclists the right of way over motor traffic, or one-way for motor vehicles but two-way for bicycles (Pucher and Dijkstra, 2000). Bus and cyclist only lanes, bicycle traffic lights, road networks that involve dead ends for cars but direct routes for bikes, and allowance for bicyclists to make left and right turns where prohibited for motor vehicles all have been used to help increase cyclist safety and convenience (Pucher and Dijkstra, 2000).

An extreme technique that can give pedestrians and cyclists nearly as much right of way as motorists is known as traffic calming (Pucher and Dijkstra, 2000). Through the use of the law and various physical barriers, road speeds can be kept to acceptably low values, sometimes requiring motorists to travel at speeds comparable to walking (Pucher and Dijkstra, 2000). In Germany and The Netherlands, traffic calming is used as an area-wide solution, and not a street specific solution. Traffic calming ensures that traffic is not simply displaced to neighboring streets, but typically transferred to primary routes designed to handle additional traffic outside of the calmed area (Pucher and Dijkstra, 2000). The study states that in The Netherlands, area-wide traffic calming "has reduced traffic accidents by 20% to 70% and serious traffic injuries by 35% to 56%."

As the study shows, there are many factors that may contribute to an increase in cyclist and pedestrian safety. Note that many of these techniques have to do with restricting motorists. This research suggests that road closures, such as the Nørrebrogade closures, will increase the safety (and convenience) of bicyclists and pedestrians along that road.

2.7 Traffic Alleviation

Developing ways to alleviate traffic congestion is an important task that requires careful planning. . Two Swiss economists, Bruno Fey and Alois Stutzer, found that many people consistently underestimate the pain of long commutes (Lehrer, 2009). Fey and Stutzer calculated that, "a person with a one-hour commute has to earn 40 percent more money to be as satisfied with life as someone who walks to the office" (Lehrer, 2009). Thus, traffic relief most certainly is important, for reducing the stress that commuters face, if nothing else.

2.7.1 Road Expansions

Perhaps the most obvious way to reduce traffic in an area is to increase the capacity of one or more roads. Adding additional lanes would seem to relieve rush hour congestion, and shorten trip times during these busy periods. However, it is generally accepted that traffic congestion typically maintains equilibrium (Litman, 2009). When road capacity increases, the eventual outcome is an equally congested rush hour, due to the concept of generated traffic (Litman, 2009).

Generated traffic can be defined as additional traffic that occurs due to improvements on a given road, such as adding additional lanes that increases total motor vehicle traffic (Litman, 2009). Diverted traffic, a component of generated traffic, consists of drivers who change their departure time and/or route. Induced traffic, another component of generated traffic, includes multiple sources of additional motor vehicle traffic (Litman, 2009). Those who previously rode trains or busses, cycled, or walked may decide to drive their own private motor vehicles because of the increased road capacity (Litman, 2009). Also, additional trips that were otherwise not worth taking maybe made as the road allows for such trips (Litman, 2009). Thus, through both diverted travel and induced traffic, generated traffic can reduce the primary gains of expanding busy urban roads (Litman, 2009).

Litman discusses counter-arguments to his case. His primary argument is that generated traffic is underestimated and should be more heavily factored into traffic engineering decisions. He agrees, however, that this is mostly applicable to busy urban roads. Roads with lower latent travel demand, or additional peak-period vehicle trips that would occur if congestion is relieved would not have to worry about generated traffic nearly as much. For such roads, road expansions may be quite useful (Litman, 2009). Since Nørrebrogade is a busy urban street, Litman's research indicates that expanding this road would not have the desired effect.

2.7.2 Road Closures

Working in the opposite direction, road closures as a solution to traffic problems may seem counter-intuitive. Eliminating potential routes to drive from one location to another naturally seems as if it would lengthen travel times and thus worsen traffic situations. In some cases the initial, obvious response holds true, and traffic issues do become worse. There are, however, two primary ways in which a well-planned road closure can alleviate traffic. The first is somewhat complicated and mathematical in nature, while the second way is more intuitive.

2.7.2.1 Nash Equilibriums and Braess's Paradox

The mathematical reasoning why road closures can reduce car traffic is subtle. Understanding road closures properly requires an understanding of a few key underlying concepts. The first of these concepts is the Nash equilibrium. In Nash equilibriums, decision-making agents always make the best possible choice for themselves based on complete knowledge over all other agents. In the case of traffic flow, drivers are the agents. Every entity in such a system can ask itself whether, knowing the strategies of other players, and assuming that they won't change, there is a possible way to benefit by changing strategies. If all agents answer no, then the system is in a Nash equilibrium. It has been shown traffic flow moves towards Nash Equilibriums.

As a consequence of this behavior, a problem entitled “Braess's paradox” can result. Braess's paradox states that adding capacity to networks where the entities in the network attempt to selfishly choose their own route can actually worsen the performances of all entities in the network. With regards to traffic, this means that adding a road can worsen travel times. The mathematics that explains why this happens can be complicated, but can be understood fairly easily after minimal research[1].

Many studies have found that traffic networks can often lock themselves in suboptimal Nash Equilibriums, and thus, the counter-intuitive Braess's paradox applies. A recent study titled *The Price of Anarchy in Transportation Networks: Efficiency and Optimality Control* shows these claims to hold true. The simulation conducted by the researchers shows that, "uncoordinated drivers possibly waste a considerable amount of their travel time. Counter intuitively, simply blocking certain streets can partially improve the traffic conditions" (Yeon, et al. 2008). By applying mathematically sound models to real life city streets, the team investigated Braess's paradox. The team systematically simulated the results of closing down one street at a time in several cities

[1] http://www.davros.org/science/roadparadox.html offers a good explanation of this paradox in simplistic terms.

(Yeon, et al. 2008). In most situations, removing the street increased travel times, as one would expect. However, sometimes closing a street did indeed lessened the travel time for vehicles (Yeon, et al. 2008).

The results of the simulation can be easily interpreted. First, it should be realized that if drivers were able to work together and not try to take their own optimal routes, the entire Nash equilibrium would be avoided and all would benefit. However, so long as drivers continue to be greedy, avoiding Nash equilibriums is impossible. What this simulation suggests is that "Braess's paradox is more than an academic curiosity or an anecdote with only sketchy empirical evidence" (Yeon, et al. 2008).

Real life traffic scenarios can exhibit Braess's paradox. Adding roads can worsen certain traffic situation, and conversely, removing roads can better traffic situations. The exact nature of which road closures will be successful and which closures will not is a complicated field of research, where work is still being done.

2.7.2.2 Traffic Evaporation

Besides the mathematical reasoning, road closures can lessen traffic in another way. This other way is more relevant to this project, but also less well-defined. If a road closure does indeed lengthen travel times or create additional inconveniences for drivers, a natural solution from the driver's perspective is to choose an alternative method of transportation. Public transport, cycling, or walking may all become better options when a road is closed to private motor vehicles. A 2009 traffic study analyzed the results of closing two sections of Nørrebrogade to regular traffic (see Appendix B). Data analysis indicated that the number of trips made by private motor vehicles in the sampled areas of Nørrebro was reduced by 7.3% due to the trial road closures. Similarly, the study found an 11% increase in bus trips and an 18.6% increase in bicycle trips. The team had less confidence in these two numbers since less data was available for cyclists and busses than motor vehicles. The results suggest that private motor traffic was transferred to busses and bicycles. As such, part of this project is to verify these tentative conclusions with updated traffic data. Another possibility is that people simply make fewer trips because of the added inconvenience. Traffic evaporation typically means fewer vehicle trips for both these reasons.

Chapter 3: Methodology

This project was designed to help Agenda 21 investigate the quality of life impact on local residents and establishments from closing sections of Nørrebrogade. The team investigated changes in air quality and noise levels and surveyed stakeholders to obtain information regarding changes in health, safety and other factors associated with the road closure. At the conclusion of our project, we were able provide Agenda 21 Copenhagen with scientific evidence specifying the effects of the closing of Nørrebrogade on the quality of life of the people in the surrounding area. Specifically, our team accomplished this mission through the following objectives:

- Performed a traffic analysis of the Nørrebrogade and surrounding streets and calculate the changes in traffic due to the road closures.
- Discovered potential changes in health resulting from any differences in air quality through traffic emissions calculations.
- Performed a noise level evaluation and determine possible health-related outcomes from changes in noise levels.
- Evaluated the locals' expectations and experiences regarding safety, health, and transportation from closing sections of Nørrebrogade.

The following chapter contains the details of the methods developed and utilized by the team to accomplish our objectives. Figure 20 displays our team's methodology overview. First, our methods for the Nørrebrogade Traffic Analysis are explained. Then our procedure for Nørrebrogade noise evaluation is discussed. Following the noise evaluation is our procedure for emissions calculations. Last, our surveying and interviewing methods are explained.

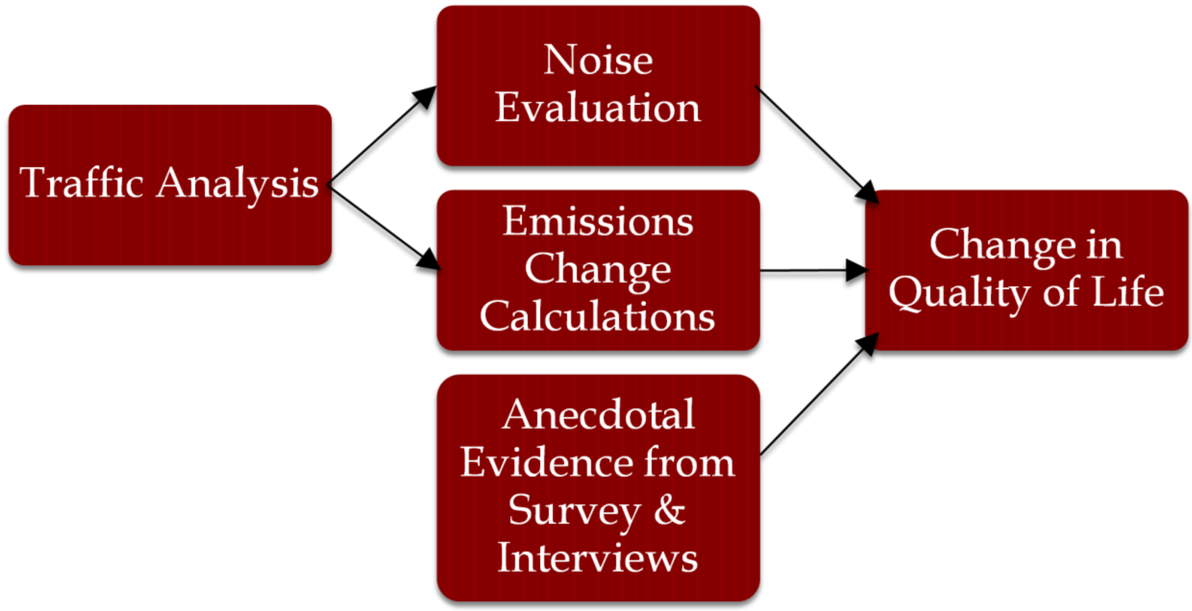

Figure 20: Methodology Overview

3.1 Update Nørrebrogade Traffic Analysis

This section provides the overview of the procedure the team followed and the detailed models developed in order to accomplish our first objective.

3.1.1 Nørrebrogade Traffic Analysis Overview

The foundation of our project was the Nørrebrogade traffic data gathered by the Municipality from various time periods. The D09 Traffic Study IQP (see Appendix B) determined that the trial 1 road closure of Nørrebrogade resulted in 7.3% traffic evaporation in the measured areas, and calculated exactly how many fewer vehicle trips were made at specific points in the Nørrebro area. Our project required more specific traffic calculations in order to properly calculate the reduction in pollution. The traffic readings that were used in this study were taken during March and September 2008 (before all trials), October 2008 and May 2009 (during Trial 1), and June, September, and October 2009 (during Trial 2).

In order to accomplish our primary objectives regarding changes in the quality of life on and around Nørrebrogade, we required reliable, understandable, and explainable traffic data that would be easily integrated into our other calculations, such as emission and noise levels changes. Understanding precisely how the calculations were made and exactly what the results meant was critical in assuring that our results would be reproducible and easily updated with new data in the future. Updating the calculations made during the project from last year with new data helped to ensure that the results were as accurate and applicable as possible. We updated the traffic data by following the steps listed here.

1. Developed a spreadsheet to reorganize vehicle trip data used in the D09 Traffic Study IQP for maximum readability and ease of understanding. The team used the traffic data from 7:00 to 18:00 on the traffic sheets and organizing vehicle categories.
2. Traced traffic flow data calculations made by the team member from last year for locations with daylong readings. The team then queried last year's team about the model used last year for the rush hour traffic flow data sheets, but the team was unable to provide us with the procedure. Thus, we developed our own method to estimate the number of vehicles for daylong traffic using the morning and evening rush hour data (8:00-10:00 and 16:000-18:00) and other full reading data available for that location.
3. Obtained additional applicable traffic data from the Municipality for June 2009.
4. Analyzed all traffic flow data.
5. Designed new graphics and tables to display our results in order to provide Agenda 21 with information on the change of traffic flow from the Nørrebrogade trial road closures.

By following these steps, we accomplished our first objective to validate results from the 2009 Denmark Traffic Study Interactive Qualifying Project.

3.1.2 Traffic Data Extrapolation

For our project, the team utilized traffic flow data work sheets provided by the Municipality. These traffic flow data sheets had many consistencies and inconsistencies. Each of the data sheets contained traffic counts for one reading location in the Nørrebro area. At these reading locations, the passing traffic was counted by vehicle category. These sheets included counts for both directions of traffic, 1 hour time blocks between 6:00 and 18:00, date the readings were conducted, and vehicle categories. However, the traffic flow data were presented in seven different table set ups in Microsoft Excel. These sheets contained different numbers of vehicle categories and some combined vehicle categories. Furthermore, the table arrangements were not consistent for each street for the various counting time periods. A list of reading locations and the types of traffic flow data sheets made at these reading locations are presented in Appendix C. The types of traffic flow data sheets from the Municipality are outlined below in Table 4.

Table 4: Types of traffic flow data sheets

Sheet Type	Vehicle Categories
a	Combined personal motor vehicles with motorcycles
b	Combined mopeds with Bicycles; buses with trucks; personal motor vehicles with motorcycles
c	Trucks counted by number of axles and combines bicycles with mopeds
d	Keeps all categories separate
e	Evaluations sheets with rush hour data
f	Combines personal vehicles with motorcycles; mopeds with bicycles; buses with trucks
g	Combines personal vehicles with motorcycles and vans; mopeds with bicycles
h	Combined buses and trucks; bicycles with mopeds
i	Combined buses and trucks; personal motor vehicles with motorcycles

Since the traffic flow data sheets provided by Copenhagen were not all structured in the same manner, we focused on the vehicle categories listed in Table 5. Inconsistencies in the trucks and buses categories lead us to group several different types of vehicles into the heavy duty vehicle category. Vehicles grouped in to the heavy duty vehicle category are displayed in Table 6.

Table 5: Main vehicle categories used when updating traffic flow data in Danish and English.

Vehicle Categories on Traffic Flow Sheets	
Danish	**English**
Personbiler	Passenger cars
Varevogne (max 3,5 T)	Light duty vehicles
Knallerter	Mopeds
Motorcykler	Motorcycles
Cykler	Bicycles
*seeTable 6	Heavy duty vehicles

Table 6: The various vehicles grouped into the Heavy Duty Vehicle category.

Heavy duty vehicles	
Danish	**English**
Sololastbiler> 3,5 T	Trucks over 3,5 T
Lastbiler med Sættevogn	Trucks with Semi-trailer
Lastbiler med Påhæng	Trucks with trailer
Busser I Fast Rute	Buses en route
Lastbiler, 2-4 aksler	Trucks with 2-4 axles

The seven different types of traffic flow data sheets presented the team with many issues. Since many sheets combined categories such as personal motor vehicles with motorcycles and mopeds with bicycles, we needed to develop a method to separate the combined categories. The categories needed to be separated because each vehicle emits different amounts of pollution. For example, if personal motor vehicles and motorcycles remain combined, then the emissions calculations would not reflect accurate traffic-related pollution generation in the Nørrebro area.

For the traffic flow data sheets that combined passenger cars with motorcycles, bicycles with mopeds, and passenger cars with vans, we calculated three sets of ratios for vehicle composition as listed in Table 7.

Table 7: Ratios calculated for determining separate vehicle categories from data sheets with combined categories

Vehicle Type	Reading Totals from Data Sheet	Ratio
Knallerter (Moped)	3716	0.0124
Cykler (Bicycle)	294945	0.9876
Combined	*298661*	-
Motocykler (Motorcycle)	9710	0.0137
Personbiler (Passenger Car)	697541	0.9863
Combined	*707251*	-
Varevogne (van)	128489	0.1571
Personbiler (Passenger Car)	689517	0.8429
Combined	*818006*	-

We created the following model to calculate the vehicle ratios. This model was reviewed and approved by Kåre Press-Kristensen, a civil engineering professor at the Technical University of Denmark in Lyngby, Denmark.

1. Totaled passenger cars, motorcycles, bicycles, mopeds, and vans for sheets that separated the categories.
2. Created three sets of vehicle ratios as shown in Table 3. Ratios were made for passenger cars + motorcycles, bicycles + mopeds, and vans + passenger cars.
    - Example: Two using the totals from passenger cars and motorcycles
        a. Total of passenger cars from separated sheets/(motorcycles + passenger cars from separated sheets)
        b. Total of motorcycles from separated sheets/(motorcycles+ passenger cars from separated sheets)

Once the three sets of vehicle ratios were calculated, we used the ratios to estimate the number of passenger cars, motorcycles, bicycles, mopeds and vans for the data sheets that combined these vehicle categories. The procedure is outlined below for sheets with that combined passenger cars with motorcycles.

1. passenger cars and motorcycles

- (total number of passenger cars + motorcycles on a given day) x passenger car ratio= estimated number of passenger cars for that reading
- (total number of combined passenger cars + motorcycles on a given day) x motorcycle ratio= estimated number of motorcycles for that reading

A few examples of the outcomes from using the ratios for combined categories are in Appendix H.

3.1.3 Eval Sheet Traffic Data Extrapolation

Aside from the traffic flow data sheets with day long readings, we were given another set of traffic data sheets in Microsoft Excel entitled "Eval" sheets. These Eval sheets contained morning (8:00-10:00) and evening (16:00-18:00) rush hour traffic data for 16 streets in the Nørrebro area. The majority of the readings taken on the Eval sheets were from September 2008(before trial 1) and October/November 2008 (about one month after the Trial 1 closure began). Four reading locations were presented in each Eval sheet. Two vehicle categories were represented in the Eval sheets which are displayed in Table 8. Since rush hour traffic and two vehicle categories were only represented in the Eval sheets, the team developed another model to extrapolate the data from the sheets in order to unify and incorporate the data into the project.

Table 8: Vehicle categories represented in the Eval Traffic Data sheets

Danish	English
Person-ogvarebiler	personal motor vehicles and vans
Lastbilerogbusser	trucks and busses

In order to incorporate data from the Eval sheets, the team developed the following procedure.

1. Filtered through the Eval sheets
    a. Since each of the 16 Eval sheets contained 4 reading locations on streets scattered across Nørrebro, it was necessary to filter through the sheets and find the most relevant locations. Highest priority was given to the Eval sheets with reading locations on Nørrebrogade, then to sheets that have a corresponding data sheet with day long (7:00-18:00) traffic readings.

2. Ratio Calculating
    a. Since the Eval sheets only had rush hour traffic, we used the daylong traffic data from the streets in Nørrebro to extrapolate daylong traffic for the Eval sheets. We calculated two ratios for each vehicle category from the daylong traffic data. The ratio formulas are listed here:
        i. (Day/morning rush hour) or (7:00-18:00 traffic / 8:00-10:00 traffic)
        ii. (Day/evening rush hour) or (7:00-18:00 traffic/ 16:00-18:00 traffic)
    b. For reading locations with multiple days, the day and evening rush hour ratios were averaged together to make two overall ratios.
    c. All the ratios derived for the Eval sheets are listed in Appendix I.
3. Extrapolate Data for Eval Sheets
    a. Once the ratios for each vehicle category at each location were calculated, we were able to extrapolate day long traffic for the Eval sheets. We accomplished this task by:
        i. Multiplying the 8:00-10:00 count by the (day / morning ratio) for these locations and vehicle categories.
        ii. Multiplying the 16:00-18:00 count by (the day / afternoon) ratio for these locations and vehicle categories.
        iii. Averaging these two results, and use this count as the 7:00-18:00 count for that location and vehicle category.

3.1.4 Further Standardization of Data

After using the multiple types of ratios to account for as much missing and inconsistent data as possible, we still found some gaps in the data. Since not many reading locations had counts for motorcycles even with the extrapolated data, motorcycles were removed completely from all calculations along Nørrebrogade.

Similarly, there were still large gaps within the moped category. However, since mopeds use the bike lane and were not affected by the road segment closures, we assumed that the same number of mopeds used the bike lane after the closures. Also, it is important that we include mopeds in our calculations because our traffic calculations carry over into emissions and mopeds are a large contributor to hydrocarbon emissions. We averaged original moped readings (not from extrapolated sources) from Before Trials from all available reading locations (which include Dronning Louises Bro and Nørrebrogade northwest of Jagtvej) in order to determine a constant to use for mopeds throughout all time periods. The constant value for mopeds came out to be 153 and this value was used for all time periods and reading locations along Nørrebrogade.

Finally, some adjustments were made when adding up categories to calculate total motor vehicles. If it was impossible to extrapolate for the categories which are not present for 1 time period, then these categories were dropped from the other time periods as well. This was done for reading locations on Nørrebrogade and those not directly on Nørrebrogade. However, those on Nørrebrogade include an adjusted total, which include the 153 mopeds. Examples of this are seen in Appendix J.

3.2 Emissions Calculations

After reorganizing the traffic flow data we developed a mathematical model to investigate possible changes in the traffic-related air pollutants, CO, NO_2, HC, and PM caused by the road closure trials on Nørrebrogade. The goal of this equation was to find increases or decreases in traffic-related air pollution on Nørrebrogade during the trial closures. Our emissions model relies on the traffic data and was also reviewed and approved by Kåre Press-Kristensen. The equation we developed for our model is:

[L/km] * [g/L] * % comp* [km/trip]*Trips = amount of pollutant in grams

Where,

- Term 1: **[L/km]** = fuel consumption rate of vehicle category
- Term2: **[g/L] =** emission factor
- Term 3: **% comp=** percentage of vehicle composition which uses a certain fuel type
- Term 4: **Trips** = average number of trips from all of the traffic reading dates within one time period
- Term 5: **[km/trip]** = relative length per trip

This model can be separated into 4 steps, which are listed here:

1. **Multiply by Inverted Fuel Economy of Vehicle Category- [L/km]**

   In order to figure out how much fuel a vehicle category used per km, we had to multiply by the inverted fuel economy of each vehicle category.

2. **Emission Factor (EF) Converting and Multiplying- [g/L]**

   Since the emission factors were presented in g/GJ (grams/ gigajoule), we had to convert into GJ/L (gigajoule/liter).

   - **EF (g/GJ)*(GJ/L) = EF g/L,** where GJ/L is specific for diesel, gasoline, gas conventional, and gas catalyst fuel types. This conversion was done for each fuel type and the converted emission factor was incorporated into the equation.

3. **Multiply by Percent Composition of Fuel Type- % comp**

   The next component in the emissions calculations was the composition of how many vehicles used each of the different type of fuel. The fuel types consisted of conventional gas, catalyst gas, diesel, and gasoline. Kåre Press-Kristensen provided information about approximately how many vehicles use each fuel type, as shown in Table 5. Since the type of fuel a vehicle uses is age dependent, the fuel percent composition of the traffic acts as an age distribution of the traffic.

Table 9: Distribution of Fuel Types Used Among Vehicle Types (Kåre Press-Kristensen, personal communication, 2010)

Category	% Gasoline		% Diesel
	Conventional	Catalyst	
Passenger cars	6%	69%	25%
Light duty vehicles	4%	46%	50%
Heavy duty vehicles	25%		75%
Mopeds/Motorcycles	100%		0%

The distribution of fuel types among vehicle types is important for the accuracy of our emissions calculations. Each fuel-vehicle combination has a different emission factor; therefore, if we assumed that all vehicles used the same type of fuel, we would either be under-estimating or over-estimating the outcome. The percent composition of fuel type was the last term incorporated into the equation.

4. **Multiply by Relative Length Per Trip- [km/trip] and Averaging Trips**

   The last terms in our emissions equations rely on the traffic analysis. In order to perform our emissions calculations, we needed to incorporate length per trip. Since it is impossible to know how long each car drove on Nørrebrogade during any time period, calculating the average trip length for the emissions equation is impossible. However, if there is constant traffic flow along segments of Nørrebrogade during the different time periods, then we can assume that for every car leaving there is a car entering in the same segment and making up for the distance the other car did not cover. If many cars exited Nørrebrogade at one intersection and were not replaced by a roughly equivalent number of cars going onto Nørrebrogade at that intersection, there would be large inconsistencies in the traffic counts along Nørrebrogade.

From our traffic data, we know the approximate traffic flow along Nørrebrogade before the closures and during Trial 1 and 2. Figure 21,Figure 22, and Figure 23 depict the traffic flow along Nørrebrogade before the trials began and during Trials 1 and 2. The long horizontal black line inthese figures represents Nørrebrogade and the short vertical lines represent intersections where traffic readings were taken. Each of the vehicle categories are color coded. In both Figure 22 and Figure 23 the fluctuation of traffic flow is displayed along the length of Nørrebrogade.

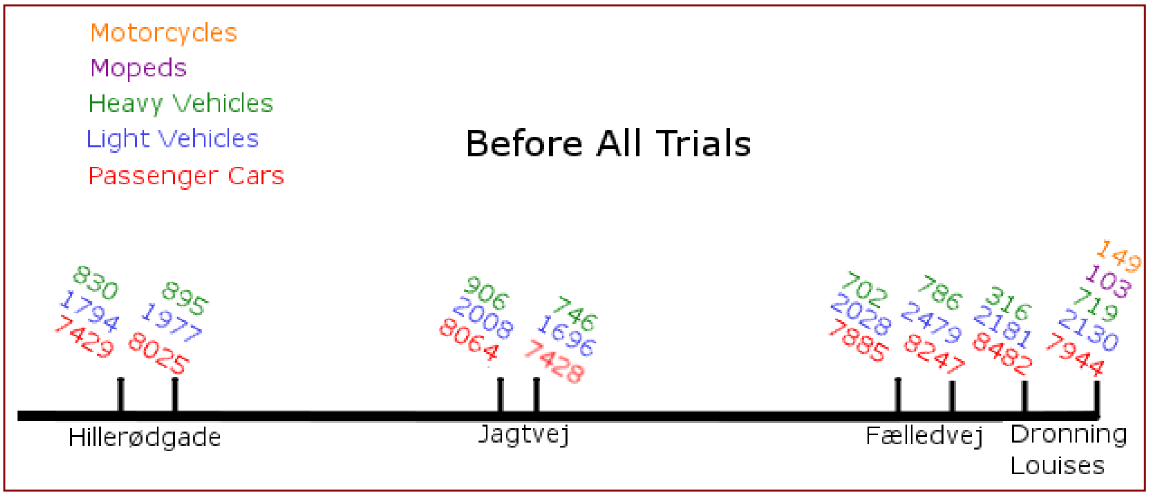

Figure 21: Traffic flow along Nørrebrogade before the trial closures began

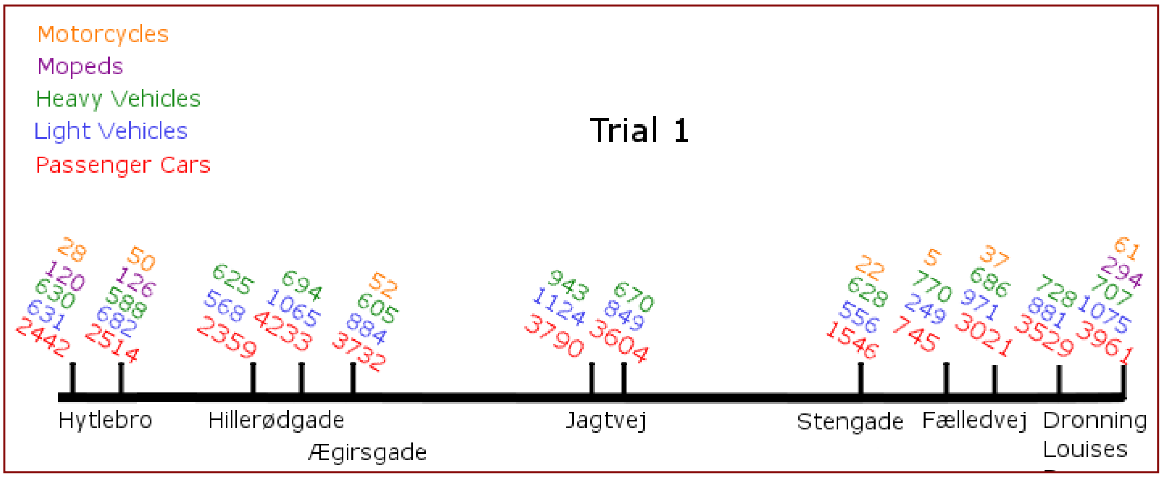

Figure 22: Traffic flow along Nørrebrogade during the first trial closure.

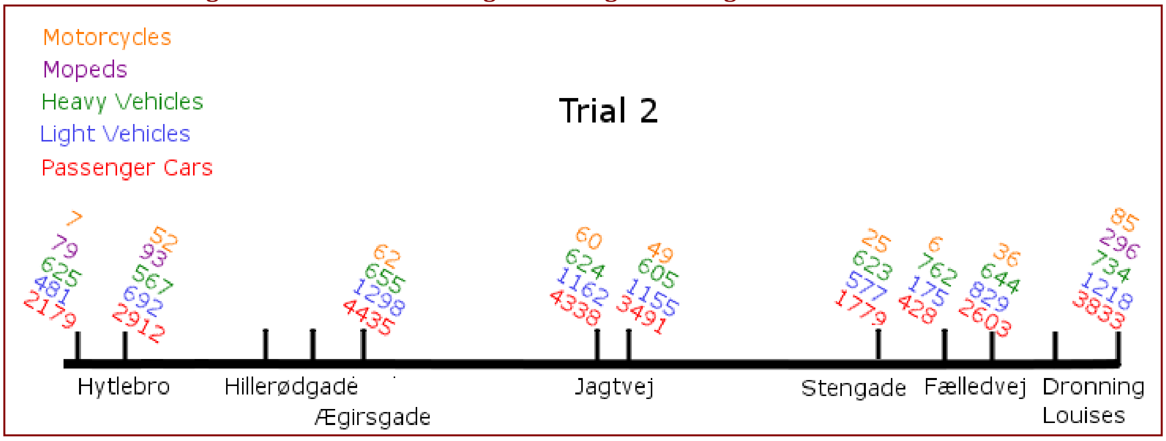

Figure 23: Traffic flow along Nørrebrogade during the second trial closure.

Since the traffic flow along Nørrebrogade is not constant during the trials, as seen in the figures above, it cannot be assumed that cars leaving Nørrebrogade are equally being replaced at every intersection. We can break down the length of Nørrebrogade into smaller segments that have similar traffic flow in order to carry out the emissions calculations. Since there was constant traffic flow before the trials, the segments were divided according to the traffic flow after the closures. The segments are assumed to each have the same "trip length" and can be assigned a variable to account for this since an actual length is not used. For example, we can assign *a* to Segment 1, *b* to Segment 2 and so forth. We created four segments along Nørrebrogade which are listed here and visually shown in Figure 24:

Segment 1:

1. Nørrebrogade west of Hyltebro
2. Nørrebrogade east of Hyltebro
3. Nørrebrogade west of Bragesgade
4. Nørrebrogade west of Baldersgade
5. Nørrebrogade northwest of Hillerødgade

Segment 2:

1. Nørrebrogade southeast of Hillerødgade
2. Nørrebrogade east of Ægirsgade
3. Nørrebrogade northwest of Jagtvej(Runddel)
4. Nørrebrogade southeast of Jagtvej(Runddel)

Segment 3:

1. Nørrebrogade west of Stengade
2. Nørrebrogade west of Faelledvej (closed section)

Segment 4:

1. Nørrebrogade east of Faelledvej
2. Nørrebrogade (near bridge)
3. DronningLouises Bro

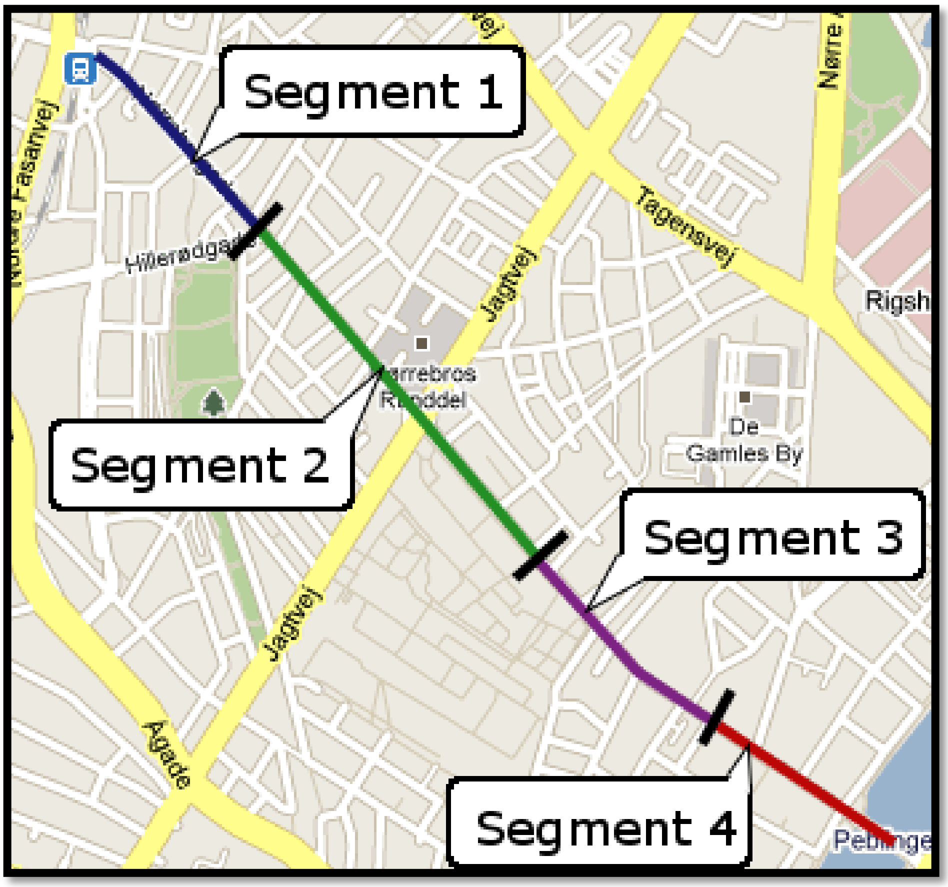

Figure 24: Nørrebrogade labeled by segments (Adapted from Tele Atlas, 2010)

Once we created the segments, we averaged the traffic counts for each vehicle category in each segment for each time period. These averages were the numbers of vehicles used in the emissions calculations.

The emissions calculation was completed for each pollutant and road segment Before the Trials and for Trials 1 and 2. The calculations produce the number of grams of the pollutant of interest multiplied by the trip length variable for the respective road segment. However, the ideal way to display our findings was in relative terms, or percent change. In order to complete this, the following steps were taken.

A. Since segments are a group of reading locations averaged together, for each segment, we averaged the number of vehicles in each vehicle category for each time period.
B. Then, the totals of each pollutant from each vehicle category average were totaled for an overall sum of grams multiplied by segment variable in Before Trials and Trials 1 and 2.
C. The overall sums from Before Trials and Trials 1 and 2 for each road segment are compared by the following equations:
    a. (Time Period x-Time period y) / Time Period x = % change in grams of pollutant for one road segment along Nørrebrogade.
        - Example: $\frac{\text{Trial 1}*a - \text{Before } *a}{\text{Before } *a} = \frac{\text{Trial 1} - \text{Before}}{\text{Before}}$ = % change in pollutant in segment 1

By comparing segments between time periods, the segment variables cancel out. This process results in a positive or negative percentage, which shows the increase or decrease in pollution for the pollutant of interest for the appropriate road segment. Emission calculations were repeated for each pollutant by simply changing the emission factors appropriately.

3.3Noise Evaluation

In order to evaluate the changes in traffic-related noise pollution on Nørrebrogade due to the road closure trials, the team discussed methods with Kåre Press-Kristensen and developed the following procedure. It is important to realize that the noise evaluation depends directly on our traffic analysis. Furthermore, noise is also dependent on the physical surroundings. The majority of Nørrebrogade follows the street canyon model, so we were able to reduce outside factors when developing our procedure. The only area of Nørrebrogade that does not have the same physical characteristics as the rest is the segment next to Assistens Kirkegaard, a large cemetery along the center section of Nørrebrogade, south of the Nørrebrogade-Jagtvej intersection. Along Nørrebrogade these factors are otherwise consistent:

- Road texture – pavement.

- Building height – 5-6 stories tall.
- Road slope – very flat.

The following factors may not be entirely consistent along the length of Nørrebrogade

- Traffic lanes
- Average speed
- Traffic volume
- Traffic flow
  - Stop and go traffic versus constant flow traffic
  - Number of intersections
- Traffic composition
- Background noise

Press-Kristensen provided the team an Interference Suppression - Traffic Reduction graph from the Danish Ecological Society displayed in Figure 25. The relationship shown in Figure 25assumes that the average vehicle speed is 50-60km/h. It assumes that background noise has not changed, and the absolute number of heavy vehicles has not changed. It is ideal for roads that had initial noise levels between 50-70dB. The team compared the percent change in motor vehicle traffic for various segments of Nørrebrogade to the graph, and estimated the reduction in noise that occurred due to the Nørrebrogade trial closures.

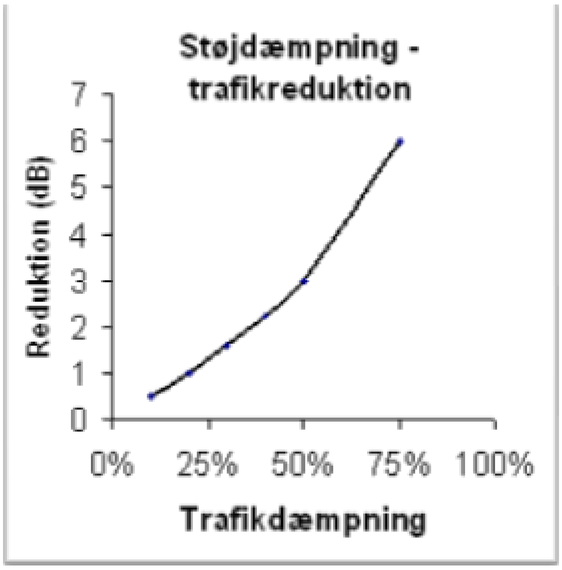

Figure 25: Noise Reduction vs. Traffic Reduction (The Danish Ecological Society, 2010)

In addition to the above calculation for change in noise levels, the team also obtained an estimate for actual noise levels on Nørrebrogade before the trials. This was made possible through the use of the Støjkortlægning (see section 2.5.5). Using these values, which were calculated using the Nord2000 noise modeling model, a comparison between Nørrebrogade's initial noise levels and the recommended noise levels for a road like Nørrebrogade became possible. The Miljøministeriet's guideline for urban residential roads like Nørrebrogade is 58dB. The 58dB guideline is a weighted average of noise levels during the day, evening, and night. In order to compare a road's noise level against this value, the Miljøministeriet describes a simple procedure.

1. Add 5dB to the evening (19:00 – 22:00) noise level to get the adjusted evening noise level.
2. Add 10dB to the nighttime (22:00 – 7:00) noise level to get the adjusted nighttime noise level.
3. Average the daytime, adjusted evening, and adjusted nighttime readings levels.
4. Compare this value to the 58 dB recommended limit.

Since the Støjkortlægning provides daytime and nighttime noise levels, the only missing information was the evening noise levels. The team estimated the evening noise levels on Nørrebrogade to be in between the daytime and nighttime noise levels, so the average of these two values was used for the evening noise level. The Støjkortlægning also gives the noise levels in ranges as opposed to discrete values, so the team chose to calculate the lowest noise estimate by taking the smallest values in these ranges. With these three values, we were able to calculate the weighted noise levels and compare Nørrebrogade's initial noise levels to the recommended values.

With these two separate calculations complete, the team had discovered both an estimate of the initial noise levels on Nørrebrogade (and how this compared to the desired values), and the reduction in noise on Nørrebrogade.

3.4 Assess Locals' Views

Our noise evaluation and emissions calculations provided the team with a foundation for our investigation into the health-related quality of life changes due to the Nørrebrogade road closure. In order to provide support for these analyses, our team assessed the views of various stakeholders regarding the road closures through a combination of surveying and interviewing. Utilizing simple survey questions, prepared in both English and Danish, we gathered numerical data regarding the opinions of stakeholders. We also gathered some written responses through these surveys. By interviewing those who are comfortable speaking English with us, we were able to gather qualitative evidence to help us in describing the exact nature of the health, safety and other changes, as experienced by actual stakeholders.

In order to investigate the opinions the stakeholders correctly, the team had to categorize our stakeholders into groups. The types of stakeholders in our project are listed on the left of Figure 26and the different modes of transportation that the stakeholders can utilize are on the right of Figure 26. A stakeholder can be any combination of the categories and take any combination of transportation listed in Figure 26.

A: Stakeholders

- Residents of Nørrebrogade and the surrounding area
- Shop Owners
- Employees
- Shoppers

B: Modes of Transportation

- Private Motor Vehicle
- Bicycle / Moped
- Bus
- Walking

Figure 26: Two Categorization Techniques for Interview Subjects

Since any combination of stakeholder and mode of transportation is possible, we tailored our survey questions to various combinations. We produced two versions of our survey, one for shop owners and employees and one for residents and shoppers. The survey forms we developed and utilized are available in Appendix F. On the survey for residents, and shoppers, we allowed the stakeholder "check off" which category they fall under and which methods of transportation they take. We developed our survey to focus on the habits and thoughts of stakeholders before and after the trials. We proposed questions that allowed the stakeholder to evaluate Nørrebrogade before and after the trials and if they changed transportation or activities.

The goal was to survey at least 20 residents, 20 shop owners, 20 employees, and 20 customers. We also attempted to survey 20 stakeholders who use each type of transportation listed in Figure 26.However, we realized that our surveying methods limited us to only certain stakeholders (those who were walking on the sidewalk and shopping/working in stores). We also realized finding drivers of private motor vehicles would be harder to find due to the fact that there is no parking allowed on the road, but the ones we found provided some interesting insights. As such, we surveyed a total of 75 people, 27 of which were either shop owners or employees, while 48 were residents, shoppers, or people utilizing Nørrebrogade for other reasons.

At the bottom of the survey we indicated that if the stakeholder was comfortable speaking English that we would appreciate it if they participated in an interview too. Ideally we wanted to speak with stakeholders who use each of the various modes of transport and who have been positively or negatively affected by the closure to gain as much insight as possible, but equally speaking with the full spectrum of stakeholders was limited to the stakeholder deciding if they wanted to be interviewed and since the stakeholder could fall into multiple categories.

The following steps allowed us to accomplish our objective to assess locals' views regarding the Nørrebrogade road closure:

1. The team created a series of survey questions in English for participants that can be easily understood and checked off. We had the questions translated into Danish so participants were able to choose which language they take the survey in.
2. We conducted 75 surveys. The surveying was conducted with the following procedure during which we followed all IRB protocols.
    a. The team traveled to various locations on and around Nørrebrogade for several days (South, Central, and North sections) between April 14th and April 26th at different time intervals with surveys in both English and Danish.
    b. We selected at random throughout the north, central, and south sections of Nørrebrogade:
        i. persons walking, biking, or waiting for the bus on Nørrebrogade
        ii. shops along Nørrebrogade to interview the owner, employees, and customers
3. Each potential participant was asked if they were willing to participate in a short survey. If the person agreed, they were given the survey in the language they requested and told that they may withdraw at any time.
4. As we conducted the surveys and interviews, we filled out Daily Bias Forms for each day and group of surveys. These forms were kept in a folder along with the filled out interviews/surveys. The Bias Forms allowed us to record factors like

the weather, type of day (i.e. workday or holiday) that can potentially affect the way a participant answers the questions. Furthermore, we labeled the surveys with an ID that corresponds to each team member's first name which we recorded on the bias sheet for record keeping. An example of a Daily Bias Sheet is displayed in Table 10. Appendix L contains the completed Daily Bias Sheets.

Table 10: Daily Bias Sheet- Form filled out each day surveys and interviews were conducted

Daily Bias Worksheet	
Date:	
Day of week:	
Holiday?	
Time of day:	
Temperature:	
Weather:	
Section of Nørrebrogade:	
IDs	
A	
F	
I	

5. The team analyzed the responses of these individuals, looking for patterns and common observations. We investigated the interview anecdotes to find supportive evidence for the noise evaluation, and emission calculations. Through this investigation, we identified "quality of life" aspects that may have changed due to the road closures.

3.5Methodology Summary

It is important to realize that our methods were built upon each other. The traffic flow calculations were the base of our project. The emissions calculations and noise evaluation depended on the accuracy of the traffic data. Our surveys and interviews were supplements to the quantitative data received from the calculations. Our methods described above enabled us to accomplish our project goals and missions.

Chapter 4: Nørrebrogade Traffic Analysis

This chapter contains the results, analysis and conclusions from the all traffic calculations. The first section presents the results of our traffic data organizational methods and calculations. A thorough discussion of the results is then followed by conclusions we drew from the traffic calculations.

4.1 Nørrebrogade Traffic Calculations

After completing the mathematical procedures we developed to estimate values for missing traffic data and calculating changes in traffic for the Nørrebro area and along Nørrebrogade, the following quantitative results for the Nørrebrogade Traffic Analysis were obtained. In order to easily read our data, we divided the data into two tables. Changes in traffic on streets in the Nørrebro area (excluding Nørrebrogade itself) are presented in Table 11and changes in traffic along Nørrebrogade are displayed in Table 12. Table 11 includes the reading locations in the Nørrebro area (not including Nørrebrogade), the total motor vehicle traffic from Before the Trials, Trial 1 and Trial 2, and the percent changes in motor vehicle traffic between the time periods. The increases above 10% in traffic are bolded in red and decreases above 10% are bolded in green. Maps with the percent changes in traffic in the area are presented later in this chapter. Appendix D contains a table that breaks down the total motor vehicle traffic by vehicle category for these reading locations. It is important to recognize that not all reading locations have traffic counts for each time period. Since we were presented with a large amount of traffic data, we selected the reading locations either by how much data was available or by their relative location to Nørrebrogade. We used all reading locations which were available on Nørrebrogade. For the reading locations surrounding Nørrebrogade, we chose to include the ones with traffic counts from before the closure and at least one traffic count after the closures began (Trial 1 or 2). Reading locations closet to Nørrebrogade that were presented in the Eval sheets were chosen. Figure 27displays a histogram of the increases and decreases in total motor vehicle traffic at the reading locations during the three time periods.

Table 11: Changes in total motor vehicle traffic between data from before the closure,Trial 1 and Trial 2 for streets in Nørrebro area during 7:00-18:00.

Reading Location	Before	Trial 1	ΔBT1	Trial 2	ΔBT2
Åboulevard Northwest of Tomrergade	36579		N/A	35408	-3.20%
Baldersgade	1569	1060	-32.44%	1009	-35.69%
Blegdamsvej Southwest of Fredensgade	4442		N/A	5185	16.73%
Bragesgade	523		N/A	413	-21.03%
Fælledvej Northeast of Nørrebrogade	4915	3865	-21.36%	3432	-30.18%
Frederiksborggade	4939	4826	-2.29%		N/A
Gyldenløvesgade off the lakes	42801		N/A	44498	3.97%
Jagtvej Northeast of Nørrebrogade	17003	14724	-13.40%	14894	-12.40%
Jagtvej Southwest of Nørrebrogade	16661	14410	-13.51%	13563	-18.60%
Lundtoftegade	6773	7871	16.21%	7990	17.97%
Møllegade	1121	695	-38.00%	980	-12.58%
NørreSøgade	24952	25105	0.61%		N/A
ØsterSøgade Northeast of Gothersgade	21904	22659	3.45%	20617	-5.88%
Peter FabersGade	748	713	-4.68%	669	-10.56%
SortedamDossering by DronningLouises Bridge	1798	1103	-38.65%	997	-44.55%
Tagensvej Northwest of Jagtvej	14868		N/A	15772	6.08%
Ægirsgade	912	827	-9.32%	853	-6.47%

According to Table 11, reading locations in the Nørrebrogade area have both increased and decreased in motor vehicle traffic. Figure 27displays a histogram of the increases and decreases greater than 10% in total motor vehicle traffic at the reading locations during the three time periods.

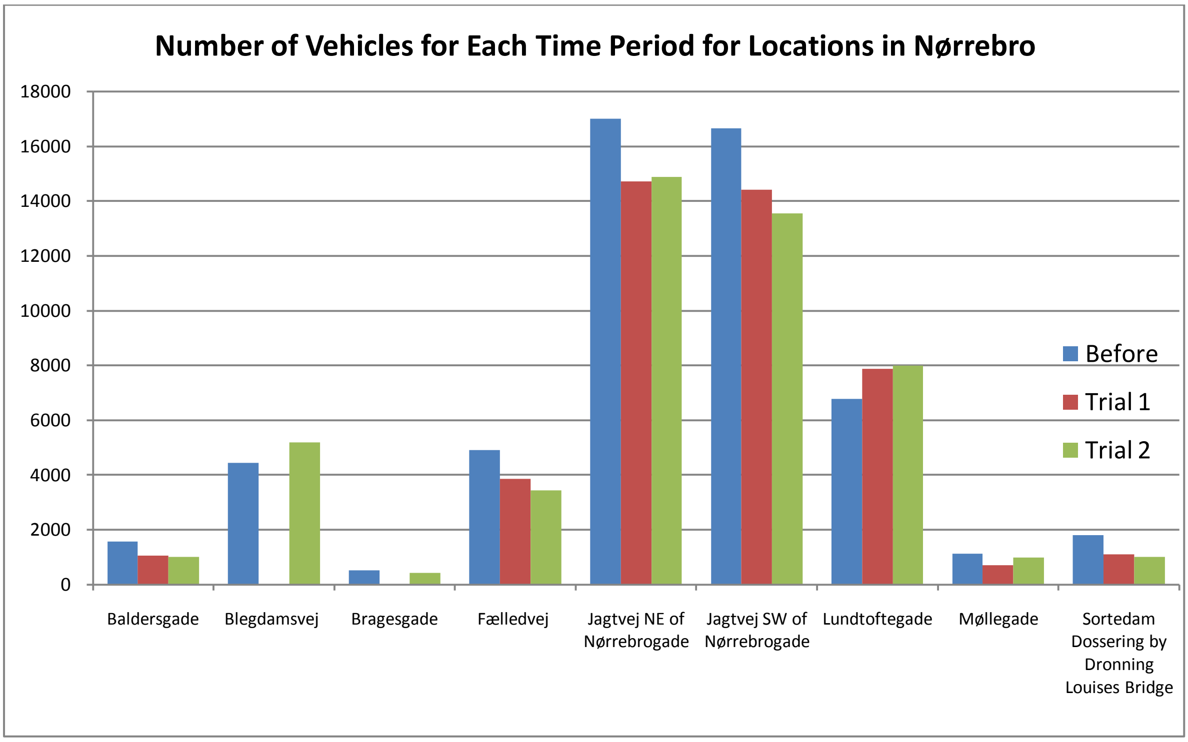

Figure 27: Reading Locations in Nørrebro that increased or decreased due to the Nørrebrogade Closures

Out of the reading locations that were investigated during the project, Lundtoftegade is the only reading location that increased in traffic during both trials, by about 17%.Blegdamsvej also increased in traffic during Trial 2 by about 17%. Although we do not have Trial 1 data for Blegdamsvej, it is likely that the traffic on the street also increased during Trial 1. Jagtvej, the major artery that runs perpendicular to Nørrebrogade at the Runddel Rotary, decreased in total motor vehicle traffic during both trials on average at both locations by about 14%.

The traffic results for the reading locations along Nørrebrogade are located in Table 12. Nørrebrogade is displayed in segments created for use in our emissions calculations. Traffic counts for each reading location and available time period are listed and changes in traffic between the time periods are also shown. Decreases in traffic are in boldfaced green. Not all of the reading locations along Nørrebrogade had traffic counts available for each time period. Appendix D contains the traffic counts by vehicle category for each reading location along Nørrebrogade as well.

Table 12: Changes in total motor vehicle traffic from data before the closures, Trial 1 and Trial 2 for segments along Nørrebrogade during 7:00-18:00.

	Reading Location	Before	Trial 1	ΔBT1	Trial 2	ΔBT2
Segment 1	Nørrebrogade W of Hyltebro		3855		3438	
	Nørrebrogade E of Hyltebro		3936		4324	
	Nørrebrogade W of Bragesgade				1911	
	Nørrebrogade W of Baldersgade		2329.5		2738	
	Nørrebrogade NW of Hillerødgade	10206	3704	-63.71%		
	Segment Average	**10206**	**3456**	**-66.14%**	**3102**	**-69.60%**
Segment 2	Nørrebrogade SE of Hillerødgade	11049	6144	-44.39%		
	Nørrebrogade E of Ægirsgade		5374		6541	
	Nørrebrogade NW of Jagtvej	11130	6010	-46.01%	6277	-43.61%
	Nørrebrogade SE of Jagtvej	10023	5276	-47.36%	5404	-46.09%
	Segment Average	**10734**	**5701**	**-46.89%**	**6074**	**-43.42%**
Segment 3	Nørrebrogade W of Stengade		2883		3132	
	Nørrebrogade W of Faelledvej (closed section)	10766	1917	-82.20%	1518	-85.91%
	Segment Average	**10766**	**2400**	**-77.71%**	**2325**	**-78.41%**
Segment 4	Nørrebrogade E of Faelledvej	11664	4831	-58.59%	4229	-63.75%
	Nørrebrogade (near bridge)	11132	5290	-52.48%		
	DronningLouises Bro	10946	5896	-46.14%	5938	-45.75%
	Segment Average	**11247**	**5339**	**-52.53%**	**5083**	**-54.81%**
	Whole Road Average	**10864**	**4419**	**-59.33%**	**4132**	**-61.97%**

The data in Table 12 show that each of the locations along Nørrebrogade experienced a significant decrease in traffic during the time periods available for the locations. The average decrease in motor traffic along Nørrebrogade during both trials is about 60%. Figure 28 displays the decreases in traffic along the Nørrebrogade reading locations as a histogram.

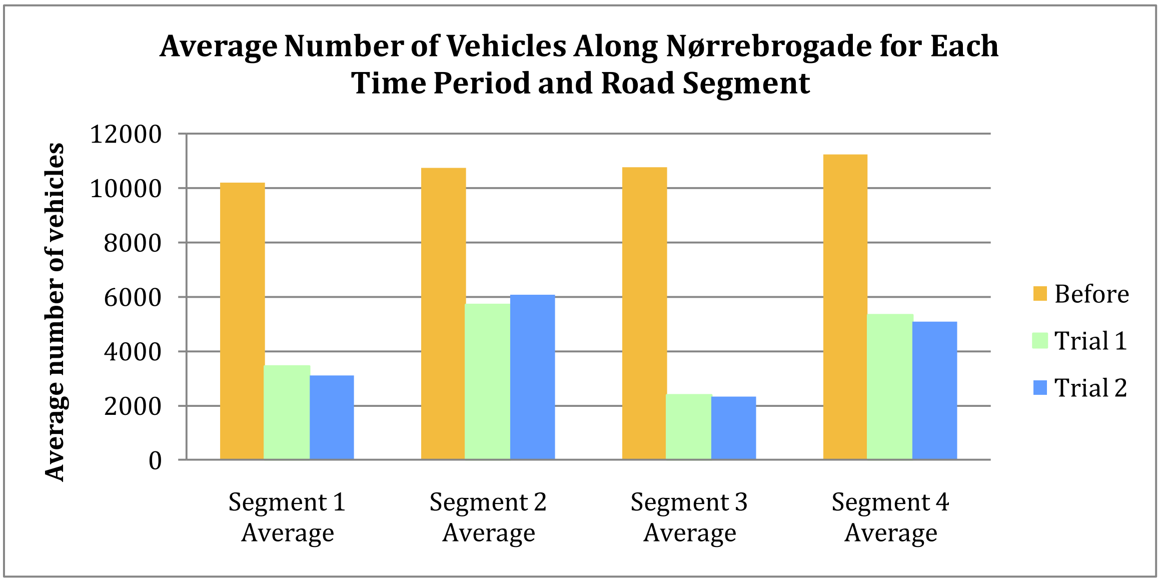

Figure 28: Decreases in traffic along Nørrebrogade for the three time periods

In terms of our traffic counts, some of the early Trial 1 results may be skewed. The acclimation period may indicate that roads which increased in traffic, such as Lundtoftegade, should possibly have increased more because some drivers had not yet changed their route to that street. Conversely, locations that decreased in traffic during early readings for Trial 1 should probably have decreased more such as Baldersgade.

We further investigated the effects of the acclimation period on our Trial 1 traffic data. For this investigation, Trial 1 was divided into two parts, Trial 1 Early (T1E) and Trial 1 Late (T1L) for reading locations along Nørrebrogade that contained traffic counts in Oct/Nov 2008 and April 2009. Trial 1 Early represents the acclimation period and Trial 1 Late represents the possible equilibrium in traffic. We obtained the following data, present in

Table 13, which shows Early and Late Trial 1 for the Nørrebrogade and several reading locations in Nørrebro.

Table 13: Changes in total motor vehicle traffic for Trial 1 during 7:00-18:00 without the acclimation period readings for Nørrebrogade and several locations in Nørrebro.

Nørrebrogade Reading Locations	T1E	T1L	% Change
Nørrebrogade West of Hyltebro	4338	3373	-22.26%
Nørrebrogade East of Hyltebro	4596	3276	-28.73%
Nørrebrogade West of Faelledvej (closed section)	2419	1415	-41.53%
Nørrebrogade East of Faelledvej	5269	4394	-16.61%
Dronning Louises Bro	6195	5408	-12.71%
Nørrebro Reading Locations	**T1E**	**T1L**	**% Change**
Baldersgade	1183	934	-21.05%
Møllegade	665	724	8.87%

The data in Table 13 shows the traffic along Nørrebrogade decreased more during T1L than in T1E. This suggests that right after Trial 1 began, drivers that normally would have changed their routes were still using Nørrebrogade and had not decided on the best alternate route, or change in type of transportation. This suggest that   an equilibrium in traffic flow for Trial 1 was not reached until later during Trial 1 and that T1E may be during the acclimation period.

Table 13 also shows that the acclimation period theory carries over to both Baldersgade and Møllegade. Baldersgade decreases in traffic more during Trial1 Late and Møllegade increased more in traffic. The team wanted to calculate Lundtoftegade without the acclimation period readings because it increased in traffic during Trials 1 and 2 and would strengthen our investigation, but the only readings available for Lundtoftegade were during the acclimation period. This again illustrates the importance of having consistent reading locations and traffic data. Since removing the acclimation period from the Nørrebrogade calculations resulted in a larger decrease in traffic, it is quite possible that Lundtoftegade might have shown larger increases in motor vehicle traffic during later stages of Trial 1.

Table 14 displays the increase in traffic on Nørrebrogade from Trial 1 (Late) to Trial 2.

Table 14: Traffic Increase between Trial 1 (Late) and Trial 2.

Nørrebrogade Segment	ΔT1L->T2
Segment 1	3.67%
Segment 2	13.03%
Segment 3	8.19%
Segment 4	3.72%

The data in

Table 14suggests that the differences in traffic flow along Nørrebrogade witnessed some fluctuation between Trials 1 and 2, but overall, the differences in traffic are not great.

4.2 Nørrebrogade Traffic Analysis and Conclusions

Maps of the Nørrebro area were created to help visualize changes in traffic flow around Nørrebrogade. We separated Nørrebro into three sections according to approximately where the closures along Nørrebrogade took place. Figure 29 displays the changes in motor traffic for the northern section of Nørrebrogade, Figure 30 shows the central section, and Figure 31 shows southern section.

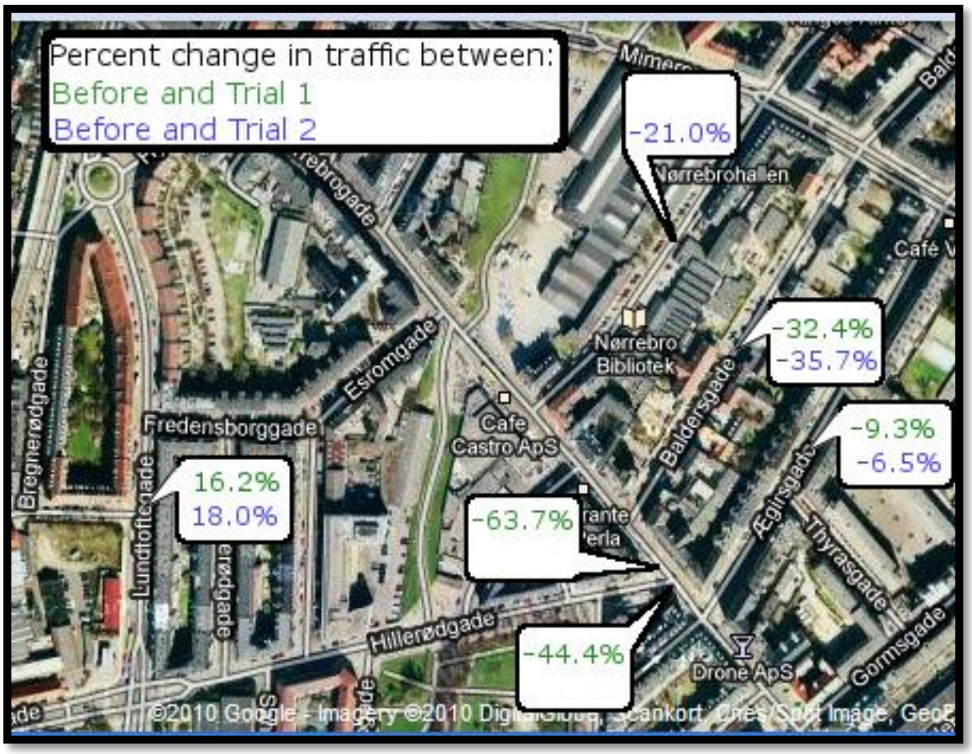

Figure 29: Northern portion of Nørrebrogade with percent changes in traffic (Image adapted from Digital Globe, 2010).

Figure 30: Central portion of Nørrebrogade with percent changes in traffic (Image adapted from Digital Globe, 2010).

Figure 31: Southern portion of Nørrebrogade with percent changes in traffic (Image adapted from Digital Globe, 2010).

As shown in these figures, streets that intersect with Nørrebrogade decreased in traffic. The one street that increased in traffic during both trials, Lundtoftegade (Trial 1 approximately by 16.2% and Trial 2 by 18%) runs somewhat parallel to Nørrebrogade, and leads to Ågade, a major artery which runs parallel to the middle and southern parts of Nørrebrogade.

Table 15 shows Lundtoftegade's traffic data broken down by vehicle category. Traffic on Lundtoftegade increased by approximately 1100 motor vehicles during Trials 1 and 2. According to

Table 15, the largest increase in vehicle type on Lundtoftegade was personal motor vehicles. This may indicate that passenger car drivers who may have previously driven the whole length (or a sizable portion) of Nørrebrogade diverted their route to Lundtoftegade (and probably Ågade) to avoid the closures.

Table 15: Lundtoftegade traffic data broken down by vehicle category for pre trials, Trial 1 (Oct/Nov) and Trial 2 during 7:00-18:00.

607_Lundtoftegade	Before	Trial 1(Oct/Nov)	Trial 2
Passenger cars	5238	6306	6211
Light duty vehicles	1071	1128	1363
Heavy duty vehicles	368	329	313
Mopeds	23	20	17
Motorcycles	73	88	86
Bicycles	1801	1561	1352
Totals (all, unadjusted)	**8574**	**9432**	**9342**
Totals (motor, unadjusted)	**6773**	**7871**	**7990**

Since some of the readings for Trial 1 were taken right after the trial began (October or November 2008) and this closure represented a major change in the traffic rules, we believe based on our research into road closure case studies, that these readings were during the acclimation period, where drivers are still adjusting their behaviors. When the Rathausplatz/Theresienstrasse Square in Nuremberg, Germany was pedestrianized in the late 1980s, traffic increased in the area for the first two months of the project. However, when spring arrived, the traffic decreased significantly and after one year traffic in the whole city decreased by 25% (Wallström, 2004). We believe that the road closures on Nørrebrogade are comparable to the Nuremberg, Germany road closure, meaning that drivers in Nørrebro probably had not adjusted to the new traffic rules and did not find alternate routes or forms of transportation before these early counts were taken.

Our investigation into the traffic acclimation period has lead us to believe that the Trial 1 Late data is more accurate than using Trial 1 all (the average of Trial 1 Early and Late). Since our investigation supports the acclimation period, the emissions calculations and noise evaluation for Nørrebrogade only utilize Trial 1 Late Readings.

4.3 Final Traffic Conclusions

The calculations that the team performed during this project indicate that the Nørrebrogade Road Closures Project indeed decreased traffic in the Nørrebro area, especially along Nørrebrogade. However, it is important to recognize that some streets in the Nørrebro such as Lundtoftegade and Blegdamsvej have increased in motor vehicles. It is possible that these streets have absorbed approximately 4480 motor vehicles from Nørrebrogade due to the closures. Ideally, we wanted to be able to calculate possible traffic evaporation for Nørrebro, but the data provided by the Municipality are not consistent between reading times, locations, and vehicle categories. There could possibly be traffic evaporation, but there is insufficient data to support or refute this claim.

Our traffic calculations would be more accurate if the traffic data from the City of Copenhagen was more complete. Having to develop a method to extrapolate daylong data from the rush hour Eval sheets decreased the reliability of our results. Time constraints prevented us from performing more data extrapolation from the Eval sheets. However, we believe that our methods and results from our traffic analysis reasonably represent in the changes in traffic in the Nørrebro area due to the closures on Nørrebrogade.

Chapter 5: Air Pollution Emissions

This chapter presents the results, analysis, and conclusions drawn from performing the Emissions Calculations. The first section shows the outcomes of our emissions calculations which include the reductions in emissions along the Nørrebrogade segments. Next, these results are analyzed and finally, conclusions about possible health effects due to the change in pollutants are made.

5.1 Emissions Calculations

The team followed the mathematical procedures outlined in section 3.2 to obtain quantitative results for changes in emissions. Figure 32 and Figure 33display the results of these emissions calculations. Each graph represents the change in NO_x, HC, CO and $PM_{10/2.5}$ on each road segment of Nørrebrogade for different time periods. Figure 32 shows the reduction in pollution for Trial 1 after the acclimation period. Figure 33 shows the reduction in pollution for Trial 2. These graphs display both the reduction in traffic for the four segments of Nørrebrogade and the reduction in traffic-related air pollutants: NO_x, HC, and CO, and PM.

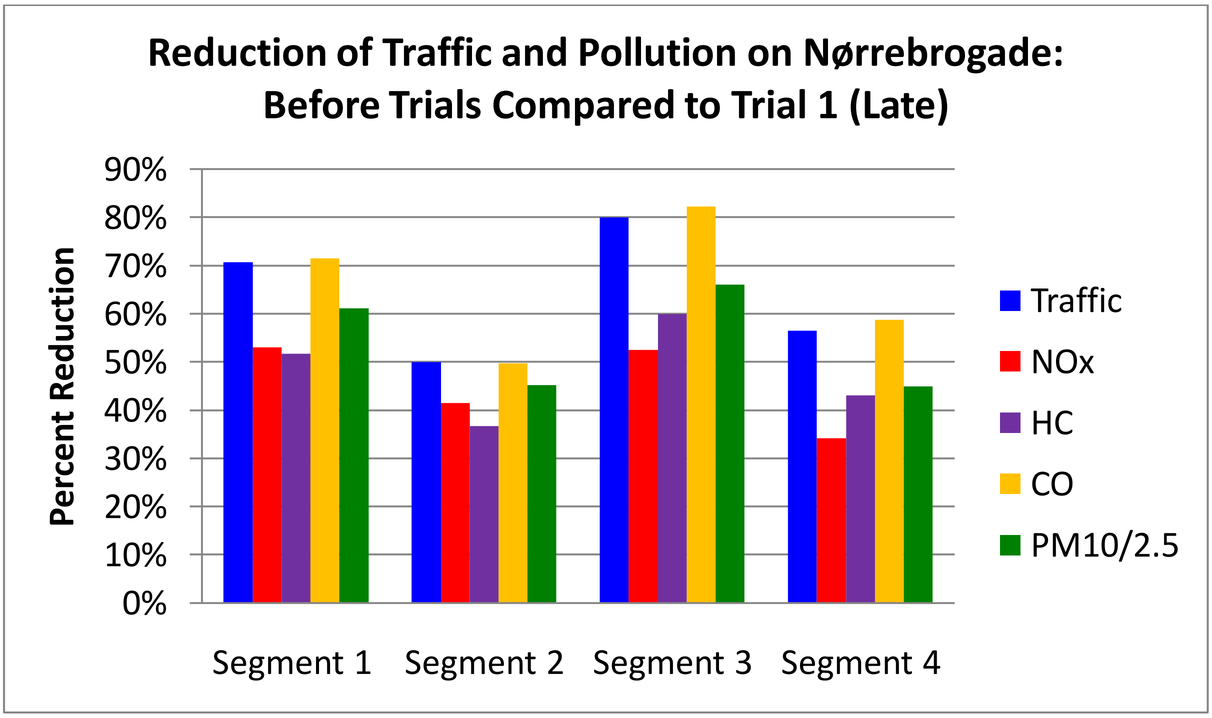

Figure 32: Pollution levels remaining on Nørrebrogade in Trial 1 compared to traffic

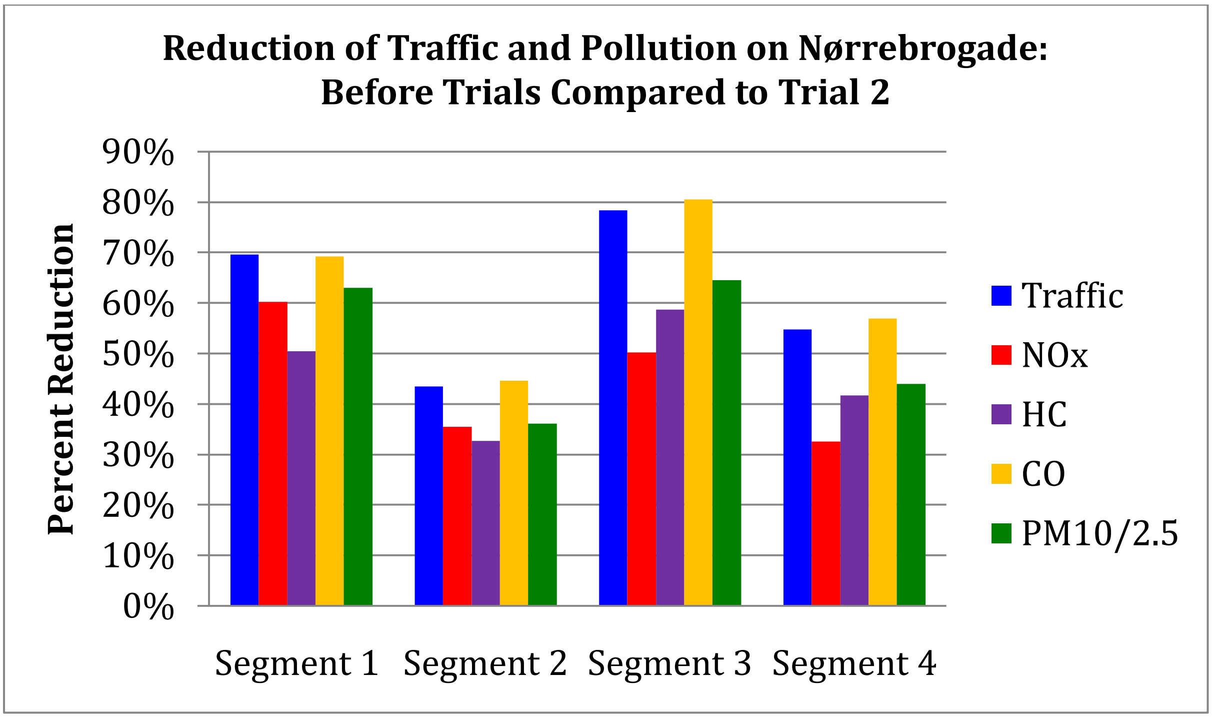

Figure 33: Pollution levels remaining on Nørrebrogade in Trial 2 compared to traffic

The bar graphs above show that all pollutant types decreased during each trial closure when compared to before the road closures. According to Figures 32 and 33, both trials witnessed a similar change in emissions, with segments 1 and 3 having the largest reductions. These figures also show that all pollutants, except CO, were not reduced as much as the traffic. In general, the greatest pollution reductions were in carbon monoxide and particulate matter.

In order to account for the change in ultrafine particles along Nørrebrogade, we consulted Olsen, Olesen, and Petersen (2009) along with the results of our traffic analysis. Figure 34 shows the clear linear relationship between traffic and ultrafine particles. The ultrafine particles study considered all vehicle types except buses in their data because buses use particle filters. The correlation in Figure 34 is not directly proportionate to our results because we did not separate buses from heavy vehicles. Since there is currently no method to calculate the exact change in ultrafine particles, we can demonstrate from this information that because buses were not counted that the reduction of ultrafine particles should be greater than the reduction in traffic.

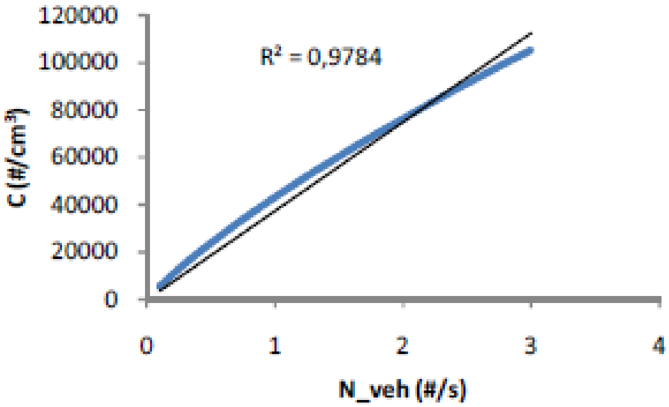

Figure 34: Graph showing the relationship between ultrafine particles and number of vehicles present (Olsen, Olesen, & Petersen, 2009)

5.2 Analysis of Emissions Calculations

Vehicle composition played a large role in determining the change in pollution from change in traffic along Nørrebrogade. One may think that the change in emissions should be the same as the change in traffic, but this is not the case due to the differences in emissions between vehicle categories. These differences include use of various types of fuel, fuel economy and emission factors. Therefore, each type of vehicle produces different amounts of the various pollutants. Figure 35 shows how the reduction in traffic on Nørrebrogade was not equal across all vehicle categories. Segment 3 is used as an example.

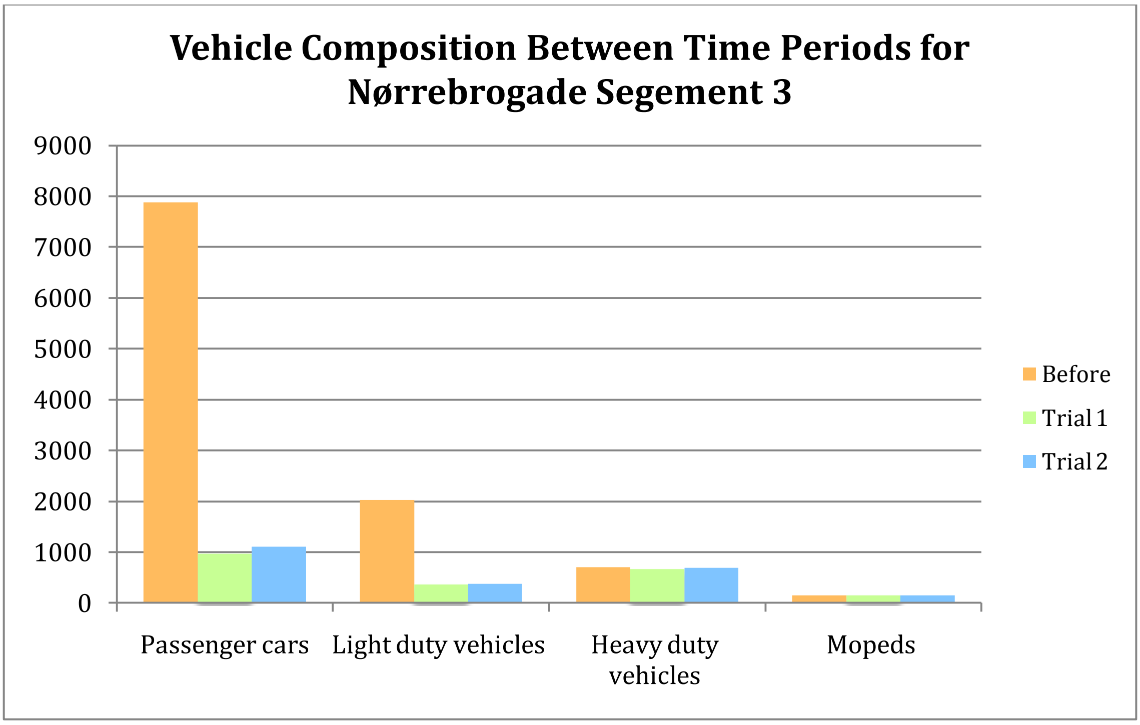

Figure 35: Vehicle Composition Between Time Periods for Nørrebrogade Segment 3

The data in Figure 35 demonstrates that passenger cars, reduced the most on Segment 3 whereas heavy duty vehicles remained approximately constant throughout the time periods. Examining the difference in emission factors for various pollutants allows us to see the effect of changes in vehicle composition on the air pollution results. By referring to Figure 36 below, one can see which vehicle categories are primarily responsible for carbon monoxide emissions.

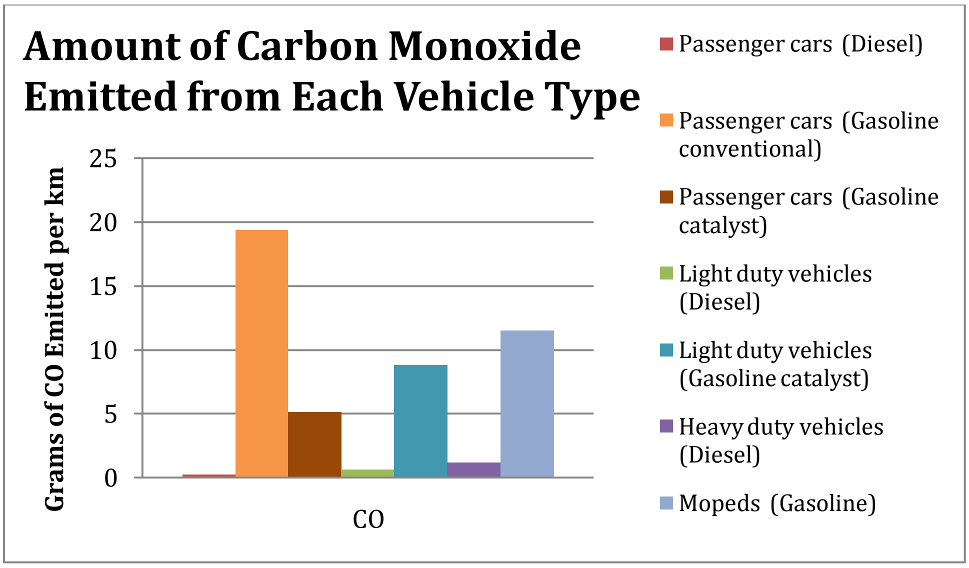

Figure 36: Grams of carbon monoxide emitted by each vehicle type (created with information from DMU, 2010)

Figure 36 shows that conventional gasoline passenger cars, shown in orange, contribute to carbon monoxide air pollution more than the other vehicle categories; however, according to Table 9, only 6% of the passenger vehicles in Denmark are conventional gasoline and 69% of passenger cars are gasoline catalysis. This indicated that gasoline catalyst passenger vehicles, shown in brown, actually contribute the most to CO and is the important vehicle category to analyze when discussing CO emissions in Figure 36. Since passenger cars reduced the greatest after the closures began, CO was reduced most from this category. Furthermore, gasoline catalysts light duty vehicles contributed to a proportion of the CO on Segment 3 and since they were reduced from around 2000 to 300, CO was able to be reduced even more on Segment 3. Due to these two factors, CO was reduced equal to or slightly greater than the traffic reduction. Similarly, nitrous oxides emissions were reflected in our vehicle categories. Figure 37 shows that heavy-duty vehicles emit significantly more NO_x than every other vehicle category. Since there were no restrictions on buses, which make up almost all of the heavy-duty traffic along Nørrebrogade, the number of these remained relatively constant during the three time periods. Furthermore, heavy-duty vehicles, which use diesel fuel, have much higher nitrous oxide emissions than passenger cars using the same type of fuel. Therefore, heavy duty vehicles did not have a large impact on the reduction in nitrous oxides. Even though there were traffic reductions in passenger cars and light duty vehicles, which are mostly gasoline catalyst, their emission of NO_x were very small compared to heavy duty vehicles and their decline did not significantly impact the reduction in NO_x. Additionally, diesel and gasoline conventional passenger cars compose 31% of all passenger cars and together emit a relatively high percentage of NO_x. Since these types of passenger cars reduced along Nørrebrogade, their reduction allowed NO_x to decrease slightly. As a result, nitrous oxides displayed the lowest percent change out of our four traffic-related air pollutants.

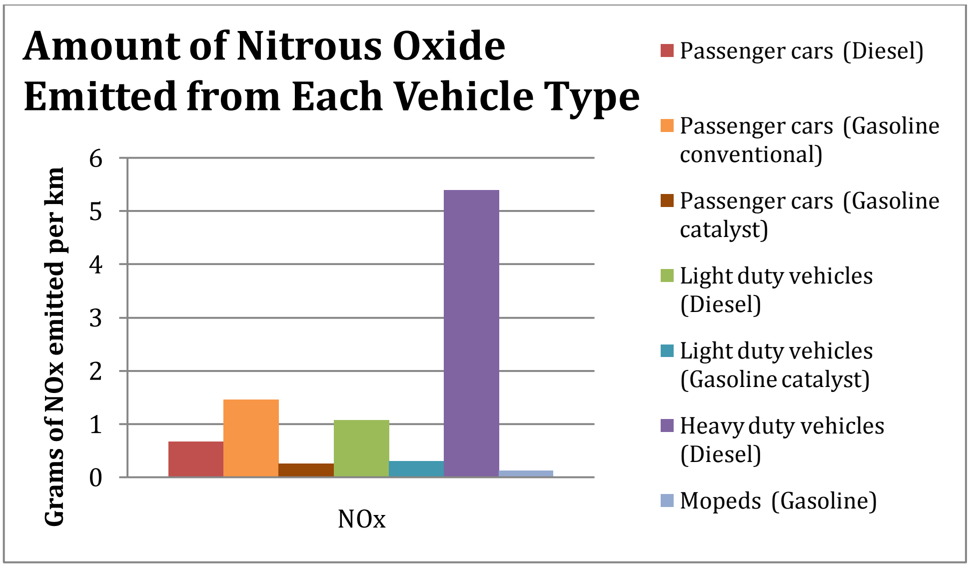

Figure 37: Grams of nitrous oxides emitted by each vehicle type (created with information from DMU, 2010)

Mopeds, though small in number, can significantly influence the outcome of the emissions calculations, most notably for hydrocarbons. Mopeds emit much more hydrocarbons per liter of fuel than all other vehicle types, and therefore contribute to a large part of the overall hydrocarbon pollution (see Appendix K, Figure 49). Many of the traffic readings did not count mopeds. Because of this, we assumed that moped counts were the same for each time period. This was a reasonable assumption since the number of mopeds would not be significantly affected by the closure, as mopeds usually drive in the bicycle lanes. Also, since mopeds do not require inspection in Denmark, the number and age distribution of mopeds are not known. This may cause the emission factor to not be an accurate representation of the average moped and cause a larger error associated with the emission calculations of hydrocarbons.

There are additional sources of error in our emissions calculations. The speed of traffic effects how much pollution is emitted, but we did not adjust the emissions factors for changes in average speed, since we had little evidence indicating what this change would be, if any. Additionally, we did not take into consideration any changes in how often drivers have to stop while driving down Nørrebrogade. Braking and accelerating habits affect emissions, but we did not have data on any changes in the braking and acceleration habits of drivers on Nørrebrogade.

5.3 Health-Related Effects of Reductions in Emissions

Through our research, a correlation can be seen between pollution and health. All pollutants which we have investigated including NO_x, HC, and CO, and PM are expelled from motor vehicle traffic and have been associated with negative health effects. Here is a short summary of the negative health effects caused by traffic-related air pollution (see section 2.4.3for full details):

- Constant NO_2 Exposure:
  - damage Clara cells in the lungs
  - increase the chance of asthma onset in children
- Constant HC Exposure
  - DNA damage and bone marrow deformation by benzene metabolites
  - childhood cancers
  - drowsiness, dizziness and possible death
- Constant PM Exposure
  - clots in lungs and the brain (Ultra Fine Particles)
  - increase the chance of hospitalization for respiratory problems ($PM_{2.5}$)
- Constant CO Exposure
  - CO poisoning
  - death

Thus, if traffic-related air pollution is reduced, then the probability of developing these health problems listed above may decrease. Furthermore, our research indicated that living near high traffic roads causes a wide variety of health problems which have not been linked to specific pollutants. These may also be alleviated if traffic is reduced. These health problems include:

- asthma symptoms in children
- lung cancer
- rheumatoid arthritis in women
- atherosclerosis

However, it is difficult to conclude whether people on or near Nørrebrogade have seen significant changes in health since the road closures. Based on previous research, the segments have not been closed for a long enough time period to have a direct affect on people's health quality of life. The majority of the studies presented in sections 2.4.3-2.4.3.3 took between 5 and 10 years to complete. If the segments along Nørrebrogade remain closed for a longer duration (possibly 5-10 years) and traffic continues to be reduced, then health benefits can be expected and the health quality of life may improve amongst the residents of Nørrebro.

Chapter 6: Noise Evaluation

This chapter contains the results, analysis, and conclusions drawn from the noise evaluation. The results section displays the results of all noise calculations along Nørrebrogade. The analysis section investigates our results and discusses potential inaccuracies. The last section discusses some health-related conclusions based on our study.

6.1 Estimated Noise Changes

The results of our noise calculations for each of the four Nørrebrogade segments are given in Table 16.

Table 16: Change in Noise Levels along Nørrebrogade

Road Segment	Noise Reduction Trial 1 (Late) (dB)	Noise Reduction Trial 2 (dB)
Segment 1	-5.03	-4.94
Segment 2	-3.42	-2.92
Segment 3	-5.75	-5.62
Segment 4	-3.92	-3.80

As Table 16indicates, all segments exhibit noise level reductions of about 3 dB or greater. Segment 3, which contains one of the segments that remained closed through all trials, experienced the greatest reduction when compared to pre-closure noise. Segment 1, which contains the other closed segment, experienced a greater noise reduction than segments 2 and 4 as well.

Using traffic information provided by various municipalities from 2007 to 2009, the Miljøministeriet created a tool called the Støjkortlægning, which uses the Nord2000 noise modeling system to calculate the noise levels for Copenhagen and much of Denmark ("Støj-Danmarkskortet", 2010). Figures Figure 38, Figure 39, Figure 40, and Figure 41 display the Støjkortlægning noise level maps for Nørrebrogade during the daytime and nighttime, 1.5 and 4.0 meters from the ground. The locations of Nørrebrogade and Nørrebro Station are indicated on the maps.

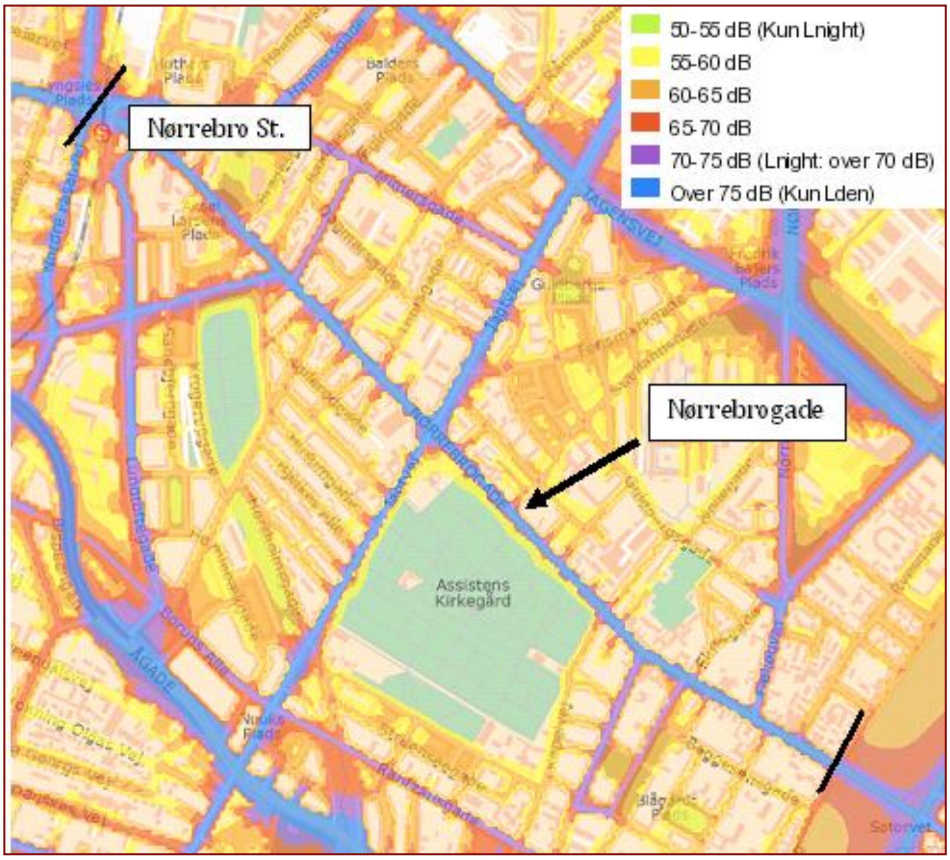

Figure 38: Nørrebrogade Noise Map, Daytime and 1.5m. (Adapted from Miljøministeriet, 2010. Retrieved 3 May 2010 from noise.mst.dk.)

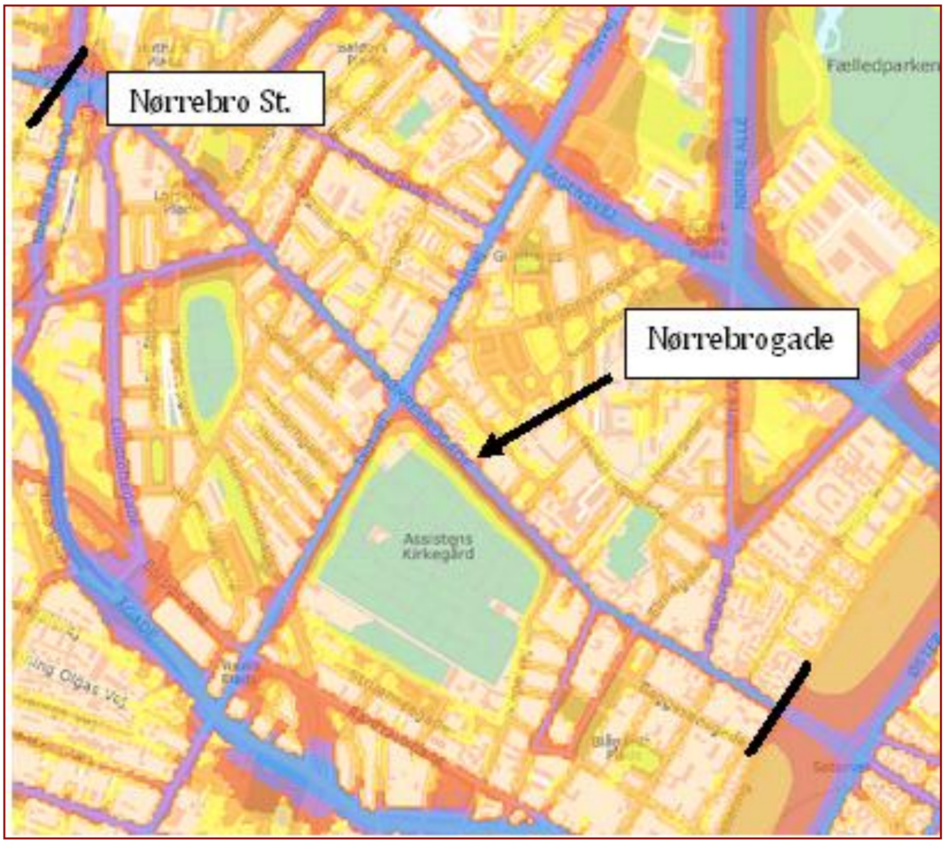

Figure 39: Nørrebrogade Noise Map, Daytime and 4.0m. (Adapted from Miljøministeriet, 2010. Retrieved 3 May 2010 from noise.mst.dk.)

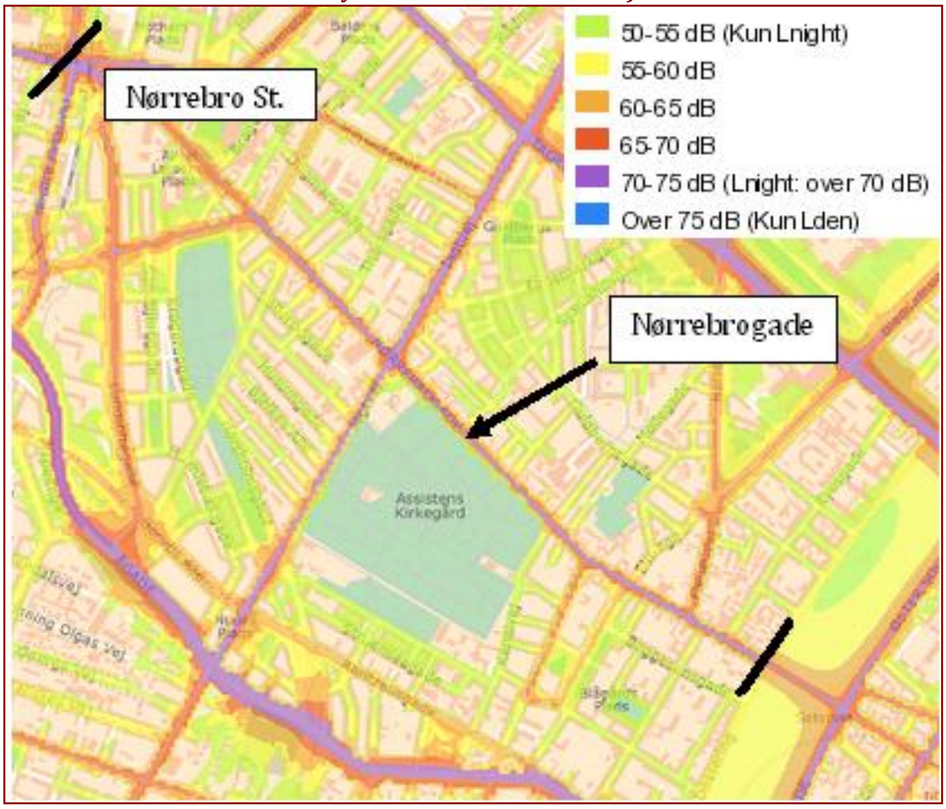

Figure 40: Nørrebrogade Noise Map, Nighttime and 1.5m.(Adapted from Miljøministeriet, 2010. Retrieved 3 May 2010 from noise.mst.dk.)

Figure 41: Nørrebrogade Noise Map, Nighttime and 4.0m. (Adapted from Miljøministeriet, 2010. Retrieved 3 May 2010 from noise.mst.dk.)

The noise levels for Nørrebrogade as obtained from the Støjkortlægning are listed in Table 17.

Table 17: Noise levels on Nørrebrogade

Street	Noise Level at Time of Day and Height off Ground			
	Daytime 1.5m	Daytime 4m	Nighttime 1.5m	Nighttime 4m
Nørrebrogade	>75 dB	>75 dB	>70 dB	65-70 dB

The Støjkortlægning also indicated that there is no significant industrial, aero, or rail noise on Nørrebrogade. The map did show some trivial rail noise near Nørrebro station, but this is entirely negligible since the road traffic noise is several orders of magnitude louder. Based on the numbers shown in Table 17, the following low-end adjusted noise level was calculated for comparison to the Miljøministeriet's guidelines at 4.0m:

- Daytime: 75dB
- Evening: 70dB + 5dB = 75dB
- Night 65dB + 10dB = 75dB

- Weighted Average = 75dB

6.2 Noise Analysis

As expected, the Nørrebrogade road segments that experienced greater traffic level reductions also experienced greater noise level reductions. Segment 3 and Segment 1 experienced greater noise reductions since they had greater traffic reductions from the closed parts in these segments.

The noise calculations that were performed were very straightforward and were accompanied by less uncertainty than the emissions calculations. Kåre Press-Kristensen provided the function to convert the traffic reduction to a noise reduction. The function was designed for a reduction in light vehicles only. Since the absolute number of heavy vehicles travelling on Nørrebrogade remained approximately the same, we were able to use this graph. However, the function used was designed for urban traffic moving about 50 – 60 km/h, which is 10-20km/h faster than Nørrebrogade's traffic. The difference in speed along Nørrebrogade may alter the results very slightly. Furthermore, as mentioned in section 3.3, the noise function disregards background noise because it is negligible compared traffic noise. Overall, we hypothesize that any differences from these or other factors would have a minor impact on the results of the noise calculations.

The low-end calculation of the weighted average noise level on Nørrebrogade was 75dB, which is 17dB higher than the 58dB weighted limit that the Miljøministeriet recommends. A 75dB daytime noise level is 20dB higher than the 55dB daytime limit that WHO recommends, and a 65dB nighttime limit is also 20dB higher than the 45dB nighttime noise level that WHO recommends (WHO, 1999). Clearly, Nørrebrogade's noise levels were *significantly* higher than the recommended values before the road closure. This estimate chooses the lowest value in each range and ignores the short segment of Nørrebrogade that had slightly lower noise levels. Also, this estimate predicts that the "evening" noise levels is in between the daytime and nighttime noise levels, since evening data from the noise map was not available. Even considering all the potential areas for error, it still appears that Nørrebrogade's noise levels are much higher than the guidelines suggest.

6.3 Impact of Noise Reduction

Our estimates suggest that there have been reductions in noise levels along Nørrebrogade ranging from about 3dB to 6dB, or 50-75% of all noise, depending on which section of Nørrebrogade is examined. Though these numbers may appear small, research shows that reductions of this magnitude can impact many different aspects of people's lives. According to Miljøministeriet, a reduction in noise between 3-6dB would have significant impact on the residents, shoppers, and employees on Nørrebrogade. Figure 19shows that the number of highly annoyed individuals from road traffic noise would be reduced from about 35% to 25% with just a 5dB reduction in noise levels from 75dB to 70dB.

Our research has shown that noise pollution is associated with many different health concerns. There is controversy over many of these correlations, and thus it is very difficult to identify exactly which health effects are actually affected by noise and what levels of noise significantly impact these health problems. The following list is a sample of some frequently cited correlations between noise and health (see section 2.5.4 for additional details):

- Increased stress levels, risk of myocardial infarction, risk of ischemic heart disease, and systolic blood pressure
- Increased levels of annoyance and aggressive behavior
- Poor sleep quality

Based on our research, we believe that the reduction in noise levels on various parts of Nørrebrogade will have a positive impact on people's health. The 4.0m noise level on Nørrebrogade is over 75dB during the day, and 65-70dB at night, which is often around the threshold level for many health risks. For instance, a 1997 study in Japan on 500 women suggested that physical symptoms from traffic noise manifest at 70dB(A) and disease onset is more likely to occur above 65 dB(A)(Yoshida, T. et. al, 1997). Reducing the chance of developing any of these illnesses can greatly increase health related quality of life, especially when considering a large population. Additionally hearing impairment from noise can begin at levels of 75db(A), so if the 3-6dB reduction has lowered noise levels to 70dB, then those who are frequently outdoors on Nørrebrogade will have reduced risks of hearing loss (Berglund et. al, 1999). Thus, even a small reduction of 3-6dB, which represents a decrease in volume of 50-75%, is beneficial.

In addition to the impacts of a reduction in noise on health, a noise reduction in a residential area increases the value of homes in that area. Due to the effects of noise pollution, urban apartments or homes with lower noise levels are more attractive and thus more valuable. There is some variance in the exact relationship between noise levels and the value of a home. According to Kåre Press-Kristensen, for each dB noise is reduced (above 58dB), the value of homes are increased by 1 – 1.5% (Personal communication, 2010). A study in Hong Kong found that a 1dbA increase in noise levels reduced the price of a residential apartment by 0.31% (Man & Mak, 2010). The European Road Federation stated in a report that Germany estimates each 1dBA increase in noise levels results in a reduction of the value of homes by 0.5% (Papí&Halleman, 2004). Though the exact economic effect of the 3-6dB reduction in noise on Nørrebrogade can't be shown, it appears that the value of apartments would increase by at least 1%, and perhaps considerably more. An increase in value like this is considered beneficial from an economic standpoint.

Overall, reducing traffic along Nørrebrogade reduced the noise levels by 3dB to 6dB, or 50-75% of all noise along Nørrebrogade. Although the noise reduction did not place the noise levels below the Miljøministeriet's noise guidelines, the reduction can decrease negative health effects on the residents and increase property values on Nørrebrogade.

Chapter 7: Assessment of Local Stakeholders' Views

Within this chapter, the results for the stakeholders' views assessment will be presented and analyzed. In section 7.1, tables and graphical representations display the data that were compiled through surveys and interviews. These data are then analyzed in section 7.2. Conclusions are drawn from the data in section 7.3.

7.1 Results From Assessing Locals' Views

The team conducted the surveys and interviews as discussed in section 3.4 with local people traveling along Nørrebrogade as well as owners and employees of shops on Nørrebrogade. In section 7.1.1 information regarding the sampled population is given. Section 7.1.2 presents the results found from the local people using Nørrebrogade while the 7.1.3 displays the data collected from shop owners and employees.

7.1.1 Demographics of Respondents

As explained in our methodology, volunteers who filled out our surveys can be placed in multiple stakeholder categories, and may use several different forms of transportation on Nørrebrogade. The types of locals we surveyed are represented in Figure 42 and their transportation habits are represented in Figure 43.

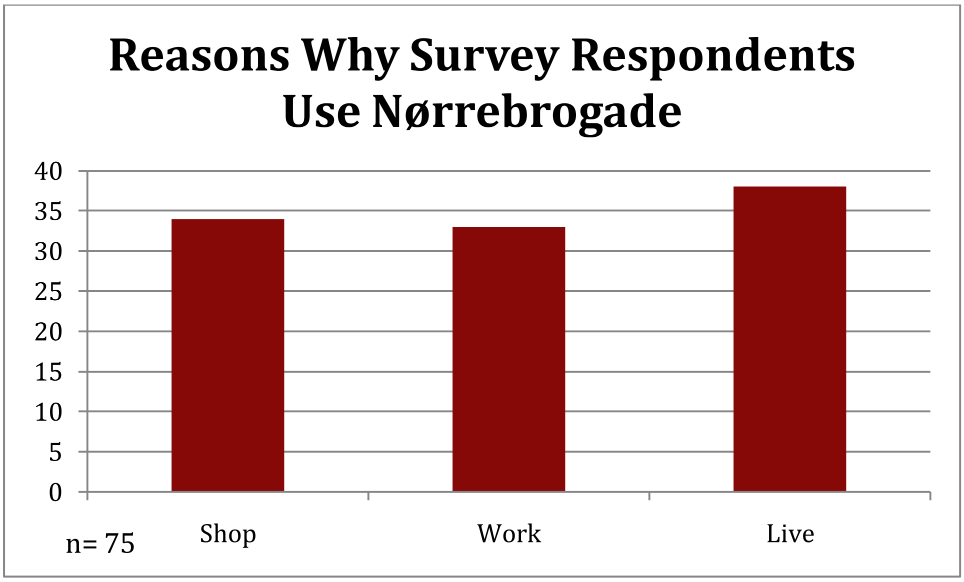

Figure 42: Bar chart showing how people use Nørrebrogade. Respondents had the option of choosing multiple answers.

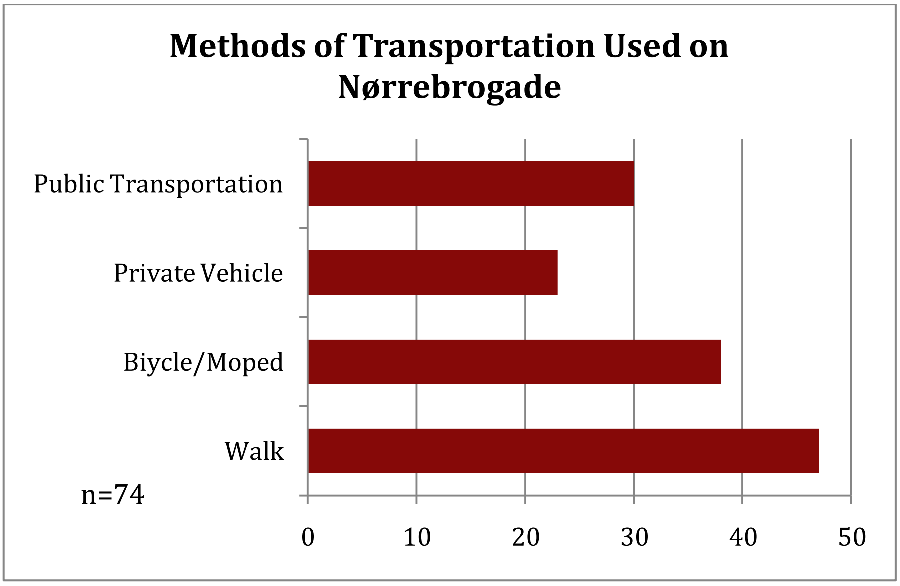

Figure 43: The types of transportation the survey respondents utilize while on Nørrebrogade. Respondents could have multiple answers for this question.

From Figure 42, the majority of the locals we sampled live on Nørrebrogade. The next highest response was shopping. Since Nørrebrogade is a highly populated street with many shops on the ground floor, our results in Figure 42 appear to correlate with the identity of the area.

Figure 43displays the types of transportation that the sampled population uses. It shows that about two thirds of the sampled population walks on Nørrebrogade as a form a transportation, making walking the most common form of transportation among the sampled population. About half of the respondents reported that they bike on Nørrebrogade, and nearly half reported that they use public transport on Nørrebrogade (buses). Only a third of respondents reported that they drive private vehicles on Nørrebrogade.

7.1.2 Locals Traveling Along Nørrebrogade

The following results show the data collected from surveying and interviewing 48 local people utilizing Nørrebrogade. Since there was considerable overlap between the questions the shop owners answered and those on the regular survey, responses from 27 shop owners and employees, have been included where appropriate.

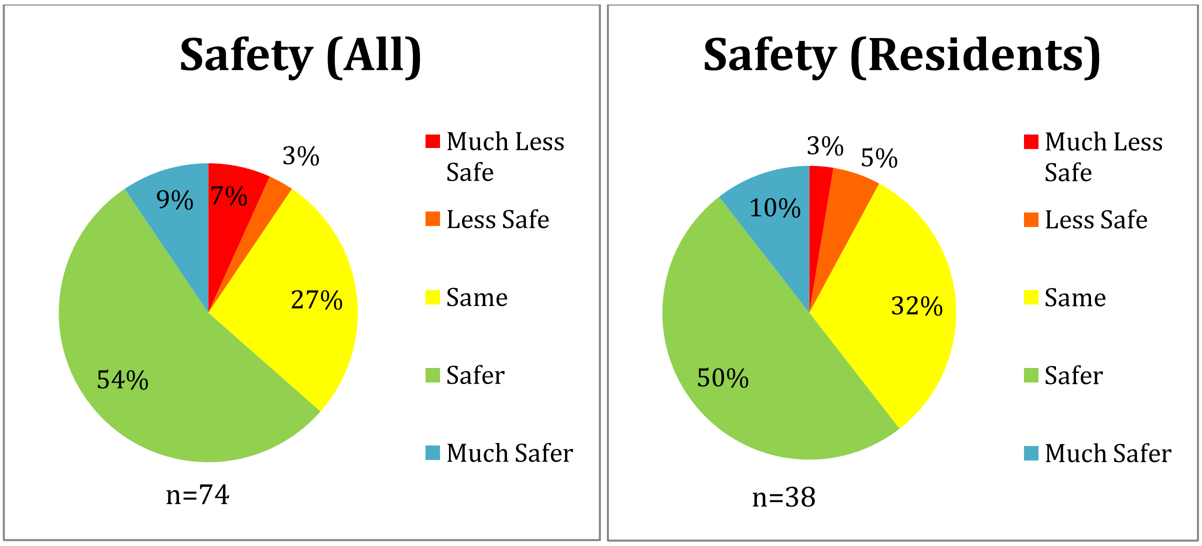

Figure 44: Pie charts displaying how stakeholders rated the change in safety along Nørrebrogade after the closures

The distribution of how people's perception of safety has changed since the road closures is shown in Figure 44 above. The distributions are very similar for all of the respondents compared to only those who were residents. Overall, 64% of respondents reported an increase in perceived safety, while only 10% of respondents reported feeling less safe.

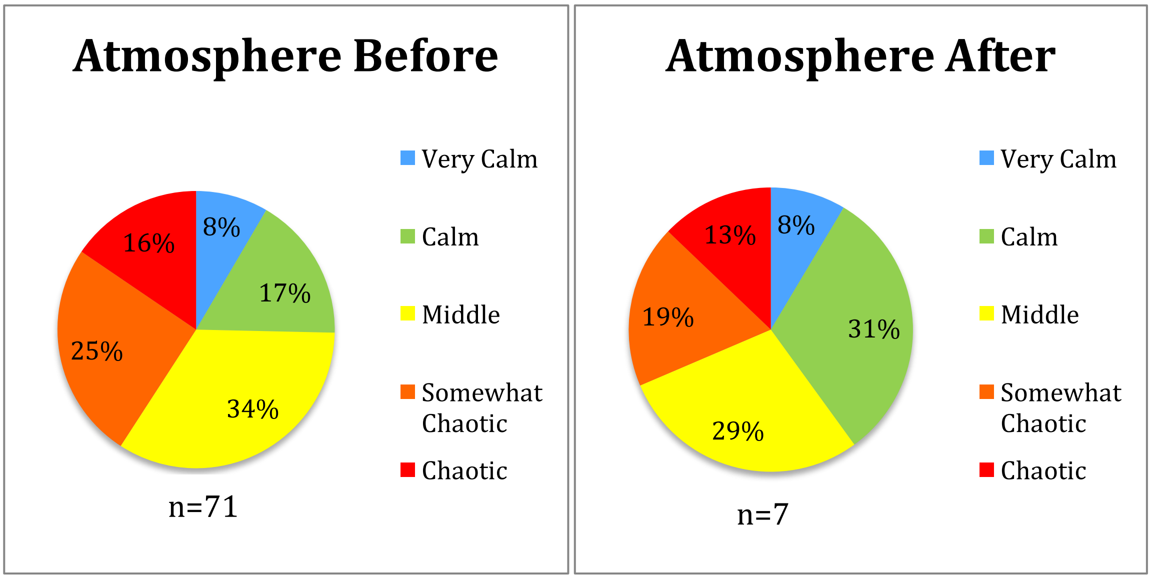

Figure 45: Ratings of how calm or chaotic the atmosphere is on Nørrebrogade during different time periods

Above in Figure 45, the percentages of how people rated Nørrebrogade's atmosphere from before and after the closures can be seen. The pie charts show that the percentage of respondents who reported that Nørrebrogade felt calm or very calm increased from 25% to 39%. The number of respondents who chose one of the chaotic options decreased from 41% to 32%.

About 31% of respondents reported a change in their stress levels since the road closure. Many people did not elaborate in writing on what types of stress they experienced, or how their stress levels changed. At least 4 people associated lower stress levels with the changes in safety or calmness. However, one person reported being more stressed due to confusion with driving.

About 22% of people reported that they had experienced a change in their shopping experiences along Nørrebrogade. Out of those who responded that they had experienced change, at least 8 reported that the change was at least partially due to lack of parking or not being able to drive their car to the stores they intended to visit.

When asked whether they expected to experience any benefits from the road closures, the responses were almost evenly split. Thirty-seven out of 73 said they expected benefits while 36 people said they did not. Additionally, 42 out of 75 people said they expected disadvantages to the road being closed. The remaining 33 reported that they did not expect any disadvantages. In the written responses about 5 people complained of not being able to drive directly to where they want to go on Nørrebrogade. An example of this type of response is, "The extra driving through the small streets is a handicap." Some people reported mixed feelings towards the closure. Some did not see the point in closing the road segments, while others believe the closures are positive. One person reported that the closure was very positive because the air is clean and the atmosphere is calm.

Only 7 out of 44 people reported that they or someone they live with have existing respiratory problems. Out of the people who provided written responses, 4 people reported that they have not experienced any change in their respiratory problems. Interestingly, one person who did not report respiratory problems responded during an interview that they noticed an improvement in the air quality while riding a bicycle down Nørrebrogade.

Finally, when questioned about changes in modes of transportation, 24% of those surveyed said that they made a change in their methods of transportation along Nørrebrogade. The remaining 76% reported that they did not make any changes to their transportation methods. Two people that used personal vehicles reported that they changed their driving routes to Tagensvej instead of Nørrebrogade. Two responses stated that the buses are a much faster way to get down Nørrebrogade now. Furthermore, our interviews revealed that several locals felt the restriction on the

Nørrebrogade-Jagtvej intersection was useless because drivers were making U-Turns on Jagtvej and turning back into Nørrebrogade.

7.1.3 Shop Owners and Employees

The data collected from shop owners and employees who work along Nørrebrogade are presented below. The data presented here are responses from questions targeted directly at shop owners and employees, regarding their businesses. Below in Figure 46 and Figure 47 the responses to the business-oriented questions are presented in bar graphs.

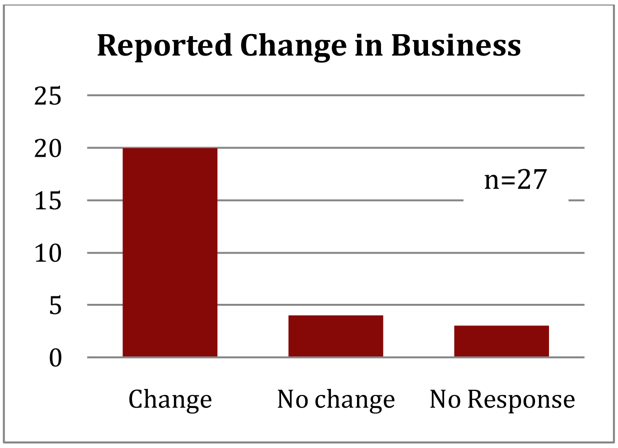

Figure 46: Changes in business observed by shop owners and/or employees

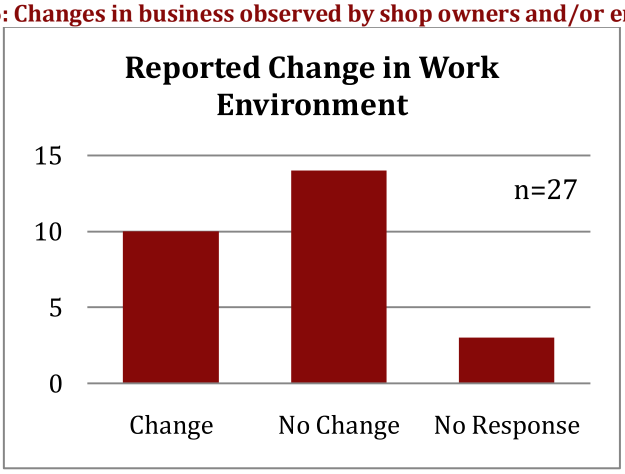

Figure 47: Changes in work environment observed by shop owners and/or employees

There were two Yes/No questions and two open response questions directed towards shop owners and employees. Figure 46 shows a clear majority of shops feel that their business has been affected by the road closures. One shop owner or employee reported, "Driving customers can't find our store. They give up and go to other places instead. Our drivers have to take longer detours that are time consuming. Some trips cost more money now." At least 5 shops have reported less business and fewer customers. Also, there has been a complaint that since people cannot park their cars outside the store, they cannot bring home large or heavy items. However, one shop reported that since the closure they have been able to add outdoor seating, and another shop said that they were not affected from the closure because most of their customers are cyclists.

From Figure 47, one can see that ten out of twenty-seven shop owners or employees reported that they experienced a change in the work environment since the road closure. Two people reported that they noticed there is less noise outside and one person explained that there are more people walking around outside since the closures.

7.2 Discussion

In this section the discussion is split up by the different categories of results we obtained. First the biases of our surveying techniques will be discussed followed by the discussion of our results including safety, stress, respiratory health, transportation, shopping, and business.

7.2.1 Survey Bias

The first point of discussion is the sampled population. Since the sample size for everything is not overwhelmingly large (largest n-value is 75), and sampling techniques were not always fair, our sample of the users of Nørrebrogade may not represent the actual population very well. However, Figure 42 indicates that the sample contained a good mix of shoppers, residents, and employees, so even if the percentage composition isn't entirely accurate, these three groups are at least represented fairly well.

Figure 43 shows that our sample contains people who use all four methods of transportation. Again, the percentage composition is probably not accurate due to sampling techniques, but all of these groups do have some significant representation. In particular, we hypothesize that those who drive on Nørrebrogade are underrepresented since approaching people who were driving on Nørrebrogade was not feasible. Our sampling techniques probably favored pedestrians. Those who were taking the bus were approached while waiting for their bus to come, and cyclists were often approached if they were walking their bikes or were parking.

There were several additional biases. Sampling was not even along all parts of Nørrebrogade. Though we do not have exact numbers, a higher percentage of the surveys were filled out on the southern part of Nørrebrogade. Most of the shop owners and employees who responded to the survey were also on the southern part of Nørrebrogade. We are unsure of how this may have affected our results. Also, since all surveyed individuals knew what the survey was about before choosing to take it, there is probably a natural bias towards those who have stronger feelings about the road closure, one way or the other. This might mean that people who don't care or don't think that the road closure has changes things are underrepresented.

7.2.2 Safety and Stress

Our survey results indicate that the restrictions on motor vehicle traffic on Nørrebrogade made the users of the road both feel safer and perceive a calmer atmosphere. Written and oral comments from the respondents lead us to believe that cyclists feel safer due to wider bike lanes. They also indicate that pedestrians feel safer and attribute a calm environment to the reduction in motor vehicles, but may feel less safe because of cyclists that ignore the traffic rules. An interesting discussion point is the exact value of an increase in *perceived* safety. Arguably perceived safety has little to no bearing on actual safety. However, it could also be argued that simply feeling safer benefit one's mental health, even if the subject is not actually any safer. For this reason, we believe that perceived safety is just as important as actual safety. Perceptions of a "calmer atmosphere" would similarly have a positive effect on one's mental health, since a calmer residence or place of employment or shopping may lower stress.

About a third of those surveyed reported a change in stress. Unfortunately, due to the lack of written responses, we cannot conclude whether these changes were positive, negative, or a mix of both. Based on the results of the safety and atmosphere questions, the best we can do is guess that stress levels were lowered more often than they were increased, since perceived safety and calmness of the atmosphere are somewhat correlated to stress. Conversely, there were 6 business owners or employees that reported a change in their stress levels, and two of them clarified that the change was due to lowered business levels (the rest did not clarify). This indicates that stress levels for the business owners and employees who are suffering probably have increased. Of course, the financial crisis in Denmark may be partially or fully responsible for this as well. Overall, we cannot make a simple conclusion regarding the effect of the road closure on peoples' stress levels.

7.2.3 Respiratory Health

Results on changes in respiratory illnesses are also inconclusive due to a lack of responses. Very few changes in respiratory issues were reported, but this is due to so few respondents actually suffering from these problems. The number of respondents who live nearby and suffer from a respiratory problem (or live with someone who does) was only 7 – too small to make any conclusions at all. Even if there were more applicable respondents, the studies we analyzed in our background research indicated that health changes are usually not noticeable for many years.

7.2.4 Transportation

Even though most people reported that they did not need to change their mode of transportation, this might be because they were already using transportation which was not affected (such as bicycles, mopeds, or buses). Furthermore, the majority who did change their transportation, they did not write a response explaining what they change their transportation to. The sampling method did not facilitate surveying of drivers of private motor vehicles, who would be expected to experience more change in their mode of transportation.

7.2.5 Shopping and Business

In terms of shopping, 22% of the respondents said that their shopping experience changed and written responses told us that this was often because of parking issues. Virtually all respondents who explained their answers either complained about parking issues, or simply said that traveling on and around Nørrebrogade is more difficult. These annoyances have, in at least some cases, caused the respondents to change their shopping habits.

According to shopkeepers, in general their opinion is that their shops are being negatively affected by the road closure. Fewer customers frequent the stores and customers are unable to bring large purchases home without a personal vehicle. It can be seen that shops need to adapt to the road closures and that from a commercial standpoint Nørrebrogade may transform over time. Stores which thrive without personal vehicles, such as small walk-in restaurants or cafes, may become more prevalent on Nørrebrogade while shops with heavy items like a hardware store may need to move to stay in business. We personally have not been in Nørrebro long enough to observe first hand whether shops are new or old. From our own observations, there are not many closed shops along Nørrebrogade and we did not collect this information from the stakeholders.

7.2.6 Survey Summary

Based upon the outcomes of our surveys, the road closure has had various effects and has brought about mixed views among stakeholders. The Nørrebrogade road closures have benefited some stakeholders and hindered others. It has probably increased the quality of life in some areas already, and potentially decreased quality of life temporarily in other areas for some stakeholders.

Chapter 8:Conclusions

This chapter includes a discussion of whether the Nørrebrogade road closures have benefitted those who utilize Nørrebrogade, whether they are residents, shoppers, commuters or workers. Throughout our conclusions, we refer back to our previous chapters regarding traffic, emissions, noise, and surveys in order to assess how the quality of life of the stakeholders has been affected. Assessing quality of life can be related back to a variety of factors as explained in the background chapter, 2.2.

We believe that while the road closures have been in effect the quality of life has improved for the majority of the stakeholders who utilize Nørrebrogade. According to our surveys and interviews, the reduction in traffic in the area created a calmer and safer environment for many of the stakeholders. In Maslow's Hierarchy of Needs, safety is the second layer of the pyramid indicating that the QoL is highly dependent on people's safety. Since the safety needs of the people of Nørrebrogade are being improved, we can say that some quality of life has improved.

Also, another important component of quality of life is health. From our Emissions Calculations and Noise Evaluation we concluded that we can expect to see improvements in health if the road closures continue and traffic levels remain at the reduced level or more. Since disease lowers the HRQoL, if the closure continues for another several years, people should experience improvements in ailments such as asthma, bronchitis, high blood pressure and poor sleep quality; therefore, improve those people's health related quality of life.

However, stakeholders who have experienced a decrease in quality of life are the shop owners and employees. Many reported a change in business which could either be related to the road closures, the current financial crisis, or a combination of both issues. Businesses which have been affected by the closures include those which sell heavy merchandise. Since The Economist Intelligence Unit reported that financial and job security are major contributors to quality of life, decrease in business can lower the quality of life for those who are affected. Negative changes in business can cause additional stress to these stakeholders, which can engender additional problems like disease, which as mentioned above, lowers the HRQoL. If losing business is associated directly with the road segment closures, which we were unable to specifically investigate, then it can be concluded that the Nørrebrogade closures have caused a decrease in quality of life for this subset of stakeholders.

From our personal observations, there are not many vacant shops along Nørrebrogade. These observations do not reflect the possible financial stress stores located along Nørrebrogade have been facing due to the closures or the economic status of Denmark. Businesses which are suffering from the road closures will have to adapt to the road closures, close, or move to a different location. The businesses that permanently close or move off Nørrebrogade may be replaced with businesses more suited for Nørrebrogade's new environment such as cafes without outdoor seating.

Furthermore, residents who own cars and live on side streets blocked by the closures and shoppers who normally use their car may have been hindered by the Nørrebrogade road closure. Residents who are unable to use their cars may have witnessed an increase in stress, which can decrease quality of life. The residents who are dependent on their private motor vehicles and who do not want to change their transportation will move and potentially be replaced with residents who wish to live in areas with road closures. Shoppers who no longer have places to park along Nørrebrogade will adapt by changing transportation methods or where they shop. This too increases stress for these stakeholders, but new shoppers who are partial towards Nørrebrogade's new atmosphere can replace the shoppers who leave.

Finally, by seeing the outcomes of the Nørrebrogade segment closures, we deem the experiment a success. The road closures reduced traffic and encouraged people to use bicycles or public transportation. The safety of pedestrians and cyclists increased and buses can move quickly and efficiently along Nørrebrogade.

Overall, the Nørrebrogade road closures have improved the quality of life for the majority of the stakeholders while perhaps hindering those in other categories or situations. Future health benefits for residents are expected to be experienced if the Nørrebrogade segment closures are continued over time. As Nørrebrogade changes, businesses, patrons, and residents will adapt, or leave, and be replaced by those who enjoy Nørrebrogade's new identity.

Chapter 9: Recommendations

This chapter contains our recommendations regarding the Nørrebrogade road closures. These recommendations include whether or not the closures along Nørrebrogade should continue, the possible optimal configuration of the closures, and how to streamline an urban planning project to reduce the inconsistencies and error to maximize results and conclusions.

9.1 Recommendations for Nørrebrogade

As Chapter 8 discusses, we believe that Nørrebrogade has benefited from the segment closures and will continue to benefit as the businesses and users of Nørrebrogade adapt to the new atmosphere. As such, it follows that the Nørrebrogade road closures should remain permanent. Eventually the business composition along Nørrebrogade will change to only businesses that thrive in the new environment, and the users of Nørrebrogade will consist of people who enjoy the new atmosphere.

Though we recommend keeping the road closures permanent, based on our data, we cannot conclude which Trial configuration was optimal for traffic reduction along Nørrebrogade. Traffic flow data from Trial 3 may help shed light on which closure reduced the most traffic along Nørrebrogade.

9.2 Streamlining an Urban Planning Project

Improvements regarding the organization and execution of the Nørrebrogade Road Closures on behave of the Municipality of Copenhagen could have make our project more efficient and informational. We believe that more specific conclusions could be made about changes in quality of life for those who utilize Nørrebrogade by taking the following recommendations into consideration.

Regarding the traffic analysis, more consistency is needed. The inconsistencies in the traffic readings caused confusion and time-consuming data extrapolation and interpolation, which decreased the reliability of our data. We recommend that traffic readings be performed at constant intervals (such as every 3 to 6 months) for one week to remove extraneous factors such as differing traffic levels between Mondays-Thursdays and Friday afternoons. Counting traffic during the nighttime hours would also be beneficial for a traffic study because it would give more data to analyze.

Constant intervals and weeklong traffic data would provide more data points for the calculations, which would increase the statistical standing of our data.

Furthermore, the reading locations must be consistent. In order to observe changes in traffic flow during different closure configurations, the reading locations must be the same during all trials. If the reading locations are different for each trial period, much like many of the reading locations we worked with, then the data cannot show a full representation of the traffic flow in the area. Also, consistency between recorded vehicle categories would eliminate the need to separate vehicle types from combined categories and remove any uncertainty in these numbers and simplify future studies.

In order to observe the direct health effects due to traffic reduction, a specific study over a long period of time is necessary. As mentioned before, many reports in our research described studies which spanned from 5 to 10 years. In the case of the Nørrebrogade road segment closures, we would recommend that the health of the area's population be assessed before any change in traffic perhaps through a survey, and then continue to assess their health as time went on with the road segment closures in place. For example, finding children in the Nørrebro area with and without asthma for a cohort study that analyzed asthma symptoms and onset compared to reducing traffic would be a beneficial study to determine how the road closures have affected people's health. Cohorts to investigate other diseases associated with air and noise pollution would capture other changes in health over time in the Nørrebro area.

A very important concept to keep in mind while performing studies such as this are baselines, or levels which are normal at the time the study is begun. For example, we would have been able to make more precise conclusions if we were able to obtain an exact measurement of what the noise and pollution levels were on Nørrebrogade before any changes to the traffic were made. This would allow us to apply our percent changes to an absolute value. Therefore, we could use the change in absolute values to see if they dropped below the pollution or noise level thresholds associated with health problems. Without the appropriate baseline values, we can only provide speculation as to how health may have changed from our calculations.

Further investigation into the effects the segment closures had on the stakeholder's stress levels is recommended to gain additional understanding of the changes in health-related quality of life. Detailed questions in surveys regarding the degrees of stress, reasons for stress, and whether the stress levels had increased or decreased since the closures would have provided more insight on this topic.

Ideally we would have liked to gather as much information as possible through surveys. We noticed that not many people elaborated in their written responses. In order to streamline this process and gather data more efficiently, we recommend asking more specific multiple choice questions and fewer open response questions. Without presenting leading questions, more useful data can be collected from multiple choice questions because participants will not feel rushed to write out a response and end up skipping over it entirely.

Implementing the suggestions mentioned in the previous paragraphs would provide clearer and more reliable information about the road closure. The project would definitely be more streamlined and easier to reproduce over time. Additionally, stronger conclusions could be drawn about changes in quality of life effects, changes in business, and other factors related to the road closure. When designing an urban planning project that can potentially have a drastic effect on the area, every aspect must be considered. The urban planners need to consider what types of studies, such as health studies, can possibly accompany the project. We recognize that it is impossible to take everything into consideration when designing an urban planning project, but if communication is increased between the locals and other organizations that wish to make a study concerning the project, then it is possible to assess what baselines need to be addressed to the fullest potential.

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Appendix A: Agenda 21

Agenda 21 was created in 1992 at the United Nations Conference on Environment & Development in Rio de Janerio, Brazil. Adopted by 181 countries at that time, Agenda 21 was created to address the most urgent developmental and environmental problems that the world faces today in preparation for the 21st century ("Copenhagen Agenda 21," 2004 and "Agenda 21," 1992). The programme areas are as follows:

- Promoting sustainable development through trade Making trade and environment mutually supportive
- Providing adequate financial resources to developing countries
- Encouraging economic policies conducive to sustainable development ("Agenda 21" 1992).

Agenda 21 considers sustainable development to have three main tenets: society, economy, and environment. Agenda 21 in Copenhagen has focused on environmental aspects in particular, working to ensure that fewer natural resources are consumed, environmental impacts are reduced, and future generations will have the same quality of lives as we do ("Copenhagen Agenda 21", 2004). Agenda 21 Copenhagen recognizes that citizens desire lower traffic noise and air pollution, believes the city should have more green and blue areas, and wants the City of Copenhagen to encourage urban ecology solutions ("Copenhagen Agenda 21," 2004).

Appendix B: Traffic Study, a D09 IQP

The following is a summary of the 2009 IQP project entitled Traffic Study. In D term of 2009, a Worcester Polytechnic Institute Interactive Qualifying Project team studied traffic fluctuation on Nørrebrogade and the surrounding area. The team consisted of Jenna Beatty, Thomas Coletta, and Ryan Rogan, and the project was sponsored by Agenda 21 Copenhagen.

The IQP focused its examination on the traffic effects of the trial closure of Nørrebrogade. Two short segments of Nørrebrogade were closed to private motor traffic. The City of Copenhagen collected data both before Trial 1, and during it. Therefore, the IQP team was able to compare the number of trips that vehicles from various categories had made from these two time periods. The results of this comparison indicated that there was a 7.3% decrease in overall personal vehicle traffic in the area around Nørrebrogade. During the counted hours, the number of trips of personal motor vehicles recorded decreased from about 205,000 to 190,000, a difference of about 15,000 trips per day. In addition to the decrease in private motorized vehicles, the team also reported that the number of cyclists and bus trips had increased by 18.6% and 11% respectively. These statistics, however, were not made with the same confidence as the car statistics, since less data was available for cyclists and busses.

In addition to the quantitative data found, the team also interviewed ten people in each of five categories: car owners, cyclists, pedestrians, bus passengers, and shopkeepers. These interviews were conducted to try and understand the public's opinion on the road closure. The interviews found that pedestrians and cyclists favored the road closure since they felt their safety had increased. Drivers tended to disapprove, since traveling became more difficult or longer. Seven out of ten of the interviewed shopkeepers saw a decrease in business, though the others reported no difference.

The team reported that some drivers of personal vehicles still use the restricted area. They recommended two potential ways to fix this problem. The first solution recommended was retractable permanent barriers on the entrances to the restricted area. The second recommended solution was increasing the number of tickets given to drivers who violate the restriction. The team argued that this is important since drivers who violate the restriction get in the way of emergency vehicles and busses. Another concern that led the team to make recommendations was the loss of business that the shop owners reported. If this becomes a serious concern, the team recommends allowing traffic through the restricted area during certain time periods. The restriction could perhaps only be in place during the busiest time periods.

Agenda 21 reported that this IQP was helpful in convincing the City of Copenhagen to continue with more trial segment closures of Nørrebrogade. Agenda 21 would have liked to keep all the original road segments closed, but a compromise was reached with the City and other segment closure combinations were made in the future.

Appendix C: List of reading locations and the type of traffic flow data sheets that were available for each

Location	Sheet Type(s)
DronningLouises Bro	c, d, e
Fredericksborggade 43, sø f. Søtorvet	d, e
Gothersgadesydøst for Søtorvet	b
Gyldenløvesgadeud for Søerne	c, d
Jagtvejsydvest for Nørrebrogade	c, d
Sølvgadenordvest for Sølvtorvet	d
ØsterSøgade	e
ØsterSøgadenordøst for Gothersgade	c, d
Åboulevard, nordvest for Tomrergade	c, d
Fredensbro	d
Frederikssundsvejøst for Frederiksborgvej	d
Fælledvejnodøst for Nørrebrogade	b, e, f
Lygten	d
Nørrebrogade nordvest for Jagtvej	d
NørreSøgade	d, e
Hamletsgadenord for Mimersgade	f
Blegdamsvejsydvest for Fredensgade	f, g
NørreAllésyd for Tagensvej	f
Tagenvejnordvest for Jagtvej	c, d
Ågade vest for Jagtvej	d
Webersgadenordvest for ØsterFarimagsgade	d
Bispeengbuen	d
Lundtoftegade	f
Tagensjev_nf_Frederik	d
Hillerøgade vest for Lundtoftegade	f
Tagensvejfordvest for Rovsingsgade	d
Hyltebrosydvest for Nørrebrogade	f
Gyldenlovesgade	c
Møllegade	d, f
Peter FabersGade	d, f
Ægirsgade	f

Baldersgade	f
Bragesgade	f
Elmegade	f
Sortedam_Dossering_ved _DLB	e, f
Baggesensgade	f
Stengade	f
Guldbergsgade	f
Møllegade_sf_Nørre_Sidealle	f
Prinsesse_Charlottes_Gade	f
Stefansgade_mel_Husumgade	f
Esromgade	f
Hillerødgade	f
Mimersgade_vf_Hamletsgade	c, f
Hamletsgade	f
Nannasgade	h
Birkegade	f
Egegade	f
Rådmandsgade	f
Nørrebrogade_vf_Hyltebro	c, e
Nørrebrogade_øf_Hyltebro	c, e
Nørrebrogade_vf_Bragesgade	e, i
Nørrebrogade_vf_Baldersgade	a, e
Nørrebrogade_øf_Ægirsgade	a, e
Nørrebrogade_vf_Stengade	a
Nørrebrogade_vf_Faelledvej (closed section)	a, e
Nørrebrogade_øf_Faelledvej	a, e
Nørrebrogade_nvf_Jagtvej_(Runddel)_1,2,3,6,8,10	e, i
Nørrebrogade_søf_Jagtvej_(Runddel)_7,8,9,2,4,12	e, i
Jagtvej_nøf_Nørrebrogade_(Runddel)_4,5,6,1,9,11	e, i
Jagtvej_svf_Nørrebrogade_(Runddel)_10,11,12,3,5,7	e, i

Appendix D: Sample Traffic Data Sheet from KøbenhavnKommune

Manuel tælling

København Kommune
Teknik og Miljøforvaltningen, Center for Trafik
Njalsgade 15, 1. sal, 2300 København S

TÆLLESTED NR.	5	DRONNING LOUISES BRO							MOD BYEN		TORSDAG D. 30. AUG.			2007	Sum begge retn.	
KLOKKESLET	6-18	%	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	%	Kl. 6-18
PERSONBILER	4722	76.2	103	285	566	373	328	344	380	440	467	463	489	484	75.3	8673
MOTORCYKLER	76	1.2	3	8	14	2	2	1	4	6	7	8	10	11	1.1	128
VAREVOGNE (MAX. 3,5 T)	915	14.8	37	65	100	79	82	73	92	89	96	87	63	52	15.2	1750
A: LET TRAFIK IALT	5713	92.2	143	358	680	454	412	418	476	535	570	558	562	547	91.6	10551
SOLOLASTBILER > 3,5 T	146	2.4	2	4	5	25	25	19	14	10	5	19	9	9	2.7	311
LASTBILER MED SÆTTEVOGN	15	0.2	0	0	1	2	3	6	0	0	1	2	0	0	0.2	18
LASTBILER MED PÅHÆNG	3	0.0	0	2	0	0	1	0	0	0	0	0	0	0	0.1	6
BUSSER I FAST RUTE	266	4.3	14	19	28	25	23	19	24	23	24	24	22	21	4.7	538
ANDRE BUSSER	55	0.9	0	0	1	6	5	3	0	0	3	13	16	8	0.8	89
B: TUNG TRAFIK IALT	485	7.8	16	25	35	58	57	47	38	33	33	58	47	38	8.4	962
A+B: KØRETØJER IALT	6198	100.0	159	383	715	512	469	465	514	568	603	616	609	585	100.0	11500
KNALLERTER	96	0.9	4	10	9	11	7	5	7	13	8	14	3	5	0.9	186
CYKLER	10899	99.1	282	1169	2178	1364	622	608	659	647	768	978	973	651	99.0	19869
KNALLERTER+ CYKLER	10995	100.0	286	1179	2187	1375	629	613	666	660	776	992	976	656	100.0	20060
VEJRKORR. KNAL.+ CYKL.	14294	VEJR:	Overskyet, regn fra kl. 11.00, kraftig regn fra kl. 17.30										VEJRKORR. KNAL.+ CYKL.			26070
ANMRK: Ungdomshusdemonstration fra kl. 18.00													ÅDT KØRETØJER			13700

Manuel tælling

København Kommune
Teknik og Miljøforvaltningen, Center for Trafik
Njalsgade 15, 1. sal, 2300 København S

TÆLLESTED NR.	5	DRONNING LOUISES BRO							FRA BYEN		TORSDAG D. 30. AUG.			2007	Sum begge retn.	
KLOKKESLET	6-18	%	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	%	Kl. 6-18
PERSONBILER	3951	74.3	103	218	335	288	247	268	364	385	374	398	493	478	75.3	8673
MOTORCYKLER	52	1.0	3	4	0	1	2	2	1	11	5	3	13	7	1.1	128
VAREVOGNE (MAX. 3,5 T)	835	15.7	43	67	64	71	79	71	92	81	92	69	59	47	15.2	1750
A: LET TRAFIK IALT	4838	91.0	149	289	399	360	328	341	457	477	471	470	565	532	91.6	10551
SOLOLASTBILER > 3,5 T	165	3.1	7	10	9	22	29	24	8	7	8	18	13	10	2.7	311
LASTBILER MED SÆTTEVOGN	3	0.1	0	1	0	1	0	0	0	1	0	0	0	0	0.2	18
LASTBILER MED PÅHÆNG	3	0.1	0	1	0	0	0	0	0	1	0	0	0	1	0.1	6
BUSSER I FAST RUTE	272	5.1	11	25	23	22	23	23	22	24	26	23	26	24	4.7	538
ANDRE BUSSER	34	0.6	1	1	5	8	2	2	0	1	1	5	6	2	0.8	89
B: TUNG TRAFIK IALT	477	9.0	19	38	37	53	54	49	30	34	35	46	45	37	8.4	962
A+B: KØRETØJER IALT	5315	100.0	168	327	436	413	382	390	487	511	506	516	610	569	100.0	11500
KNALLERTER	90	1.0	6	5	8	1	1	3	3	4	13	21	18	7	0.9	186
CYKLER	8970	99.0	92	373	672	394	343	338	550	649	912	1307	1848	1492	99.0	19869
KNALLERTER+ CYKLER	9060	100.0	98	378	680	395	344	341	553	653	925	1328	1866	1499	100.0	20060
VEJRKORR. KNAL.+ CYKL.	11778	VEJR:	Overskyet, regn fra kl. 11.00, kraftig regn fra kl. 17.30										VEJRKORR. KNAL.+ CYKL.			26070
ANMRK: Ungdomshusdemonstration fra kl. 18.00													ÅDT KØRETØJER			13700

Appendix E: Vehicle Type Ratios

Category	Sum	Fraction
Knallerter	3716	0.01244
Cykler	294945	0.98756
Combined	298661	
Motocykler	9710	0.01373
Personbiler	697541	0.98627
Combined	707251	
Varevogne	128489	0.157075865
Personbiler	689517	0.842924135
Combined	818006	

Appendix F: Survey Sheets

Agenda 21
4 Blegdamsvej, 2200 København

Nørrebrogade Road Closure Survey

Thank you for taking the time to complete this survey and interview. This survey is about the effects of the partial closing of Nørrebrogade to private motor vehicles. The segment closures began on October 1st, 2008. You may withdraw from this survey at any time and you do not need to answer all of the questions. None of the information you provide will be used to identify you. Please ask if you have any questions.

Check off all that apply:
I shop frequently on Nørrebrogade ☐
I work on Nørrebrogade ☐
I live on or near Nørrebrogade ☐

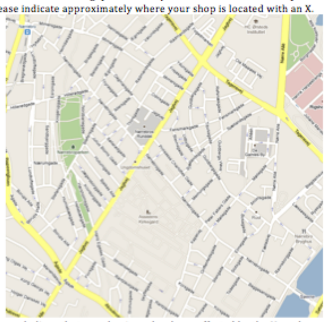
What methods of transportation do you regularly use on Nørrebrogade?
Walking ☐
Bikes/mopeds ☐
Private vehicle ☐
Public transport ☐
Other (please explain) ☐

1. Have your methods of transport changed since the road closure?
   Yes ☐ No ☐
   If yes, how?
2. Did you *expect* to experience any benefits from the Nørrebrogade segment closures?
   Yes ☐ No ☐
3. Did you *expect* to experience any disadvantages from the Nørrebrogade segment closures?
   Yes ☐ No ☐
   How were these expectations met or not met?
4. Please rate how much you think your safety has changed since the Nørrebrogade segment closures.
   Much less safe ☐ Less safe ☐ Same ☐ Safer ☐ Much safer ☐
   If you think your safety has changed, please explain why.
5. Please rate the atmosphere of Nørrebrogade before the segment closures.
   Very Calm Chaotic
   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
6. Please rate the atmosphere of Nørrebrogade after the segment closures.
   Very Calm Chaotic
   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
7. Do you feel that your stress levels have been affected by the Nørrebrogade segment closures?
   Yes ☐ No ☐
   If so, how have your stress levels changed, and what caused these changes?

Please turn the page.

Please answer the following questions if you own or work in a shop on Nørrebrogade.

8. Please indicate approximately where your shop is located with an X.



9. Do you believe that your business has been affected by the Nørrebrogade segment closures?
   Yes ☐ No ☐
   If so, how has your business been affected, and why?
10. Do you believe your work environment changed since the road closure?
    Yes ☐ No ☐
    If so, how has your work environment changed, and why?
11. Do you experience respiratory problems such as asthma, bronchitis or chronic coughing and wheezing?
    Yes ☐ No ☐
    If yes: Have you experienced any positive or negative changes in these respiratory problems since Nørrebrogade segment closures?

Please answer the following questions if you frequently shop on Nørrebrogade.

12. Have you found that your shopping experience on Nørrebrogade has changed since the segment closure?
    Yes ☐ No ☐
    If so, how has your shopping experience changed, and why?

Thank you for completing this survey. If you feel comfortable speaking English, we would like to discuss some of your responses with you to gain further understanding.

Agenda 21
4 Blegdamsvej, 2200 København

Nørrebrogade Road Closure Survey

Thank you for taking the time to complete this survey and interview. This survey is about the effects of the partial closing of Nørrebrogade to private motor vehicles. The segment closures began on October 1st, 2008. You may withdraw from this survey at any time and you do not need to answer all of the questions. None of the information you provide will be used to identify you. Please ask if you have any questions.

Check off all that apply:
I shop frequently on Nørrebrogade ☐
I work on Nørrebrogade ☐
I live on or near Nørrebrogade ☐

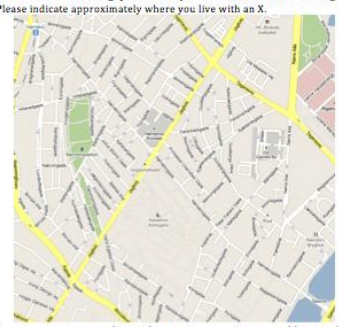
What methods of transportation do you regularly use on Nørrebrogade?
Walking ☐
Bikes/mopeds ☐
Private vehicle ☐
Public transport ☐
Other (please explain) ☐

1. Have your methods of transport changed since the road closure?
   Yes ☐ No ☐
   If yes, how?
2. Did you expect to experience any benefits from the Nørrebrogade segment closures?
   Yes ☐ No ☐
3. Did you expect to experience any disadvantages from the Nørrebrogade segment closures?
   Yes ☐ No ☐
   How were these expectations met or not met?
4. Please rate how much you think your safety has changed since the Nørrebrogade segment closures.
   Much less safe ☐ Less safe ☐ Same ☐ Safer ☐ Much safer ☐
   If you think your safety has changed, please explain why.
5. Please rate the atmosphere of Nørrebrogade before the segment closures.
   Very Calm Chaotic
   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
6. Please rate the atmosphere of Nørrebrogade after the segment closures.
   Very Calm Chaotic
   1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐
7. Do you feel that your stress levels have been affected by the Nørrebrogade segment closures?
   Yes ☐ No ☐
   If so, how have your stress levels changed, and what caused these changes?

Please turn the page.

Please answer the following questions if you live on or near Nørrebrogade.

8. Please indicate approximately where you live with an X.



9. Do you or someone you live with experience respiratory problems such as asthma, bronchitis or chronic coughing and wheezing?
   Yes ☐ No ☐
   If yes: Have you or someone you live with experienced any positive or negative changes in these respiratory problems since Nørrebrogade segment closures?

Please answer the following questions if you frequently shop on Nørrebrogade.

10. Have you found that your shopping experience on Nørrebrogade has changed since the segment closure?
    Yes ☐ No ☐
    If so, how has your shopping experience changed, and why?

Thank you for completing this survey. If you feel comfortable speaking English, we would like to discuss some of your responses with you to gain further understanding.

Agenda 21
4 Blegdamsvej, 2200 København

Undersøgelse af effekten af lukningen af Nørrebrogade

Tak fordi du tog tid til at udfylde dette spørgeskema. Denne undersøgelse handler om virkningerne af den delvise lukning af Nørrebrogade for private motorkøretøjer. Den delvise lukning blev sat i kraft den 1. oktober 2008. Du kan til enhver tid holde op med at udfylde spørgeskemaet, og du behøver ikke at besvare alle spørgsmålene. Ingen af de oplysninger, du giver, vil blive brugt til at identificere dig. Du er meget velkommen til at stille spørgsmål undervejs.

Kryde af alle relevante steder:
Jeg køber ofte ind på Nørrebrogade ☐
Jeg arbejder på Nørrebrogade ☐
Jeg bor på eller i nærheden af Nørrebrogade ☐

Hvordan bevæger du dig normalt på Nørrebrogade?
Som fodgænger ☐
Som cyklist / på knallerter ☐
Via private køretøj ☐
Via offentlig transport ☐
Andet (forklar) ☐

1. Har din måde at transportere dig på ændret sig siden lukningen af Nørrebrogade?
Ja ☐ nej ☐
Hvis ja, hvordan?

2. Forventede du at opleve fordele ved lukningen af Nørrebrogade?
Ja ☐ Nej ☐

3. Forventede du at opleve ulemper i forbindelse med lukningen af Nørrebrogade?
Ja ☐ Nej ☐
Hvordan blev disse forventninger mødt eller ikke mødt?

4. Prøv at vurdere hvor meget du mener, at sikkerheden har ændret sig siden lukningen af Nørrebrogade.
Meget mindre sikker ☐ Mindre sikker ☐ Samme ☐ Sikrere ☐ Meget sikrere ☐
Hvis du mener, sikkerhed en har ændret sig, må du gerne uddybe her hvordan og hvorfor.

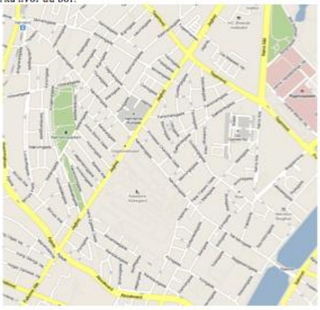
5. Hvad er din vurdering af stemningen på Nørrebrogade før lukningen.
Meget rolig ... Kaotisk
1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

6. Hvad er din vurdering af stemningen på Nørrebrogade efter lukningen.
Meget rolig ... Kaotisk
1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

7. Føler du, at dit stressniveau er blevet påvirket af lukningen af Nørrebrogade?
Ja ☐ Nej ☐
Hvis ja, hvordan er dit stressniveau blevet ændret, og hvad har forårsaget denne ændring?

Slå den side. Tak.

Besvar venligst følgende spørgsmål, hvis du bor på eller i nærheden Nørrebrogade.
8 . Angiv med et X, cirka hvor du bor.



9. Har du eller nogen du lever sammen med åndedrætsproblemer såsom astma, bronkitis eller kronisk hoste eller hvæsende vejrtrækning?
Ja ☐ Nej ☐
Hvis ja: Har du eller nogen du lever sammen med, eventuelt erfaret positive eller negative ændringer i disse luftvejsproblemer, siden Nørrebrogade blev lukket?

Besvar venligst følgende spørgsmål, hvis du ofte køber ind på Nørrebrogade.
10. Har du konstateret, at dine indkøbsvaner på Nørrebrogade har ændret sig siden lukningen?
Ja ☐ Nej ☐
Hvis ja, hvordan har dine indkøbsvaner ændret sig, og hvorfor?

Tak fordi du tog dig tid til at udfylde dette spørgeskema. Hvis du føler dig fortrolig med at tale engelsk, vil vi, for at opnå fuld forståelse, meget gerne yderligere drøfte nogle af dine svar med dig på engelsk.

Agenda 21
4 Blegdamsvej, 2200 København

Undersøgelse af effekten af lukningen af Nørrebrogade

Tak fordi du tog tid til at udfylde dette spørgeskema. Denne undersøgelse handler om virkningerne af den delvise lukning af Nørrebrogade for private motorkøretøjer. Den delvise lukning blev sat i kraft den 1. oktober 2008. Du kan til enhver tid holde op med at udfylde spørgeskemaet, og du behøver ikke at besvare alle spørgsmålene. Ingen af de oplysninger, du giver, vil blive brugt til at identificere dig. Du er meget velkommen til at stille spørgsmål undervejs.

Kryde af alle relevante steder:
Jeg køber ofte ind på Nørrebrogade ☐
Jeg arbejder på Nørrebrogade ☐
Jeg bor på eller i nærheden af Nørrebrogade ☐

Hvordan bevæger du dig normalt på Nørrebrogade?
Som fodgænger ☐
Som cyklist / på knallerter ☐
Via private køretøj ☐
Via offentlig transport ☐
Andet (forklar) ☐

1. Har din måde at transportere dig på ændret sig siden lukningen af Nørrebrogade?
Ja ☐ nej ☐
Hvis ja, hvordan?

2. Forventede du at opleve fordele ved lukningen af Nørrebrogade?
Ja ☐ Nej ☐

3. Forventede du at opleve ulemper i forbindelse med lukningen af Nørrebrogade?
Ja ☐ Nej ☐
Hvordan blev disse forventninger mødt eller ikke mødt?

4. Prøv at vurdere hvor meget du mener, at sikkerheden har ændret sig siden lukningen af Nørrebrogade.
Meget mindre sikker ☐ Mindre sikker ☐ Samme ☐ Sikrere ☐ Meget sikrere ☐
Hvis du mener, sikkerhed en har ændret sig, må du gerne uddybe her hvordan og hvorfor.

5. Hvad er din vurdering af stemningen på Nørrebrogade før lukningen.
Meget rolig ... Kaotisk
1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

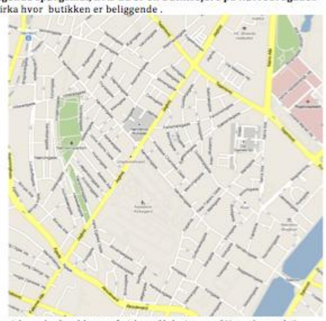
6. Hvad er din vurdering af stemningen på Nørrebrogade efter lukningen.
Meget rolig ... Kaotisk
1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐

7. Føler du, at dit stressniveau er blevet påvirket af lukningen af Nørrebrogade?
Ja ☐ Nej ☐

Hvis ja, hvordan er dit stressniveau blevet ændret, og hvad har forårsaget denne ændring?

Slå den side. Tak.

Besvar venligst følgende spørgsmål, hvis du er en butiksejere på Nørrebrogade..
8. Angiv med et X, cirka hvor butikken er beliggende .



9. Oplever du, at din virksomhed er blevet påvirket af lukningen af Nørrebrogade?
Ja ☐ Nej ☐
Hvis ja, hvordan er din virksomhed blevet ramt, og hvorfor?

10. Mener du, at dit arbejdsmiljø har ændret sig siden lukningen af gaden?
Ja ☐ Nej ☐
Hvis ja, hvordan har dit arbejdsmiljø ændret sig, og hvorfor?

11. Har du åndedrætsproblemer såsom astma, bronkitis eller kronisk hoste eller hvæsende vejrtrækning?
Ja ☐ Nej ☐
Hvis ja: Har du, eventuelt erfaret positive eller negative ændringer i disse luftvejsproblemer, siden Nørrebrogade blev lukket?

Besvar venligst følgende spørgsmål, hvis du ofte køber ind på Nørrebrogade.
12. Har du konstateret, at dine indkøbsvaner på Nørrebrogade har ændret sig siden lukningen?
Ja ☐ Nej ☐
Hvis ja, hvordan har dine indkøbsvaner ændret sig, og hvorfor?

Tak fordi du tog dig tid til at udfylde dette spørgeskema. Hvis du føler dig fortrolig med at tale engelsk, vil vi, for at opnå fuld forståelse, meget gerne yderligere drøfte nogle af dine svar med dig på engelsk.

Appendix G: Detailed Traffic Tables

5_Dronning Louises Bro	Before	Trial 1 (Later)	Trial 1	Trial 2
Passenger cars	7944	3454	3961	3833
Light duty vehicles	2130	1123	1075	1218
Heavy duty vehicles	719	678	707	734
Mopeds	103	294	294	296
Motorcycles	149	61	61	85
Bicycles	21474	23810	23810	23941
Totals (all, unadjusted)	**32519**	**29420**	**29908**	**30107**
Totals (motor, unadjusted)	**11045**	**5610**	**6098**	**6166**
12_Frederiksborggade	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	3494		3424	
Light duty vehicles	799		748	
Heavy duty vehicles	646		654	
Mopeds	92			
Motorcycles	78			
Bicycles	16744			
Totals (all, unadjusted)	**4939**	**0**	**4826**	**0**
Totals (motor, unadjusted)	**4939**	**0**	**4826**	**0**
19 Gyldenløvesgadeud for Søerne	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	33208			32581
Light duty vehicles	6666			9354
Heavy duty vehicles	2173			1797
Mopeds	227			211
Motorcycles	527			555
Bicycles	15377			16901
Totals (all, unadjusted)	**58177**	**0**	**0**	**61399**
Totals (motor, unadjusted)	**42801**	**0**	**0**	**44498**
60 ØsterSøgadenordøst for Gothersgade	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	17787	16274	17823	17304
Light duty vehicles	3057	3768	3982	2287
Heavy duty vehicles	732	563	516	732
Mopeds	117	86	86	70
Motorcycles	211	252	252	224
Bicycles	8142	6924	6924	5666
Totals (all, unadjusted)	**30046**	**27867**	**29583**	**26283**
Totals (motor, unadjusted)	**21904**	**20943**	**22659**	**20617**
61 Åboulevard, nordvest for Tomrergade	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	29751			27514
Light duty vehicles	4492			6065
Heavy duty vehicles	1671			1212

Mopeds	182			97
Motorcycles	484			520
Bicycles	7854			7768
Totals (all, unadjusted)	**44433**	**0**	**0**	**43176**
Totals (motor, unadjusted)	**36579**	**0**	**0**	**35408**
121 Fælledvejnodøst for Nørrebrogade	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	3697	2531	2584	2440
Light duty vehicles	1037	837	852	700
Heavy duty vehicles	126	289	394	258
Mopeds		88	88	85
Motorcycles	55	35	35	34
Bicycles		6976	6976	6762
Totals (all, unadjusted)	**4915**	**3692**	**3865**	**3432**
Totals (motor, unadjusted)	**4915**	**3692**	**3865**	**3432**
170_Nørre_Søgade	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	19977		19448	
Light duty vehicles	4188		5058	
Heavy duty vehicles	786		599	
Mopeds	100			
Motorcycles	376			
Bicycles	9318			
Totals (all, unadjusted)	**24952**	**0**	**25105**	**0**
Totals (motor, unadjusted)	**24952**	**0**	**25105**	**0**
397 Blegdamsvejsydvest for Fredensgade	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	3071	0		3434
Light duty vehicles	881	0		1332
Heavy duty vehicles	368	350	350	288
Mopeds	79	92	92	83
Motorcycles	43	0		48
Bicycles	6309	7317	7317	6562
Totals (all, unadjusted)	**10751**			**11747**
Totals (motor, unadjusted)	**4442**			**5185**
479 Tagenvejnordvest for Jagtvej	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	11777			12320
Light duty vehicles	1921			2578
Heavy duty vehicles	945			678
Mopeds	122			67
Motorcycles	103			129
Bicycles	6828			5416
Totals (all, unadjusted)	**21696**	**0**	**0**	**21188**
Totals (motor, unadjusted)	**14868**	**0**	**0**	**15772**
607_Lundtoftegade	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	5238	6306	6306	6211

Light duty vehicles	1071	1128	1128	1363
Heavy duty vehicles	368	329	329	313
Mopeds	23	20	20	17
Motorcycles	73	88	88	86
Bicycles	1801	1561	1561	1352
Totals (all, unadjusted)	**8574**	**9432**	**9432**	**9342**
Totals (motor, unadjusted)	**6773**	**7871**	**7871**	**7990**
1661_Møllegade	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	734	545	532	757
Light duty vehicles	329	141	128	157
Heavy duty vehicles	29	15	18	38
Mopeds	17	15	12	17
Motorcycles	12	8	5	11
Bicycles	1238	1156	1196	1351
Totals (all, unadjusted)	**2359**	**1880**	**1891**	**2331**
Totals (motor, unadjusted)	**1121**	**724**	**695**	**980**
1662_Peter FabersGade	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	534	480	497	475
Light duty vehicles	167	147	168	157
Heavy duty vehicles	29	26	28	11
Mopeds	7	18	13	19
Motorcycles	11	7	7	7
Bicycles	1687	1441	1460	1499
Totals (all, unadjusted)	**2435**	**2119**	**2173**	**2168**
Totals (motor, unadjusted)	**748**	**678**	**713**	**669**
1663_Ægirsgade	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	636	562	629	643
Light duty vehicles	218	117	139	161
Heavy duty vehicles	27	24	30	26
Mopeds	22	20	20	14
Motorcycles	9	8	9	9
Bicycles	1747	1558	1538	1111
Totals (all, unadjusted)	**2659**	**2289**	**2365**	**1964**
Totals (motor, unadjusted)	**912**	**731**	**827**	**853**
1664_Baldersgade	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	1292	796	866	869
Light duty vehicles	221	101	152	90
Heavy duty vehicles	33	19	23	34
Mopeds	5	7	7	4
Motorcycles	18	11	12	12
Bicycles	436	567	519	342
Totals (all, unadjusted)	**2005**	**1501**	**1579**	**1351**
Totals (motor, unadjusted)	**1569**	**934**	**1060**	**1009**
1665_Bragesgade	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	397			312
Light duty vehicles	81			73

Heavy duty vehicles	29			14
Mopeds	10			10
Motorcycles	6			4
Bicycles	832			782
Totals (all, unadjusted)	**1355**	**0**	**0**	**1195**
Totals (motor, unadjusted)	**523**	**0**	**0**	**413**
1668_Sortedam_Dossering_ved _DLB	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	1388		891	688
Light duty vehicles	321		194	284
Heavy duty vehicles	89		18	25
Mopeds				
Motorcycles				
Bicycles				
Totals (all, unadjusted)	**1798**	**0**	**1103**	**997**
Totals (motor, unadjusted)	**1798**	**0**	**1103**	**997**
1686_Nørrebrogade_vf_Hyltebro	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars		2011	2442	2179
Light duty vehicles		523	631	481
Heavy duty vehicles		686	630	625
Mopeds		120	120	79
Motorcycles		28	28	7
Bicycles		9518	9518	6291
Totals (all, unadjusted)	**0**	**12886**	**13369**	**9662**
Totals (motor, unadjusted)	**0**	**3368**	**3851**	**3371**
1687_Nørrebrogade_øf_Hyltebro	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars		1953	2514	2912
Light duty vehicles		623	682	692
Heavy duty vehicles		547	588	567
Mopeds		126	126	93
Motorcycles		50	50	52
Bicycles		9987	9987	7355
Totals (all, unadjusted)	**0**	**13286**	**13946**	**11671**
Totals (motor, unadjusted)	**0**	**3299**	**3959**	**4316**
1688_Nørrebrogade_vf_Bragesgade	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars				1265
Light duty vehicles				456
Heavy duty vehicles				37
Mopeds				
Motorcycles				18
Bicycles				
Totals (all, unadjusted)	**0**	**0**	**0**	**1776**
Totals (motor, unadjusted)	**0**	**0**	**0**	**1776**
1689_Nørrebrogade_vf_Baldersgade	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars		1402	1402	1624

Light duty vehicles		219	219	424
Heavy duty vehicles		556	556	537
Mopeds				
Motorcycles		20	20	23
Bicycles				
Totals (all, unadjusted)	**0**	**2197**	**2197**	**2608**
Totals (motor, unadjusted)	**0**	**2197**	**2197**	**2608**
1690_Nørrebrogade_øf_Ægirsgade	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars		3732	3732	4435
Light duty vehicles		884	884	1298
Heavy duty vehicles		605	605	655
Mopeds				
Motorcycles		52	52	62
Bicycles				
Totals (all, unadjusted)	**0**	**5273**	**5273**	**6450**
Totals (motor, unadjusted)	**0**	**5273**	**5273**	**6450**
1691_Nørrebrogade_vf_Stengade	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars		1546	1546	1779
Light duty vehicles		556	556	577
Heavy duty vehicles		628	628	623
Mopeds				
Motorcycles		22	22	25
Bicycles				
Totals (all, unadjusted)	**0**	**2752**	**2752**	**3004**
Totals (motor, unadjusted)	**0**	**2752**	**2752**	**3004**
1692_Nørrebrogade_vf_Faelledvej (closed section)	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	7885	383	745	428
Light duty vehicles	2028	179	249	175
Heavy duty vehicles	702	700	770	762
Mopeds				
Motorcycles		5	5	6
Bicycles				
Totals (all, unadjusted)	**10614**	**1262**	**1764**	**1365**
Totals (motor, unadjusted)	**10614**	**1262**	**1764**	**1365**
1693_Nørrebrogade_øf_Faelledvej	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	8247	2643	3021	2603
Light duty vehicles	2479	927	971	829
Heavy duty vehicles	786	671	686	644
Mopeds				
Motorcycles		37	37	36
Bicycles				
Totals (all, unadjusted)	**11511**	**4241**	**4678**	**4076**
Totals (motor, unadjusted)	**11511**	**4241**	**4678**	**4076**
Nørrebrogade_nvf_Jagtvej_(Runddel)_1,2,3,6,8,10	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**

Passenger cars	8064		3790	4338
Light duty vehicles	2008		1124	1162
Heavy duty vehicles	906		943	624
Mopeds	203			
Motorcycles	119			60
Bicycles	13497			
Totals (all, unadjusted)	**10978**	**0**	**5857**	**6124**
Totals (motor, unadjusted)	**10978**	**0**	**5857**	**6124**
Nørrebrogade_søf_Jagtvej_(Runddel)_7,8,9,2,4,12	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	7428		3604	3491
Light duty vehicles	1696		849	1155
Heavy duty vehicles	746		670	605
Mopeds				
Motorcycles				49
Bicycles				
Totals (all, unadjusted)	**9870**	**0**	**5124**	**5251**
Totals (motor, unadjusted)	**9870**	**0**	**5124**	**5251**
Jagtvej_nøf_Nørrebrogade_(Runddel)_4,5,6,1,9,11	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	12917		11038	11367
Light duty vehicles	3568		2904	2979
Heavy duty vehicles	518		782	548
Mopeds				
Motorcycles				158
Bicycles				
Totals (all, unadjusted)	**17003**	**0**	**14724**	**14894**
Totals (motor, unadjusted)	**17003**	**0**	**14724**	**14894**
Jagtvej_svf_Nørrebrogade_(Runddel)_10,11,12,3,5,7	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	12593		10684	10280
Light duty vehicles	3562		2936	2784
Heavy duty vehicles	507		791	499
Mopeds				
Motorcycles				143
Bicycles				
Totals (all, unadjusted)	**16661**	**0**	**14410**	**13563**
Totals (motor, unadjusted)	**16661**	**0**	**14410**	**13563**
Nørrebrogade (next to the bridge)	**Before**	**Trial 1 (Later)**	**Trial 1**	**Trial 2**
Passenger cars	8482		3529	
Light duty vehicles	2181		881	
Heavy duty vehicles	316		728	
Mopeds				
Motorcycles				
Bicycles				
Totals (all, unadjusted)	**10979**	**0**	**5137**	**0**
Totals (motor, unadjusted)	**10979**	**0**	**5137**	**0**

Nørrebrogade_nvf_Hillerødgade	Before	Trial 1 (Later)	Trial 1	Trial 2
Passenger cars	7429		2359	
Light duty vehicles	1794		568	
Heavy duty vehicles	830		625	
Mopeds				
Motorcycles				
Bicycles				
Totals (all, unadjusted)	**10053**	**0**	**3551**	**0**
Totals (motor, unadjusted)	**10053**	**0**	**3551**	**0**

Nørrebrogade_søf_Hillerødgade	Before	Trial 1 (Later)	Trial 1	Trial 2
Passenger cars	8025		4233	
Light duty vehicles	1977		1065	
Heavy duty vehicles	895		694	
Mopeds				
Motorcycles				
Bicycles				
Totals (all, unadjusted)	**10896**	**0**	**5991**	**0**
Totals (motor, unadjusted)	**10896**	**0**	**5991**	**0**

Appendix H: Examples of values calculated using ratios to separate combined vehicle categories

1663_Ægirsgade	11-Sep-08	29-Oct-09	23-Apr-09	18-Jun-09
Passenger cars	636	695	562	643
Light duty vehicles	218	161	117	161
Heavy duty vehicles	27	36	24	26
Mopeds	22	19	20	14
Motorcycles	9	10	8	9
Bicycles	1747	1518	1558	1111

607_Lundtoftegade	2-Oct-07	4-Nov-08	18-Jun-09
Passenger cars	5238	6306	6211
Light duty vehicles	1071	1128	1363
Heavy duty vehicles	368	329	313
Mopeds	23	20	17
Motorcycles	73	88	86
Bicycles	1801	1561	1352

Appendix I: All the ratios derived for the Eval sheets

5 DronningLouises Bro	Day / Morning (Average)	Day / Afternoon (Average)
Passenger Cars	5.985518867	4.515218327
Light Duty Vehicles	5.466015563	8.396391216
Heavy Duty Vehicles	5.072761912	6.482848057
Mopeds	5.035199565	4.692703577
Motorcycles	7.726960784	4.726901283
Bicycles	4.744080507	4.202235201
12 Fredericksborggade 43, sø f. Søtorvet	**Day / Morning (Average)**	**Day / Afternoon (Average)**
Passenger Cars	5.567698527	4.36973262
Light Duty Vehicles	5.172579215	6.300798258
Heavy Duty Vehicles	5.141098485	6.07670995
Mopeds	11.76666667	4.730179028
Motorcycles	7.791666667	3.204545455
Bicycles	4.298175978	3.925492625
60_Øster Søgade	**Day / Morning (Average)**	**Day / Afternoon (Average)**
Passenger Cars	5.716820922	4.885709263
Light Duty Vehicles	5.14734855	7.21630094
Heavy Duty Vehicles	4.632761247	8.916666667
Mopeds	6.140688259	3.424242424
Motorcycles	5.921436404	4.063829787
Bicycles	5.285102578	3.619026549
121 Fælledvejnodøst for Nørrebrogade	**Day / Morning (Average)**	**Day / Afternoon (Average)**
Passenger Cars	5.229717447	4.598835839
Light Duty Vehicles	4.965341669	12.10052526
Heavy Duty Vehicles	5.191886324	12.93170271
Mopeds	3.760869565	4.825077399
Motorcycles	5.091269841	4.60515873
Bicycles	3.779138118	4.896743555
170_Nørre Søgade	**Day / Morning (Average)**	**Day / Afternoon (Average)**

Passenger Cars Light Duty Vehicles Heavy Duty Vehicles Mopeds Motorcycles Bicycles	5.0813282 5.106927711 4.322834646 7.142857143 4.883116883 3.980350278	4.843577982 8.739690722 15.68571429 5 4.530120482 3.730184147
1668_Sortedam_Dossering_ved _DLB	**Day / Morning (Average)**	**Day / Afternoon (Average)**
Passenger Cars Light Duty Vehicles Heavy Duty Vehicles Mopeds Motorcycles Bicycles	5.931034483 5.568627451 3.571428571 3.770077008 5 3.770077008	3.44 5.358490566 #DIV/0! 3.181987001 3.333333333 3.181987001
1686_Nørrebrogade_vf_Hyltebro	**Day / Morning (Average)**	**Day / Afternoon (Average)**
Passenger Cars Light Duty Vehicles Heavy Duty Vehicles Mopeds Motorcycles Bicycles	7.761714481 5.831945546 4.476740696 3.939613527 10.5 3.943919277	4.572763821 8.861773256 5.067653891 4.696428571 3.966666667 4.706574672
1687_Nørrebrogade_øf_Hyltebro	**Day / Morning (Average)**	**Day / Afternoon (Average)**
Passenger Cars Light Duty Vehicles Heavy Duty Vehicles Mopeds Motorcycles Bicycles	7.125173106 6.41314487 5.156992198 4.355072464 5.377777778 4.344781647	4.460784314 7.111072015 5.863157895 4.247368421 7.123076923 4.248848188
1689_Nørrebrogade_vf_Baldersgade	**Day / Morning (Average)**	**Day / Afternoon (Average)**
Passenger Cars Light Duty Vehicles Heavy Duty Vehicles Mopeds Motorcycles Bicycles	5.010951878 6.596657633 5.642446809 4.8 	4.834973047 6.184952978 5.607954545 4.8
1690_Nørrebrogade_øf_Ægirsgade	**Day / Morning (Average)**	**Day / Afternoon (Average)**

Passenger Cars Light Duty Vehicles Heavy Duty Vehicles Mopeds Motorcycles Bicycles	**6.393853455 6.916134054 5.359519676 6.333333333**	**4.401619282 7.190214453 6.145178197 4.43030303**
1692_Nørrebrogade_vf_Faelledvej (closed section)	**Day / Morning (Average)**	**Day / Afternoon (Average)**
Passenger Cars Light Duty Vehicles Heavy Duty Vehicles Mopeds Motorcycles Bicycles	**8.806744186 6.46483376 5.585067319 5.5**	**4.413542152 10.62207358 5.280244864 4**
1693_Nørrebrogade_øf_Faelledvej	**Day / Morning (Average)**	**Day / Afternoon (Average)**
Passenger Cars Light Duty Vehicles Heavy Duty Vehicles Mopeds Motorcycles Bicycles	**5.979031338 5.715423498 5.456990358 6.083333333**	**4.437423833 10.42153209 6.1169955 4.3125**
Nørrebrogade_nvf_Jagtvej_(Runddel)_1,2,3,6,8,10	**Day / Morning (Average)**	**Day / Afternoon (Average)**
Passenger Cars Light Duty Vehicles Heavy Duty Vehicles Mopeds Motorcycles Bicycles	**7.019417476 5.958974359 4.763358779 6.666666667**	**4.167146974 10.56363636 6.5 4.285714286**
Nørrebrogade_søf_Jagtvej_(Runddel)_7,8,9,2,4,12	**Day / Morning (Average)**	**Day / Afternoon (Average)**
Passenger Cars Light Duty Vehicles Heavy Duty Vehicles Mopeds Motorcycles Bicycles	**7.288100209 6.416666667 4.879032258 7**	**4.299261084 7.21875 5.873786408 4.454545455**
Jagtvej_nøf_Nørrebrogade_(Runddel)_4,5,6,1,9,11	**Day / Morning (Average)**	**Day / Afternoon (Average)**

Passenger Cars	**5.464903846**	**5.029646018**
Light Duty Vehicles	**3.94047619**	**10.91208791**
Heavy Duty Vehicles	**3.971014493**	**10.14814815**
Mopeds		
Motorcycles	**5.448275862**	**5.096774194**
Bicycles		
Jagtvej_svf_Nørrebrogade_(Runddel)_10,11,12,3,5,7	**Day / Morning (Average)**	**Day / Afternoon (Average)**
Passenger Cars	**5.586956522**	**5.223577236**
Light Duty Vehicles	**5.568**	**10.1978022**
Heavy Duty Vehicles	**4.339130435**	**10.84782609**
Mopeds		
Motorcycles	**5.5**	**5.296296296**
Bicycles		

Appendix J: Examples of adjustments made to total motor vehicles

Table 18: Example of adjusted total for a reading location not on Nørrebrogade. Passenger cars, light duty vehicles, and heavy duty vehicles were summed in Before since only those categories exist in Trial 1.

170_Nørre_Søgade	Before	Trial 1
Passenger cars	19977	19448
Light duty vehicles	4188	5058
Heavy duty vehicles	786	599
Mopeds	100	
Motorcycles	376	
Bicycles	9318	
Totals (all, unadjusted)	**24952**	**25105**
Totals (motor, unadjusted)	**24952**	**25105**

Table 19: Example of adjusted total for a reading location on Nørrebrogade. Passenger cars, light duty vehicles, and heavy duty vehicles were summed in all columns because only those categories exist in Late Trial 1, Trial 1 Average, and Trial 2.

1692_Nørrebrogade_vf_Faelledvej (closed section)	Before	Trial 1 (Early)	Trial 1 (Late)	Trial 1	Trial 2
Passenger cars	7885	1106	383	745	428
Light duty vehicles	2028	320	179	249	175
Heavy duty vehicles	702	840	700	770	762
Mopeds					
Motorcycles			5	5	6
Bicycles					
Totals (all, unadjusted)	**10614**	**2267**	**1262**	**1764**	**1365**
Totals (motor, adjusted)	**10766**	**2419**	**1415**	**1917**	**1518**

Appendix K: Grams of each pollutant emitted by each vehicle type

It should be noted that all of these graphs are presented on different scales along the y-axis.

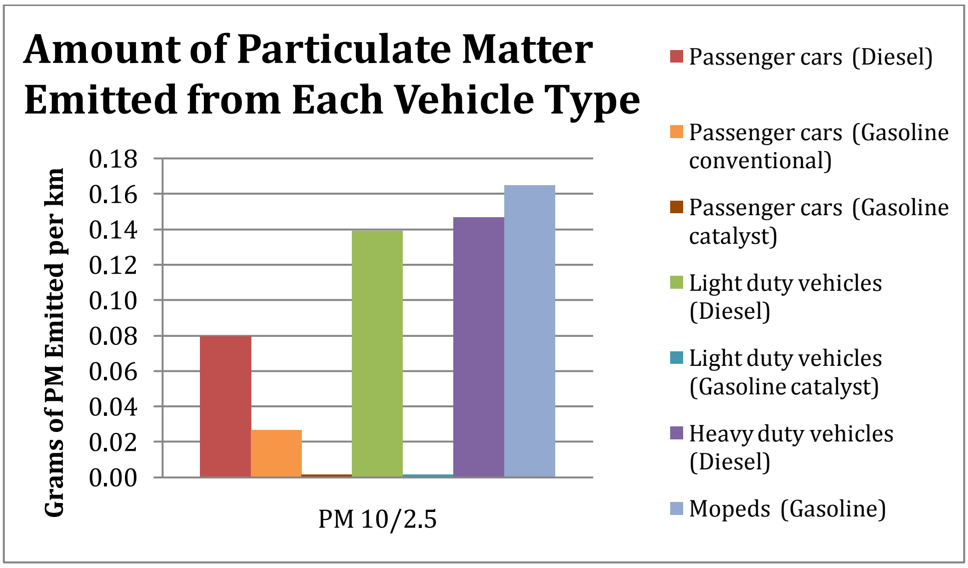


Figure 48: Grams of particulate matter emitted by each vehicle type (created with information from DMU, 2010)

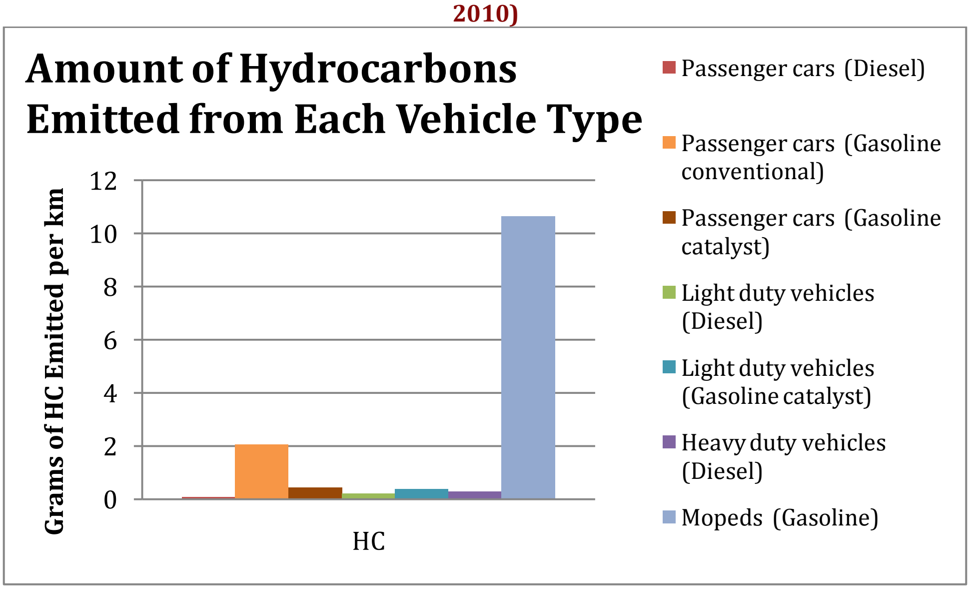


Figure 49: Grams of hydrocarbons emitted by each vehicle type (created with information from DMU, 2010)

Appendix L: Daily Bias Sheets

Daily Bias Worksheet	
Date:	8-Apr-10
Day of week:	Thursday
Holiday?	No
Time of day:	10:45-11:45
Temperature:	48°F
Weather:	Sunny with some clouds, slight wind
street/section of Nørrebrogade	Southend
IDs	
A 1-4	
I 1-7	
F 1-4	
Total: 15	

Daily Bias Worksheet	
Date:	13-Apr-10
Day of week:	Tuesday
Holiday?	No
Time of day:	13:30 - 15:00
Temperature:	50° F
Weather:	Partly cloudy
street/section of Nørrebrogade	Cemetery - Jagtvej
IDs	
A 5-9	
I 8-13	
F 5-9	
Total: 13	

Daily Bias Worksheet	
Date:	14-Apr-10
Day of week:	Thursday
Holiday?	No
Time of day:	11:30-12:30
Temperature:	50° F
Weather:	bright and sunny
street/section of Nørrebrogade	North of Jagtvej
IDs	
A 10-14	
I 14-16	
F 10-13	
Total: 12	

Daily Bias Worksheet	
Date:	21-Apr-10
Day of week:	Wednesday
Holiday?	No
Time of day:	15:00 - 16:00
Temperature:	47˚F
Weather:	Cloudy; after rain
street/section of Nørrebrogade	Southend
IDs	
A 15	
I 17-21	
F 14-15	
Total: 8	

Daily Bias Worksheet	
Date:	26-Apr-10
Day of week:	Monday
Holiday?	No
Time of day:	10:00-12:00 and 12:30-13:30
Temperature:	57˚F

Weather:	Sunny, partly cloudy
street/section of Nørrebrogade	North, South, Central
IDs	Some left overnight, picked up the next day
A 16-17	
I 22-39	
F 16-19	
Total: 23	

Appendix M: Preliminary Trial 3 Traffic Results

During the conclusion of this project, the City of Copenhagen collected traffic data for Trial 3, which is identical to Trial 1, except that the northern section of Nørrebrogade was opened to private motor traffic again. The team was able to quickly process some of this data, and obtain some preliminary results. Table 20 shows the total number of motor vehicles between 7:00 and 18:00 for a few select locations in Nørrebro.

Reading Location	Before	T1L	T2	T3
DronningLouises Bro	11045	5610	6166	5939
Fælledvej	4915	3692	3432	3860
Nørrebrogade West of Fælledvej (closed)	10614	1262	1365	1195
Nørrebrogade West of Bragesgade (T1+2 closed)			1776	5006

Table 20: Preliminary traffic results for Trial 3. Shows the number of motor vehicles between 7:00 – 18:00.

Table 20 indicates that traffic levels on the southern half of Nørrebrogade probably have not been affected by the opening of the Northern section on Nørrebrogade. This seems to be the case since the Trial 3 number is not significantly different from the Trial 1 or 2 numbers for DronningLouises Bro, Fælledvej, and the southern closed section on Nørrebrogade. The northern section of Nørrebrogade that was opened to traffic did have a very significant increase, however. A jump from 1776 motor vehicles to 5006 is a 182% increase – nearly triple the number of motor vehicles. Based on this quick look at the new traffic data, it does appear that the Northern area will increase in traffic while the Southern area will not be affected. A more detailed analysis could investigate whether this traffic increase applies to the entire north section of Nørrebrogade, and whether the rest of Nørrebro is unaffected by the opening.

Appendix N: Emission factors by vehicle type

Category	Fuel type	NOx		NMVOC		CO		PM10		PM2.5	
		[g/GJ]	[g/L]	[g/GJ]	[g/L]	[g/GJ]	[g/L]	[g/GJ]	[g/L]	[g/GJ]	[g/L]
Passenger cars	Diesel	257.64	**9.970668**	29.19	**1.129653**	97.2	**3.76164**	30.93	**1.19699**	30.93	**1.19699**
Passenger cars	Gasoline conventional	630.56	**21.94349**	883.08	**30.731184**	8347.86	**290.50553**	11.6	**0.40368**	11.6	**0.40368**
Passenger cars	Gasoline catalyst	111.72	**3.887856**	189.67	**6.600516**	2225.97	**77.463756**	0.63	**0.02192**	0.63	**0.02192**
Light duty vehicles	Diesel	278.93	**10.79459**	48.38	**1.872306**	160.87	**6.225669**	36.05	**1.395135**	36.05	**1.39514**
Light duty vehicles	Gasoline conventional	622.33	**21.65708**	732.28	**25.483344**	7578.42	**263.72902**	8.79	**0.30589**	8.79	**0.30589**
Light duty vehicles	Gasoline catalyst	87.13	**3.032124**	108.26	**3.767448**	2525.58	**87.890184**	0.38	**0.01322**	0.38	**0.01322**
Heavy duty vehicles	Diesel	697.71	**27.00138**	33.17	**1.283679**	154.48	**5.978376**	18.98	**0.73453**	18.98	**0.73453**
Heavy duty vehicles	Gasoline	456.62	**15.89038**	696.09	**24.223932**	7102.99	**247.18405**	40.59	**1.41253**	40.59	**1.41253**
Mopeds	Gasoline	113.84	**3.961632**	9177.91	**319.39127**	9905.34	**344.70583**	142.17	**4.94752**	142.17	**4.94752**
Motorcycles	Gasoline	106.67	**3.712116**	1594.63	**55.493124**	12062.59	**419.77813**	27.47	**0.95596**	27.47	**0.95596**