Visualizing Pollution in Nørrebro

An Interactive Qualifying Project Report submitted to Miljøpunkt Nørrebro and the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science

By:
Shridhar Ambady
Kevin Hancock
Katrina Kohlman
Madeline Seigle

Norrebro-dk14@wpi.edu

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Proposal Submitted to:

Stephen McCauley
WPI IGSD

Professor Robert Kinicki
Professor Steven Taylor
Worcester Polytechnic Institute

Ove Larsen
Miljøpunkt Nørrebro

ABSTRACT

The group worked with Miljøpunkt Nørrebro, the project sponsor, to gain public support for a currently proposed project, the Ladegård Daylighting Project. In order to do this, we will examine materials from previous construction projects that involve moving an existing road underground to research the impact that the projects have had on local noise and air pollution levels. Eventually we will use this research to create a report and presentation that our sponsor can show to potential sponsors and politicians to gain support for the project. The group will also create a dynamic sign to install in the area that shows real-time information about pollution levels in the area. Our hope is that the municipal government will install the sign we design in the area.

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1.0 Introduction

Every year, more people in Europe die from traffic related pollution than they do from traffic accidents (Künzli et al., 2000). Traffic pollution consists of air and noise pollution, both of which can lead to severe health problems for those who experience them in their everyday lives. In urban areas, especially cities with a high level of commuters, there are increased levels of traffic pollution due to the large number of cars traveling through the area regularly. Congestion often plagues cities, leading to traffic jams, idling cars, and air pollution, which in turn leads to pollution related health effects. Green space can help alleviate some of these problems by providing a healthy environment and noise barriers. Typically, there is less green space in cities due to the large amount of development. By reducing the levels of traffic pollution and adding more parks and recreational areas in cities, the overall physical and mental well-beings of the inhabitants will be greatly improved ("Echo: Green Spaces Benefit Health in Urban Areas," 2003).

Nørrebro, one of 10 districts in Copenhagen, Denmark, faces the same traffic problems as any city, but to a much larger degree than the rest of Copenhagen. Originally located in the countryside, Nørrebro experienced a building boom in the 1800s when the city abandoned the demarcation lines, a set of lines blocking off green space and restricting urban development. The increased growth has continued to the present day, leading to a high population density in Nørrebro- almost 20,000 inhabitants per square kilometer. At seven square meters of green space per resident of Nørrebro, the district has a significantly less amount of green space than the rest of Copenhagen, which has about forty-two square meters per person. When paired with the large amount of traffic that travels through Nørrebro from the rest of Copenhagen, the hazardous pollution effects on the residents of the area are notably larger than elsewhere in the ("Welcome to Copenhagen," 2014).

Miljøpunkt Nørrebro, the project sponsor, is looking to remedy the traffic situation by moving a road underground and bringing a river aboveground in a process called daylighting. Currently, the Ladegård River runs underneath Å St. and Å Blvd, forming the southern border of Nørrebro. The city paved over the river in 1897 to make room for the increasing urban development. The idea proposed by Miljøpunkt Nørrebro involves bringing the Ladegård back to the surface level; this would help manage storm water flooding and provide a recreational area

for the local residents. In addition, Miljøpunkt Nørrebro hopes to lessen the effect of the through-traffic on Å St. and Å Blvd by moving the roads underground into a tunnel (Larsen, 2014).

The people of Nørrebro are aware of the fact that they deal with the negative effects of traffic pollution daily, but most have no grasp on the severity of the situation (Larsen, 2014). In order to gather lasting support for the daylighting and tunneling projects, there must be proof of the current pollution levels in the area and their adverse health effects as well as a strong argument that the proposed solution is the best one for the problem. Miljøpunkt Nørrebro needs hard evidence that projects similar to the proposed project have had a positive, tangible impact on the residents of their surrounding areas, and they need to come up with a way to relay to the public how bad the pollution situation currently is in order to make sure the project has long-term support.

The ultimate goal of this project is to help Miljøpunkt Nørrebro gain public support for the Ladegård Daylighting project by creating a communication platform that spreads awareness about the negative health effects of noise and air pollution caused by the unusually high automobile traffic in the area. By gathering evidence of the benefits of this project and creating a dynamic sign that effectively communicates the pollution levels in the area, the project group hopes to create long-lasting support for the Ladegård Daylighting project.

2.0 LITERATURE REVIEW

The high number of cars that regularly pass through Nørrebro create higher amounts of noise and air pollution than anywhere else in Copenhagen (Larsen, 2014). This chapter starts by providing a brief history of Nørrebro and its growing traffic problems. The amount of through traffic in Nørrebro and the lack of green space exacerbate the health and wellness issues that the pollution from traffic creates. The solution proposed by Miljøpunkt Nørrebro, the project sponsor, involves taking a river that was previously paved over and reopening it, a process called daylighting, while moving the existing road underground. This chapter explores other projects comparable to the proposed solution and the effect that they have had on the health and well-being of the surrounding population, as well as the potential challenges and difficulties that the project could face. In order for the project to continue to construction, local politicians, potential sponsors, and the residents of Nørrebro have to remain convinced of the benefits of the project, which is shown through the evidence provided in this chapter. The background discusses the

previous and current education efforts conducted by Miljøpunkt Nørrebro, possible future education efforts, as well as the current public opinion of the project. Finally, the chapter discusses different aspects of the design of a dynamic sign, which will promote public awareness regarding current pollution levels.

2.1 Nørrebro

Nørrebro is one of ten districts in Copenhagen, Denmark. Nørrebro is divided into two administrative districts, Inner Nørrebro and Outer Nørrebro, and its residents are mostly young, working-class citizens. As of 2012, Nørrebro occupies an area of 3.82 square kilometers and has a population of approximately 75,000. It is the densest area of Copenhagen at 20,000 inhabitants per square kilometer, representing close to 14% of Copenhagen's total population of about 550,000 (Bunch-Nielsen, Benbella, Jessen, & Cornet, 2012).

2.1.1 Nørrebro Traffic Situation

The traffic problem in Nørrebro began after the city abandoned the demarcation lines, which prohibited building on designated green space. This led to a building boom, which in turn brought thousands of new residents to the area. To accommodate for the influx of people, green spaces and canals were paved to make room for the new traffic (Ruddy, Hassan, Anglin, & Higgins, 2012).

A 2009 study shows that at 13 vehicles per 100 inhabitants, Nørrebro has the lowest car ownership rates in Copenhagen. For reference, there is an average of 18 cars per 100 inhabitants in Copenhagen and 37 cars per 100 inhabitants in Denmark as a whole (Bunch-Nielsen et al., 2012). The Nørrebrogade, the main road through Nørrebro, is a perfect example of the current traffic problem in Nørrebro. The area along the road has suffered from a lack of commercial development and heavy traffic despite the low car ownership in the area due to the outside traffic from the rest of Copenhagen (Glaser, Madruga, Gridwold, & Krag, 2013). The Ladegård Daylighting project, which is the project that the group is focusing on, is centered on Åboulevard and Ågade, two roads that suffer from problems similar to those of the Nørrebrogade, notably the high pollution levels and low amount of overall development in the area.

2.1.2 Miljøpunkt Nørrebro

The project sponsor, Miljøpunkt Nørrebro, formerly known as Agenda 21, is the Nørrebro chapter of the Agenda 21 Plan, an action plan created at the UN Conference on Environment and Development (UNCED) in 1992. Miljøpunkt Nørrebro is one of 17 Danish Agenda 21 Chapters (Ruddy et al., 2012). The United Nations designed the Plan to be open ended, and as such, Miljøpunkt Nørrebro has a good amount of flexibility with the projects they undertake, as they have no set mandates. They create projects to work on as they identify a need for one. Miljøpunkt Nørrebro is run as an NGO and funding is provided from various sources, such as the city of Copenhagen, the Danish government, and the EU (Larsen, 2014).

The organization focuses mainly on "big picture" issues, such as combating climate change and reducing greenhouse gas emissions in Nørrebro. Their primary goals include educating the people of Nørrebro on environmentally friendly practices and trying to improve their quality of life. Miljøpunkt Nørrebro aims to create "green solutions for blue problems", meaning they attempt to solve water-related issues by incorporating green space into the daily life of Nørrebro residents (Larsen, 2014).

Some of their current initiatives include traffic reduction and relocation, environmentally friendly waste disposal and recycling, and adding more green space. One of Miljøpunkt Nørrebro's most well-known projects is the daylighting of the Ladegård River, which as previously discussed, will be the focus on the group's efforts while in Copenhagen (Ruddy et al., 2012).

2.2 Pollution from Traffic

Traffic is a normal occurrence in any heavily populated urban area, and it is one of the main reasons for the typically high levels of pollution, compared to less populated areas. Heavy automobile traffic results in two forms of pollution: air and noise pollution. Air pollution is a result of the fuel emissions given off by the exhaust pipes in a car. Sounds such as car horns, emergency vehicle sirens, construction on the roads, etc., can cause noise pollution. These heavy levels of pollution can negatively affect the lives of those who experience it, as prolonged exposure to both air and noise pollution can be detrimental to both a person's physical and mental well-being. In Denmark alone, pollution from traffic kills 4000 people a year, compared

to 400 a year from traffic accidents (Glaser et al., 2013). Nørrebro experiences a particularly severe level of traffic-related pollution, leading to the exploration of its associated health effects.

2.2.1 Air Pollution and Health Effects

There are four types of air pollution: gaseous pollutants, persistent organic pollutants, heavy metals, and particulate matter. The combustion of fossil fuels, in both stationary and mobile combustion sources, creates gaseous pollutants. They consist of chemicals such as SO_2, NO_2, ozone, and Volatile Organic Compounds (VOCs). The majority of this pollution type comes from combustion that occurs in transportation vehicles, when exhaust emission give of VOCs. Persistent organic pollutants are a group of toxic chemicals that include pesticides, dioxins, furans, and PCDs. Created in any industrialized process including combustion; dioxins make up the largest part of these pollutants. People living in more industrialized areas tend to have higher levels of dioxins in their systems (Schecter, Birnbaum, Ryan, & Constable, 2006). Persistent organic pollutants tend to enter food sources, which magnifies their negative health effects every time they move up the food chain due to a process called bio-magnification. Heavy metal pollution includes elements such as lead, mercury, chromium, nickel, and other heavy metals, which come from the earth's crust and are indestructible. They can enter the earth's water and food supply by traveling through air and combustion reaction and manufacturing facilities can introduce additional metals to the atmosphere. Particulate matter pollution consists of all pollution particles that are suspended in the air that people breathe. These particles come from factories, automobiles, construction sites, and many other places. Many things make up particulate matter, including metal, organic compounds, reactive gases, ozone, and ions. It can also be a variety of sizes, ranging from 1 µm to 10 µm, and smaller particles tend to be more hazardous than larger ones (Kampa & Castanas, 2008; Katsouyanni, 2003). A vehicle's combustion system produces gaseous pollutants, heavy metal pollutants, particulate matter, and persistent organic pollutants, and then releases them through the exhaust pipe. The examination of all forms of air pollution is necessary in order to fully understand the severity of the health problems associated with traffic pollution.

2.2.1.1 Effect of Air Pollution on the Respiratory System

Exposure to air pollution can have a severe impact on the respiratory system. Noise and throat irritation are symptoms of exposure to gaseous and heavy metal pollutants. Particularly

harmful pollutants include nitrous oxides, ozone, sulfur dioxide, arsenic, and nickel. They can increase the risk for chronic bronchitis, asthma, emphysema, and lung cancer, as well as worsen pre-existing conditions such as lung lesions or lung diseases (Kampa & Castanas, 2008; Künzli & Tager, 2005).

2.2.1.2 Effect of Air Pollution on the Cardiovascular System

The cardiovascular system is extremely susceptible to the negative effects of air pollution. Increased blood pressure and tachycardia, a faster than normal heart rate, can be caused by heavy metal pollution. Particulate matter can affect blood clotting and lead to angina or myocardial infarctions (Kampa & Castanas, 2008). Increased levels of air pollution can also result in higher risks for arrhythmia, thrombosis, and strokes (Künzli & Tager, 2005).

2.2.1.3 Effect of Air Pollution on the Urinary and Nervous Systems

Heavy metal pollution negatively affects both the nervous system and the urinary system. Exposure to these metals can result in neurotoxicity, which can cause memory loss, sleep disorders, tremors, fatigue, blurred vision, and slurred speech. Mercury, in particular, causes certain types of neurological cancer. Heavy metals can also cause kidney damage, increase the risk of kidney stones, and increase the risk of renal cancer (Kampa & Castanas, 2008).

2.2.1.4 The Overall Health Risks of Air Pollution

A study conducted in Austria, France, and Switzerland showed that air pollution causes 6% of the combined total deaths in these countries every year. Half of these fatalities were caused by traffic-related air pollution (Künzli et al., 2000). Specifically within Denmark, approximately 3400 people die each year from medical conditions as a result of traffic air pollution (Glaser et al., 2013). Exposure to air pollution results in more deaths than traffic accidents. For every 10 $\mu m/m^3$ increase in daily air pollution e exposure, there is 0.5% increase in the number of associated respiratory or cardiovascular-related deaths (Künzli & Tager, 2005). Living in areas with high levels of air pollution shortens a person's life expectancy by 1-2 years, which is relatively large compared to other environmental factors (Brunekreef & Holgate, 2002).

2.2.2 Noise Pollution and Health Effects

Noise pollution is any loud or disruptive sound caused by airplanes, automobiles, trains, etc. that is annoying and/or detrimental to the health of the people who experience it ("Noise Pollution," n.d.). Theoretically, anything that can make a sound can contribute to noise pollution,

including everyday things such as a neighbor playing their stereo too loud or emergency sirens passing by a building (Bronzaft, 1996). Noise pollution tends to occur more in higher populated and urban areas, such as cities and airports, due to the increased volume of automobiles, low-flying planes, and other key contributors to noise pollution. Poor urban planning can also contribute to higher noise pollution levels. In places where residential and industrial building are situated close to each other, increased levels of noise pollution can be experienced by the people living in the residential area ("Noise Pollution," 2012).

2.2.2.1 The Effect of Noise Pollution on Sleep

Noise pollution can have a serious effect on a person's ability to get a good night's sleep, which can lead to adverse psychological and physiological health effects. Sleep is an essential part of resting after a long day, and without proper recuperation during sleep, one may be unable to refresh his or herself, which can be detrimental to both one's physical and mental health. Sleep loss from noise disturbance can result in poorer task-performance and can make a person less attentive during the day, which can make one more accident prone, as they are less aware of potential danger around them. Studies have also shown that people who were exposed to high levels of noise pollution while sleeping tended to be unhappier the next day and more irritable overall. Nighttime noise disturbances can change people's sleep patterns, as well as increase their heart rate and blood pressure (S. Stansfeld & M. Matheson, 2003). People who live in noise polluted areas are more likely to use sleep aids such as tranquilizers regularly, which can lead to many other negative health effects as well (Bronzaft, 2002).

2.2.2.2 The Psychological Effects of Noise Pollution

A major human reaction to noise pollution is annoyance, and this increase in annoyance can lead to psychological effects, which can ultimately decrease a person's mental health. People exposed to higher amounts of noise pollution are more likely to get into aggressive disputes with their neighbors and react violently to stressful situations. In addition, people tend to ignore others around them when walking in a noisy urban area, even if they are asking for help (Bronzaft, 1996). Exposure to noise pollution can slow a person's memory rehearsal and affect their memory's selectivity, as well as decrease their ability to pick up on normal social cues (S. A. Stansfeld & M. P. Matheson, 2003). K. Hiramatsu and her associates conducted a study on the people who reside near the Kadena Air Base in Ryukyu, Japan, an area with a large amount of air pollution from the heavy air traffic near the base. These researchers conducted a survey asking

people about their perception of their mental well-being. Those who lived closer to the air base, and thus experienced higher levels of noise pollution, reported that they felt more mentally unstable, depressed, and nervous than those who lived further away, showing the negative correlation between noise pollution and mental health (Hiramatsu, Yamamoto, Taira, Ito, & Nakasone, 1997). There is also evidence that a change in an person's environment that leads to higher levels of noise pollution can aggravate pre-existing mental and emotional health problems, leading to psychologist intervention for a problem that a potential patient would have normally been able to handle on their own (Bronzaft, 2002).

2.2.2.3 The Physiological Effects of Noise Pollution

Researchers have most convincingly linked exposure to high levels of noise pollutions to harmful effects on the cardiovascular system. This can be attributed to the stress that a person undergoes while experiencing high levels of noise pollution, as high stress levels have been proven detrimental to a person's health, most notably to the cardiovascular system (Bronzaft, 1996). Studies have definitively shown that people who regularly experience noise levels of 85 dB have significantly higher blood pressure than those who experience less noise.

High levels of noise exposure can lead to treatment for hypertension and other heart problems. Although there have also been studies done that have shown relations between noise pollution and effects on cholesterol levels, total triglycerides, blood viscosity, platelet count and glucose levels, these relationships have not been conclusively proven (S. A. Stansfeld & M. P. Matheson, 2003). Each year in Denmark, 200-500 people die from cardiovascular problems that can be traced back to noise pollution from traffic (Glaser et al., 2013).

Noise pollution can affect other parts of the human body such as the gastrointestinal and circulatory systems, hearing, and any other weakened area of the body. People who chronically experience noise pollution are more likely to have hearing loss than those who do not. A study comparing a typical United States population and Maaban tribesmen proved that repeated exposure to moderate to high levels of noise can lead to an increase in hearing loss ("Noise Pollution," 2012). Exposure to high noise levels in industry settings can cause increased levels of noradrenaline and adrenaline secretion. People who experience regular noise pollution have reported that they feel like they are in worse health than those who have very little noise pollution in their everyday lives. People have also reported that high noise levels render them

unable to do normal activities such as having conversations, watching TV, and opening windows, as the noises around them were too disrupting to partake in these activities.

2.2.2.4 The Effect of Noise Pollution on Children

Noise pollution effects children the most, because they are the most vulnerable demographic. Similar to noise-exposed adults, noise-exposed children are at the same risk for increased stress levels, detrimental cardiovascular effects, and raised adrenaline and noradrenaline levels. A notable study examined the effects of noise pollution on primary school children within four 32-floor apartment buildings on a busy road. The researchers assumed that children living on the lower floors would experience more noise disturbances from the road than those living on higher floors. They tested Seventy-three children for reading comprehension and auditory discrimination and it concluded that the children living on the floors closer to the road had significantly lower scores for these tests. Children exposed to chronic noise have a harder time concentrating than children who are more often in quieter settings. There is evidence suggesting that noise exposure negatively affects a child's cognitive functions such as central processing and language comprehension. Noise pollution also effects children's performance on standardized tests and their memory for high processing problems. Regular noise exposure decreases a child's motivation. Studies have found that children are more likely to give up on difficult puzzles if they have been exposed to high noise levels (S. A. Stansfeld & M. P. Matheson, 2003). Linear correlations exist between road and air traffic noise and children's annoyance levels, reading comprehension, and recognition memory (Stansfeld et al., 2005).

2.2.3 Other Approaches to Reducing Traffic Pollution

With new advances in technology, it is becoming more possible to take action against pollution. A tactic to combat noise and air pollution is by researching and designing inventions such as fuel-efficient engines, clean energy vehicles, and improved noise dampeners. Some countries have also implemented new protocols, such as only allowing a limited number of cars to travel on a street on a given day as a method to decrease pollution, and have suggested building clean energy trains to replace pre-existing modes of transportation.

In the past, dangerously high levels of air pollution have led to enforcing drastic short-term solutions to the pollution problem. In 1992 in Italy, the pollution from traffic became so bad that cities put driving restrictions on their citizens. A few cities limited the number of people

who could drive each day by only allowing cars with license plates ending in an odd number to drive one day, and cars with even number-ending license plates to drive the next day, essentially cutting the number of cars on the road in half. Florence took a more severe path, and banned automobiles for seven hours each day. This solution made people walk to their destinations and helped them rediscover the pleasures of walking through car-less streets (D Aquino, 1992).

Groups have also recommended maglev, or magnetic levitation, trains as replacements for more traditional, car-based methods of transportation (Mowad, 2007). Electromagnets on both the train cars and the sides of the railways control the maglev trains. They lift and move the trains at extremely high speeds (up to 310 mph) with lower emissions than cars and traditional trains. Without the necessity for traditional fuel, maglev trains have the benefit of drastically reducing pollution in the areas in which they are used. Maglev trains are currently used in China; other countries, including the United States, are considering implementing them in order to alleviate traffic congestion and its associated air pollution.

People have suggested clean fuel vehicles as a method to reduce air pollution from vehicle emissions, but they have faced many challenges. Natural gas is a cleaner fuel than traditional gasoline and produces 90% less carbon monoxide, 85% less ozone, and emits zero particulates into the air. Clean fuel vehicles have not gained popularity due to the lack of fueling station infrastructures around the world. People do not want to buy a clean fuel car if they will not be able to refill it, and until this is no longer a problem, clean fuel vehicles will not be a viable solution to air pollution reduction (Meotti, 1995).

While clean-fuel vehicles are not currently a viable option, other alternatives to gasoline engines are gaining popularity. Every year, automobile manufacturers produce new vehicles that boast about quieter, cleaner burning engines. Manufacturers such as Mercedes and Volkswagen have started producing diesel-fueled passenger cars. These cars are both more fuel efficient (which gives off less emissions) and quieter than normal gasoline-powered engines (Douthit & Rob, 2007). Additionally, many of the main automobile companies are now selling hybrid cars, which use gasoline but because they run on both gasoline and electricity, they produce less emissions than an average vehicle. Hybrid engines are also significantly quieter than a normal engine. Most gas stations sell both regular and diesel gasoline, which means that both diesel and

hybrid cars are a feasible option as a way to reduce traffic pollution, since there are already infrastructures in place for both of them.

While companies are working on creating quieter engines, researchers are also exploring different types of noise barriers, as a method to dampen the sounds made by existing engines. Certain types of plants can act as natural dampeners to noise. One study in particular examined the effects of plant barriers in Ankara, the capital of Turkey. By placing three rows of plants such as English Ivy *(Hedera helix)*, Blackberry shrubs *(Rubus Fruticosus)*, and Silver Lace Vine *(Plygonum aubertii)* in a "noise curtain" that absorbs the noise, the amount a noise is decreased by 5 dB, meaning that a person can hear half as much noise as they would be able to without the plants. The closer the bush or plant is placed to the noise source, the more effective it will be as more noise will be absorbed by the plants before it has a chance to deflect past the barriers (Ropuš, Ivana, Vesna, & Biserka, 2013).

There is ongoing research happening on artificial noise reduction solutions, mainly on coatings. By damping a material with a water-based coating, there is substantial noise suppression in the material. Some of the newer research into acoustically dampening coatings is in nanotechnology. Multi-walled carbon nanotubes are excellent additions to coatings, due to their ability to drastically increase the surface area of the coatings, which can lead to a 700% improvement of noise dampening. There are a variety of types of noise dampening coatings that can be applied to different materials, dependent upon the material, the desired dampening effect, and the size and shape of the item to be dampened (Ropuš et al., 2013).

The city of Copenhagen has taken action to reduce traffic pollution. As previously mentioned, Nørrebrogade is a major road that runs through Nørrebro. It has undergone major redesigns in order to decrease the number of cars that travel on it each day and to increase the livability of the residents. Klaus Bondam, the former Traffic Mayor of Copenhagen, enacted a four-stage plan in order to accomplish this feat. Beginning in September of 2008, the city widened the cycle lanes on both the Queen Louise's Bridge and a stretch of road from Fælledvej to Dosseringen and added more bus-only traffic lanes to the road. As of 2010, car traffic on Nørrebrogade has fallen by 60% (15000 to 6000) cars a day, and traffic in the entirety of Nørrebro has decreased by 10% as well. Due to the decrease in cars on the street, noise pollution

has been reduced by 1.5 – 3.5 dB, as the only truly effective way of reducing noise pollution is to take the noise making things – in this case cars – away (Glaser et al., 2013; Grimar, 2010).

2.3 Major Urban Infrastructure Projects

The ongoing support for the Ladegård Daylighting project is dependent on evidence based on similar cases that prove that it will be beneficial. Section 2.3.3 fully explains the Ladegård project. While there are not many examples of construction projects that involve moving a highway underground, it is possible to build a case study using data collected from areas with traditional roads versus areas with tunnels. This includes the hazards of living near a major roadway that is above ground, the negative effects of the construction itself, and the positive effects of having an underground roadway with green space over it.

2.3.1 Highways and Tunnels

Eleven percent of US households live within 100 meters of a major 4-lane highway. In the United States, governments only monitor and regulate pollution at a regional level, and ignore the increased exposure to pollutants at the community level for those living nearby. After 1000m, the effects are relatively homogeneous, but within 100m of a highway, the amount of pollution exponentially increases. The concentration of particulate pollution is five times higher in the first 30m within a highway than the next 30m. Beyond 100m, the concentration is lower but the particles are larger, so the effects are relatively the same (Brugge, Durant, & Rioux, 2007).

People consider tunnels safer for the local residents because the particulate pollution does not go directly into the air and affects those who live around them. However, there are still pitfalls to consider. Nørrebro has high levels of through traffic and its main roads are prone to traffic jams (Larsen, 2014). Traffic jams can be very dangerous in a tunnel, where carbon monoxide can build up at a rapid rate. Simulations and measurements of a major tunnel in Melbourne, Australia showed that even with the fans working at maximum power, carbon dioxide and carbon monoxide built up at a dangerous rate (Bari & Naser, 2010). If something interrupted the power or the ventilation system unexpectedly stopped working during a traffic jam, there would need to be an evacuation. Despite this, in most situations, the level of pollution within a tunnel is perfectly manageable.

One of the benefits of building a tunnel is the control of noise pollution. The sound from traffic stays within the tunnel instead of disturbing the lives of local residents. However, if the workers do not build the tunnel properly, this effect happens only around the main body of the tunnel. A study found that the noise pollution does not simply disappear just because it is below ground. Instead, the sound reverberates within the tunnel until it leaves out either end. Essentially, the noise pollution is relocated and concentrated at the openings of the tunnel (Woehner, 1992). The only effective technique to reduce noise pollution is by using sound-absorbing material. Workers must place the material inside the walls in the understructure of the tunnel in order for it to be effective. When placed on the walls themselves, it has almost no effect. The material can get expensive, but actually reduces noise pollution instead of simply redirecting it (Herman, Seshadri, & Pinckney, 1999).

2.3.2 Central Artery/Tunnel Project

In the earlier part of the 20th century, urban centers in the U.S. were rapidly expanding with brand new infrastructure. Colossal projects began in New York City, Philadelphia, Los Angeles, Boston, and other major U.S. cities. One of these large projects was the elevated highway at the end of I-90 in Boston, which led to Logan International Airport. Bostonians instantly reviled it, because it was an eyesore and the pollution made the nearby residential area a terrible place to live due to the low property values. A proposal was made in the 70's to remove all the elevated highways going through downtown Boston, known as the Central Artery, and place them in an underground tunnel where expansion would no longer mean displacing hundreds or thousands of residents. People commonly refer to the CA/T Project as the Big Dig. The mastermind behind the project was Fred Salvucci, a graduate of the Massachusetts Institute of Technology, who was hired by the Massachusetts Department of Transportation as the transportation secretary (Gelinas, 2007).

The various statistics concerning the Big Dig, such as person-hours and material used, are far beyond that of any infrastructural renovations in recent decades. Because there were less space restrictions and no worries about expansion displacing homes and businesses, the architects planned for the tunnel to be between 8 and 10 lanes, in comparison to the original 6-lane highway. Altogether, it is 161 miles of single lane road with 14 on-off ramps, significantly sleeker than the original Central Artery. The research and fieldwork that went into planning the

Big Dig is still currently the largest geotechnical study performed in North America (Massachusetts, 2014). When construction began, workers had to dig out 16 million cubic yards of dirt, some of which workers then used to cap dumps and create parks. This large cavity was to be replaced with 26,000 linear feet of steel-reinforced concrete slurry tunneling, the largest amount ever used for a single project, set 120 feet below the surface (Massachusetts, 2014).

While the long-term benefits of the project included decreased pollution in the surrounding neighborhoods, the construction itself caused a significant amount of pollution. Construction vehicles are not subject to the same environmental regulations as normal vehicles because of their heavy-duty use. Pollution from just 70 of the construction vehicles was equivalent to 1,300 diesel buses, the type of pollution that the Big Dig aimed to reduce (Allen, 1998).The constant construction also generated excessive noise pollution, further disturbing residents in the area and lowering property values (Kim, Park, & Kweon, 2007). The city of Boston ended up placing filters on the construction vehicles to reduce the short term cost of pollution of the Big Dig and keep them in line with their long term benefits (Allen, 1998).

People have already begun to notice the long-term benefits. Elevated highways created wasted space; not only did they not leave room for parks or recreational areas, but they destroyed homes, businesses, and urban development. The Big Dig opened up space for 300 new parks, filled with 2,400 new trees and 26,000 new shrubs (Massachusetts, 2014). The expansive tunnels allowed traffic to move through at a smoother pace, decreasing congestion at peak hours by 42 to 74 percent. This reduction in traffic build up has led to a 12% reduction in carbon monoxide emissions (Massachusetts, 2014). Overall, the Big Dig has led to less pollution, less traffic, and more green space, very similar to the goals of Nørrebro.

2.3.3 Ladegård Daylighting

In 2012, a group of students from Worcester Polytechnic Institute proposed a design for daylighting the Ladegård canal by bringing it up above ground. The goal was to expose the waterways and help prevent flooding from storm water (Ruddy et al., 2012). The construction project has expanded to include a plan to remove the road paved over the canal and build it in an underground tunnel, similar to the Big Dig. This project is referred to as the Ladegård Daylighting project, and will be the focal point of the team's efforts for the duration of the project.

In the earlier days of Copenhagen, the Ladegård River was an open stream running from Damhussøen through Nørrebro and emptying into the Lakes, five rectangular bodies of water. In 1897, the city of Copenhagen paved over the canal and encompassed it in pipes to make way for the rapidly expanding population. They also constructed buildings over the roads that were previously on either side of the canal. This area was formerly used for bathing, cooking, and recreational purposes (Ruddy et al., 2012). The push for more green space along with the need for flood prevention has led to the proposal of bringing the Ladegård above ground to bring back much needed green space in Nørrebro, falling in line with Miljøpunkt Nørrebro's slogan, "green solutions to blue problems."

Creating green space in Nørrebro would have multiple benefits, which include improving drainage, absorbing rainwater, absorbing pollutants through vegetation, attracting upscale businesses, and providing a recreational area for residents (Ruddy et al., 2012). The city of Copenhagen is pushing for green space, especially in Nørrebro, which has the lowest amount of green space per capita in the city. Miljøpunkt Nørrebro believes that daylighting the Ladegård is the perfect solution, providing the green space and managing the storm water flooding.

Figure 1: Map displaying the location of the Daylighting Project (Google, 2014)

With the daylighting of the Ladegård, Miljøpunkt Nørrebro also hopes to find a solution for reducing car traffic around the area to further its effectiveness in reducing pollution while capturing rainwater. Currently, the most promising plan is to eliminate the above ground traffic completely by taking the road over the Ladegård and moving it underground. Essentially, this would mean that the Ladegård and the road paved over it (Å St. and Å Blvd) would switch places. Figure 1 shows the location of these two roads, which is the proposed location of the Daylighting Project (Google, 2014). This plan is very similar to the Big Dig, in that it aims to tunnel a road that is above ground. The major difference is that it also involves redirecting a canal so that it is on the surface. Based on the successes of the Big Dig, this ambitious project could solve several issues and become a template for other countries to use if it avoids some of the pitfalls the Big Dig had (Larsen, 2014).

2.4 Outreach and Education Efforts

In order to acquire support for the daylighting project, the group needs to build a case showing that the benefits outweigh the temporary inconveniences. For the public as a whole to understand the severity of their situation, they first need to be educated on the negative impact that cars have on the population of Nørrebro. Once the residents understand how traffic is negatively affecting their health and daily lives, the next step is to get them informed on the research findings. For the population to see the merit of the proposal, they need to be educated on the positive effects that such a project would generate.

2.4.1 Current Public Opinion

In order to determine the appropriate level education required for the residents of Nørrebro, the team first needs to gauge the residents' opinion and knowledge of the daylighting project. It is important to find out how the public feels about this issue, as this knowledge will influence how the group conducts future educational efforts. Attempting to inform the public about the benefits of daylighting will be ineffective if they do not understand the basics of daylighting.

Informing the residents in Nørrebro may not be the only thing required to get the Daylighting project on the politician's agenda. If there has been a lack of support for previous attempts at daylighting, there may be a need to reach out and have a dialogue with the district's politicians. Even with strong public support, politics often are barriers to real progress and

meaningful advancement. Such is not the case in Nørrebro, as even the "politicians are on board" (Larsen, 2014). If the majority of politicians are in favor of the project, the educational focus then has to shift onto the citizens of Nørrebro.

As a city frequently listed as one of the greenest in the world, one would expect the residents living in a district in Copenhagen to support project that would lower both air and noise pollution. A survey conducted by a group studying a specific road in Nørrebro found that the majority of people prefer an option that lowers pollution, even if it involves construction (Bunch-Nielsen et al., 2012). Since past efforts in daylighting projects have been cut due to lack of funding (Copenhagen, 2008), there is a need to promote awareness about the benefits of such a project in order to increase support.

2.4.2 Education on Environmental Issues

The people of Nørrebro know that they live in an area with increased noise and air pollution, but the majority of the residents do not actually have a grasp on the dangers associated with their current levels of pollution (Larsen, 2014). In order to have a discussion with the residents about the current risk to health and the potential to remedy the problem with a daylighting project, there needs to be an effort made to inform the community on the issue. The process of educating a group on environmental health risks is one that may require a different approach than other hazardous risks. It requires building higher levels of trust and cooperation between the community and decision makers, any attempt at changing how the community interacts with the environment has to deal with numerous preconceived notions and deep-rooted biases that may have been around for years. In order to persuade people to have a new perspective on something that they regularly experience, one must make a convincing argument in favor of the change.

The first part in the risk communication process is to gauge what the residents in the targeted area know about the issue at hand. There should be an effort to use a variety of methods in order to obtain a thorough understanding of the situation. To reach a broad group of people, it is necessary to use all resources at hand; surveys, interviews, and focus groups are just a few of many techniques to gain understanding on what the public knows and where they stand regarding an issue. Figuring out the potential differences in mindset between groups of people allows one to focus the efforts where it would be most effective. Though one may initiate the process of

understanding the public's sentiment, it should be a two-way street. While gathering information to find out what the public does not know is the main goal, it is also an opportunity for the public to teach the educators. Oftentimes there could be "unknown unknowns" that could come into play, and by allowing the groups to ask questions, it is possible to gain insight into area-specific problems that may only be apparent to residents(Council, 2011).

The second part of engaging the community is to involve them in discussions about the risk they face. It is important to reach out and educate key members of the community during these discussions, as they will act as catalysts in the process of educating the whole community. Since there should be an established baseline on where the general population stands, these discussions should be steered toward the topic on which the group wishes to inform people (Council, 2011).

Though the discussion phase should never cease during the education of the environmental risk, the next stage is to develop a clear message and to get the message out to the target population in as quick and efficient method as possible. To get the message out efficiently there has to be a look at important resources that are readily available to use. Oftentimes local media, local businesses, and community leaders are the best way to have the informational message reach large numbers. The intended message should include a multitude of information, but most importantly a description of the risk, the consequences of that risk, and the ability to change the consequences with the proposed solution (Council, 2011).

2.5 Sign Design

There are various types of communication platforms; each one has specific strengths and weaknesses. Miljøpunkt Nørrebro wishes to use a sign in conveying the noise and air pollution levels in Nørrebro. Signs and displays are the universal visual medium to present information, and the right sign can be more effective than any other form of communication. A sign acts as a point of interest to get people talking about the pollution situation in the city, and how the daylighting could help fix the problem.

2.5.1 Sign Design in Europe

Developing a universally understood sign is not a trivial task. As part of the European Union, Denmark shares many elements of its signage with the majority of European countries. While most of the mandated signs are for traffic and for workplace safety, the universally known

pictures and symbols can be a tool to convey health risks. There are four different classes of safety signs and signals in Europe, each one informing or instructing different things. From Table 1 it is apparent that a sign that wishes to warn people about a risk and perhaps seek further information should be triangularly shaped and yellow or amber in color. While a sign that informs people about levels of noise and air pollutions is not under regulations set by the European Union, having the signage be instantly recognizable as a warning sign, an example of which is shown in Figure 2, can be extremely valuable in the sign's ability to get people's attention (*Safety Signs and Signals*, 2009).

Colour	***Meaning or purpose***	***Instructions and information***
Red	Prohibition sign	Dangerous behaviour
	Danger alarm	Stop, shutdown, emergency cut out devices, Evacuate
	Fire-fighting equipment	Identification and location
Yellow or Amber	Warning sign	Be careful, take precautions
		Examine
Blue	Mandatory sign	Specific behaviour or action
		Wear personal protective equipment
Green	Emergency escape, first aid sign	Doors, exits routes, equipment, facilities
	No danger	Return to normal

Table 1: Chart displaying the significance of colors in signs (Safety Signs and Signals, 2009)

(ii) **warning sign** – a sign giving warning of a hazard or danger (eg 'danger: electricity');

Figure 2: Example of a warning sign (Safety Signs and Signals, 2009)

2.5.2 Dynamic Sign Design

Signs that provide real time information are much more complex and expensive to design and build than a standard symbolic sign. Since these signs are more costly to implement there must be a positive aspect that heavily outweighs the inevitable costs. The ability to get a person's attention and have them digest the information often tips the scale in favor of dynamic signage. The parties that use this type of sign are seeking the ability to really catch people's attention and not just have their eyes gloss over the presented information. Such is the reason that the main use of dynamic signage is in advertising. While a sign to inform the public of Nørrebro about noise and air pollution is not going to sell any products, it is trying to sell the idea that there is a solution to the high pollutant levels, e.g., the daylighting project.

2.5.2.1 Dynamic Signs Case Study: Roosevelt Field Mall

When someone first introduces a dynamic sign into an environment where there was none previously, the people that frequent the area have the greatest probability of noticing the sign and taking in the message. While not an exact match, there can be many parallels drawn between new pieces of signage which were installed in Roosevelt Field Mall, located just east of New York, New York, and any other instance of dynamic signs being introduced into a previously barren area (Rose & Williams, 2004).

The researchers that studied the effect of dynamic signs in the mall questioned people about the impact the signs had on the shopping environment. The group took special care in recording age and the frequency in which a person shopped at the mall, a "frequent shopper" was a person that had been to the mall more than ten times in the past three months. Nearly 90% of shoppers noticed the new digital displays, while approximately 80% had actually watched the displayed programming. Both of those statistics also improved while looking at the tendencies of frequent shoppers (Rose & Williams, 2004).

The ability to catch people's attention and actually get them to spend time looking at the sign is invaluable when trying to get people informed and talking about a topic. The residents of Copenhagen would be "frequent passersby" for a dynamic signage, and should notice and digest the displayed information.

2.6 Summary

The root of the problem that our project aims to solve is that the pollution in Nørrebro is greater than it is elsewhere in Denmark. The pollution comes from the high levels of traffic that pass through Nørrebro on a daily basis. This noise and air pollution has a negative effect on the health of those who live in the general vicinity of a number of large roads that run through Nørrebro. Although things like sound barriers and various plants can diminish the effects of noise pollution, the only significant reduction in air pollution would be through relocation of the road. There is currently an active effort to gain support for a project that would bring a previously covered river above ground, creating green space, and move the preexisting road underground into a tunnel, significantly reducing or eliminating air and noise pollution in the area. The project sponsor, Miljøpunkt Nørrebro, wants to secure long-term support for the project by making two items apparent: that the air pollution in the area is detrimental to a point where people need to take action for the good of the public health, and that this is the best solution to the problem. The project group has been and will continue to compile research regarding the effect projects similar to the proposed project have had on the pollution and health of surrounding areas in order to form an argument in support of the project. The group will also create a dynamic sign that effectively relays information about the current pollution situation to the residents and commuters in the area in order to gain public support for a project that would remedy the situation.

3.0 METHODOLOGY

The ultimate goal of this project is to help Miljøpunkt Nørrebro gain long-lasting public support for the Ladegård Daylighting project by both providing evidence of the benefits of similar projects and spreading awareness about the negative health effects of noise and air pollution caused by the unusually high automobile traffic in Nørrebro.

Our team will be working on this project from March 17, 2014 through May 6, 2014. We plan to have two end products resulting from our project: the research case study supporting the assumed benefits of the Ladegård Daylighting Project and an eye-catching sign highlighting the pollution problem in Nørrebro. Our goal is to have a compiled set of research that Miljøpunkt Nørrebro can use to gain support for the project by the time we depart from Copenhagen. We are

also going to be presenting Miljøpunkt Nørrebro with a prototype of an educational sign that they can use to create an actual sign to install in Nørrebro after we leave.

In order to execute our project, our team plans to complete the objectives listed below, and Table 2 shows our proposed timeline to meet them.

- To build a comprehensive research case supporting the Ladegård Daylighting project by providing concrete evidence of the benefits associated with the project
- To make the current state of pollution in Nørrebro visible by creating a dynamic sign to be installed in the area

Task	Week							
	Prep	1	2	3	4	5	6	7
1. Research similar projects								
2. Analyze and summarize research								
3. Apply research to our specific project								
4. Compile Research Report for Sponsor								
5. Create Research Presentation for Sponsor								
6. Research types of signage								
7. Conduct Pre-Focus Group Surveys								
8. Create multiple sign mockups								
9. Evaluate sign options with focus groups								
10. Select and create mock up of best sign								
11. Finish project report								
12. Present research case and proposed sign to sponsor								

Table 2: Gantt chart of Project Timeline

The rest of this chapter will go into more detail about our team's plan for completing both goals. First, we will define the overall study area and scope of the project. The next section will describe the steps that we plan to take in order build the research case. We will conclude this

chapter with an explanation of how we are going to go about creating an illustrative pollution sign.

3.1 Study Area

Before coming to Denmark, our group did background research on the history behind the traffic situation in Nørrebro. In our background, we researched key topics relating to the project, such as:

- A history of the unusually high amount of traffic in Nørrebro
- The comparatively low amount of green space in Nørrebro
- The general demographics of Nørrebro

The map below shows the district of Nørrebro, the area in which we will be working

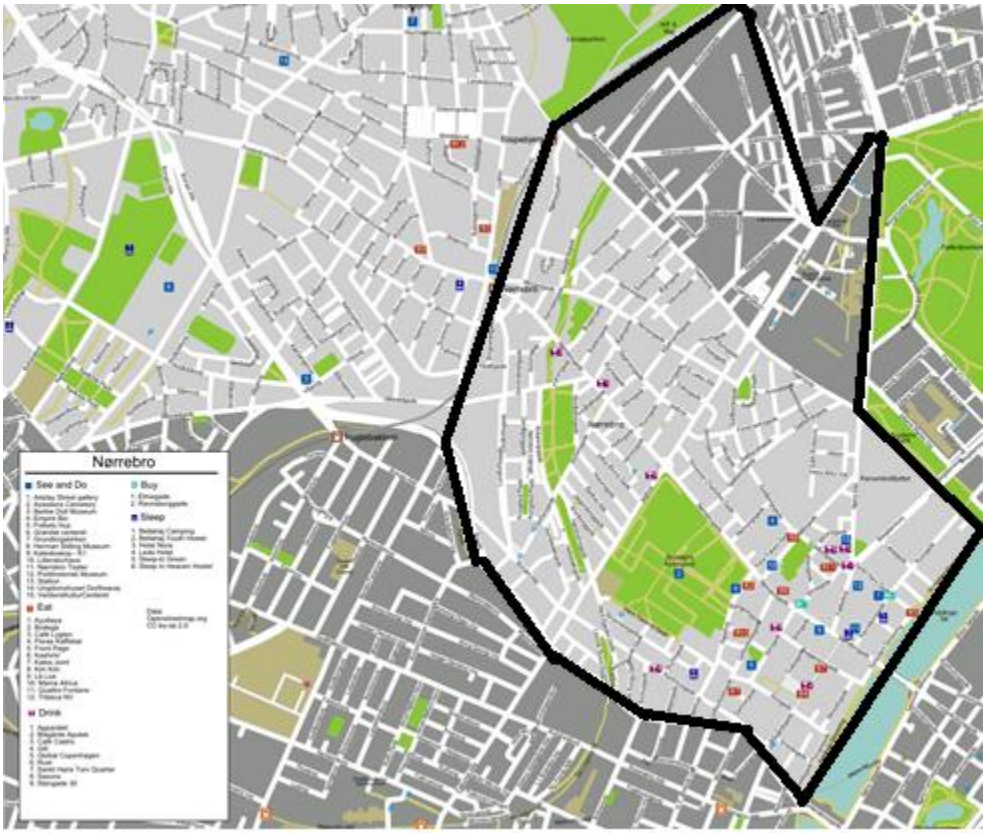

Figure 3: Map of Nørrebro("File:Norrebro map.png - Wikimedia Commons," 2009)

3.1.1 Study Participants

Our research showed that a large part of the traffic problem in Nørrebro comes from outside of the district in the form of commuters who travel through Nørrebro to get to other parts

of Copenhagen. The input of those travelling through Nørrebro regarding their opinion of the project's impact on travel conditions is also important, as car ownership amongst the residents of Nørrebro is the lowest in all of Copenhagen therefore they will face less travel disruption during the construction process.

The different groups we need to focus on include the residents of Nørrebro, as they are the ones who will have to see the sign on an everyday basis and who the information effects most, and the commuters that use Nørrebro to travel through regularly. There will naturally be some variation within the people we choose to represent each of our key groups, but our chosen strategy should get enough of a conversation going that we can get a sense of what the general population's feedback would be. Therefore, for the community feedback portion of our project, we need to focus on getting the feedback of two main groups of people.

3.1.1.1 Determining How to Obtain Community Feedback

In order to gauge the effectiveness of the various communication platform mock-ups that our group produces so that we may eventually pick a final design, we need to gather input from the different groups that we will show to the sign. We outline different methods of obtaining information from the sample groups in our background chapter. After eliminating the methods that are irrelevant or impractical for our project, our group narrowed down our choices to interviews, surveys, and focus groups.

Interviews are appropriate because we need wide ranges of opinions in order to cover all of the groups in the sample space. They are a quick way to get a good amount of information from a wide variety of people about a specific topic. Though we could potentially gather a lot of valuable information, the information would likely be from a small sample size based on estimates from previous groups and our sponsor about the response level we would see from those we approach. In our case, since there only a few different groups of people whose input is valuable and because we want to gauge the interest of the community as a whole, interviews are not an appropriate choice.

Surveys can theoretically sample a space, which statistically represents the whole population, making them appropriate for the sample spaces we plan on considering. The data gathered from a survey can help model the community response to a proposal, which would help our group to predict the way the community will respond to the different proposed signs. The

communication aspect of surveys is very limited, though; there is minimal discussion and interaction between the group and the subjects, making it difficult to take suggestions on ways to improve the designs. Our sponsor advises that the group use surveys as a preliminary way of reaching out to the community and getting feedback regarding the public's knowledge about the daylighting project more than feedback on the signs specifically. Through our surveying, we can get answers to some basic questions to help us during our further research and find potential participants in the focus groups we aim to hold later on regarding our sign design.

Our group plans to hold a focus group later on in the project, once we have some relatively well-developed mock ups for sign designs. Focus groups tend to contain similar types of people and aim to create an open discussion, which is what we are seeking to create in order to receive the most productive feedback. As our sample space is going to primarily contain two types of people, commuters and Nørrebro residents, having focus groups with similar minded people allows us to open a discussion regarding our sign with the types of people who will see it on a regular basis. We expect the people who live in the area to have a different opinion about the sign than those who simply drive by it on a regular basis and because of this, it is important that we consider these two groups of people separately.

By first handing out random surveys about our project to pedestrians along a road, we can get the answers to some very basic questions about the public's current knowledge and opinion regarding both the current proposed daylighting project and the pollution levels in the area. Included in our survey, we will have an area where those we survey can choose to leave their email to allow us to reach out to them regarding their interest in participating in focus groups. Once we gather enough participants for a focus group, we can move on to conducting focus groups regarding our sign design. The paper discusses more information regarding the strategy used during focus groups later in this section.

3.1.2 Study Location

There will be different locations of study relating to the different parts of our project. Our group will mainly complete our preliminary research about similar projects on campus and in the Miljøpunkt Nørrebro office. Once we have gathered enough information to talk confidently to the public about the project, we will begin conducting surveys. The surveys we conduct will mainly be in the area around the road we focus on within Nørrebro. We want to obtain input

from both the people who use the road every day and the people who live in the immediate area. The group will potentially travel to other areas within Copenhagen where there is a large amount of congestion to get feedback from the locals regarding their opinion of car traffic and its effects on everyday life.

Our group will work on the sign mainly within the office. We need to research different methods for creating effective signage and develop mock ups, which is all work that requires a formal setting. Once we move on to testing of our prototypes, we will have to come up with a location at which to hold our focus groups. We plan to explore Copenhagen and observe any existing dynamic signs in use. We will take note of signs that are particularly eye-catching, and we will pay special attention to those that display real-time information.

3.2 Developing a Research Case for the Ladegård Daylighting Project

The key to approving any public works project is gaining the public's confidence. For the public to be confident in anything there needs to be comprehensive evidence of past attempts that have been successful. The only complete tunneling of an existing roadway is the Big Dig; a Big Dig type project has multiple components involved, all of which we will study in isolation and then compile into a report and a presentation for politicians and potential sponsors.

3.2.1 Compiling a Benefits Report

The daylighting of the Ladegård involves redirecting the canal to the surface, taking the major roadway paved over it, move it to a tunnel below ground, and reserve the surface above the tunnel for green space around the canal. The following are aspects that we can examine individually to compile a case study:

- Major roadways above ground and the associated pollution
- Underground roadways and the associated pollution
- Green space above tunnels
- Pollution from construction

The goal is to create a report that effectively shows the long-term benefits vs. the short-term cost of tunneling Ågade and Åboulevard. So far, we have completed most of the research although there is always room for more research. We will be going through several other studies conducted on prior projects about the previously listed topics. There are studies about the air

pollution around specific highways, the increase in local pollution due to construction of roadways, problems in landscaping during construction of tunnels, the effects of green space built over a tunnel, noise pollution inside and outside tunnels near the openings, and other topics. By getting multiple studies concerning each of these aspects, all of which are involved in the daylighting project, we will have concrete, quantitative and qualitative data that will help us predict the long-term benefits and short-term costs of commencing the infrastructural renovation in Nørrebro. A complete annotated bibliography can be found in Appendix C.

While in Copenhagen, we will be writing the report under supervision of our project's sponsor. Miljøpunkt Nørrebro has allocated 1 million kroner (approx. $184,000 USD) from various public and private sponsors towards exploratory funding for two years (500,000 kroner each year) to research the feasibility of the project. We need to figure out the results of this research and first summarize that. By getting a picture of what Miljøpunkt Nørrebro has already accomplished, we can figure out where to go. For one week, we will be contacting the individuals involved in the research and compile any data they have come up with. Some of this data may be crucial; some of it may be irrelevant. We will filter through it, and create a document that contains only the relevant, useful data.

After fully reading through and understanding the results of any research already done, we will be able to apply the research we have already completed on other examples of infrastructure. What compiling the final report will involve is going through the short-term costs and long-term benefits from examples of items in the bulleted list above, and any data gathered from local research backed by the 1 million kroner. We will then combine the two in a cohesive argument that roughly predicts what the costs and benefits of this specific project will be, in terms of pollution.

3.2.2 Preparing a Presentation

While a report will be useful in being a necessary summary of the construction project as it stands now, there are better methods for presenting a quick argument to a politician or potential sponsor. For this, we will need to create a short yet effective presentation that runs through the various details and arguments made in the report. It needs to be clear and concise, but still provide thorough information. We will take much of the quantitative data and very briefly summarize it, focusing mostly on the big picture, the problem, the goal, and the solution.

The biggest challenge will be creating a presentation that will appeal to a Danish taste. There may be cultural differences that we are simply not aware of, or differences in the professional environment of Copenhagen. For example, using first names is more common in a Danish workplace than in the U.S. Much of the guidance on cultural context will come from our project's sponsor, Ove Larsen of Miljøpunkt Nørrebro.

Our group has not yet decided on the exact type of presentation. It may be a PowerPoint that our sponsor can present and then email to those who need the information for reference. It may be a series of posters that relies more on the presenter speaking and less on the visuals. There may be multiple presentations that vary dependent on who the audience is (specific politicians/sponsors). Again, we will discuss these details with Mr. Larsen upon arriving in Copenhagen.

3.3 Create a Dynamic Sign

After we build a case for why air pollution is a problem in Nørrebro and research its resulting risks, we will have to design a display to make both apparent to the public. In order to do this we will be using a sign with dynamic elements to make sure it does not fade into the background of people's day-to-day lives. There are multitudes of different aspects that we will have to take into account while designing mock-ups of our display, and in order to have a successful end product we will have to consider each one.

3.3.1 Conducting Pre-Focus Group Surveys

Before work can begin on designing a sign, our team would like to know what type of information the people of Copenhagen would like to see displayed, and their preferred method of display. Our group has decided to survey people on the street in order to gather this information. We are also hoping to use the people that we survey as the main pool of people for the focus groups that we will conduct later on in the project.

Our team has chosen this survey method for multiple reasons. By surveying people in person, we can ensure that they fully understand each question in the survey and that they completely answer each question. There is also a higher response rate associated with in-person surveys than with other methods, such as mailings or on-line surveys. We will also be able to show examples to go along with our questions. For example, our group plans to ask questions about what type of signs people like better, and we will be able to provide the respondents with

pictures of different signs to examine. We will also be able to ask people for their contact information to later contact them about attending a focus group for examining mockup signs (Charnwood, n. d.).

In order to conduct a survey effectively, we must first do the following:

1. Design the survey
2. Select what areas and times we will complete the survey
3. Decide on how we will approach people when we are surveying
4. Analyze the data gathered

In designing the survey, our group must decide on what information we would like to gather from the participants. We plan to gather information on both what people know about the current state of pollution in Nørrebro and what people would like to see in a sign. Potential questions topics include, what the subject thinks of the pollution levels in Nørrebro, what types of information they would like to see displayed on a sign, their preferred languages, and their opinion on symbols in signs. A full list of the questions we are planning to ask is located in Appendix A.

Once we finalize the survey design, our group will need to determine where we will actually go and give our survey. Our contact at Miljøpunkt Nørrebro, Ove Larsen, has told us that people will want to participate if they know that the research our group is doing will help improve Nørrebro. We will want to go to areas, both inside and outside of Nørrebro, with a large number of pedestrians who will be willing to answer our questions. We are hoping that Mr. Larsen will be able to assist us in identifying these areas, as he knows Copenhagen much better than we do.

As a group, we must decide on how will go about actually asking people to take our survey. We must consider if we will all stay as a group, or if we will split up to cover more area. We must also determine if we want to set up a table in one location and have people come up to us and complete the survey or if we want to walk up to people. We will need to make a judgment on how we present ourselves as a group, meaning we must choose if we want to dress uniformly (same type of pants and colored shirt), wear professional attire, or just dress normally. We will not be able to make any of these decisions until we arrive in Copenhagen and have the

opportunity to get a feel for the atmosphere and decide what methods would be the most appropriate.

After we conduct our surveys, we will need to compile and analyze the information we received. While our exact analytical methods will depend on the diversity of the information that we obtain, we will most likely create tables and bar graphs displaying the responses to each question. We will use these results to determine what the most important pieces of information to include in the mockup sign options will be. The responses will also allow us to gain an understanding of what the people of Copenhagen would like to see in the design of a pollution awareness sign, which will further aid us in creating the mockups. We are hoping to obtain valuable feedback on if the use of language and real time pollution data in the potential designs.

3.3.2 Design of Mockups

We will be spending our first three weeks of time with Miljøpunkt Nørrebro creating several mockups of different types of dynamic signs. In order to have an outstanding final sign we want to have multiple options from which to choose. There are many different ways to dynamically display the information we wish to present to the public, and having several options on the table will result in a better end product. While in Copenhagen, we will create our mockups using the following background information:

- The use of words and symbols in signage to send an easily understandable message
- The feasibility of dynamic signs in displaying air and noise pollution for Miljøpunkt Nørrebro

It is critical for us to have a thorough understanding of both research points and how they apply to our situation in order to create mockups that are both universally understood and feasible for our sponsor to transition into a final product. We will also have to consider our sponsor's operational limiters for the final design, understanding what Miljøpunkt Nørrebro is able fund or install will ensure that our sponsor's get what they want.

3.3.3 Conducting Focus Groups

In holding focus groups, our team's goal is to gain insight into how the public feels about the mockup signs we will be creating. We plan on to have at least three different options for the focus groups participants to study and comment on. As previously mentioned, our main pool of

people that we will be contacting to participate in the focus groups will be the people who participated in our surveys, as they will have already indicated their willingness to participate and have a vested interest in the project. We will try to have separate groups of six to eight people who both live in Nørrebro and who just commute through the district, in order to know the opinions of all the people effected by our project (Krueger, Casey, Donner, Kirsch, & Maack, 2001).

Before we hold the focus groups, we must complete the sub-tasks listed below:

1. Choose the time and location for the meetings
2. Decided on how the focus groups will be run and organized
3. Select the main questions to ask the participants
4. Determine how we will incorporate the participant information into the selection of our final design

Currently, we would like to hold the focus groups at the Miljøpunkt Nørrebro office, but since we have not seen the space, we will not know if that is feasible until we arrive in Copenhagen. Our group must also take into consideration where the most convenient and comfortable location would be for our participants. It would be easy for a Nørrebro resident to come to the Miljøpunkt Nørrebro, or somewhere else in Nørrebro, but for a commuter who just drives through the district on their way to work, it would be better if we held the meeting somewhere near their office if possible. We will also need to choose a date and time to have the focus groups. In selecting a time, we must be considerate of working with the participants schedules to allow for maximum attendance (Krueger et al., 2001).

As a group, we will be figuring out how we want to structure the focus groups. We will choose a discussion moderator, who will be the member who is most comfortable talking in front of a group and guiding a discussion. We will need to decide if we want an assistant moderator as well, and if we choose to have one, what their job function would be. A secretary must also be selected, and this will be the one of us has the best note taking abilities. We will need to determine if and how we would like to record the discussion so that we can go over it later and pick up anything that the secretary missed. We need to determine an appropriate focus group size as well. Ideally, we would have between six and eight participants in each group, but this could change based on the space where we hold them. We will also try to have four separate groups of

each group type (Nørrebro resident and commuters who drive through Nørrebro) in order to get the opinions of multiple people. We need to decide on how we want to present the mockups to the participants. We think that we will show them each design one by one, have a conversation about each one, and then display them as a group so that they can better determine if there is a preferred option. We will also need to decide which order to present the mockups to the participants in when we show them individually, but we will be unable to determine that until our group completes the mockups (Krueger et al., 2001).

Our group also needs to create the main questions to lead each focus group discussion. We will bring out each sign mockup one at a time and ask for their feedback on each sign. We will then display all the mockups at once and ask each group about what their favorite is, and what location for the sign they think will get the most impact. Appendix B lists all of our proposed starting questions, and depending on how the discussions go, we will be asking more detailed follow up questions, but we will not know what those are until we are in the focus groups (Morgan, 1996).

Once we have conducted all of the focus groups, we will need to compile the information we have received from the participants. We take the condensed information and see if there are any prevalent themes in the responses. For example, if a majority liked one sign over the rest, if multiple people suggest similar changes, etc. After establishing the overarching suggestions obtained from the focus group responses, we will move on to selecting a final design for the sign, where we incorporate this feedback (Krueger et al., 2001; Morgan, 1996).

3.3.4 Selection of Final Design

After we come up with several prototypes, we will have to narrow down our selection to our final mockup and proceed to make a prototype to present to our sponsor. We will work with focus groups to assess the public's reaction and sentiment to each of our potential mockups. The work with small groups of residents will give us insight into the minds of the average resident of Copenhagen, and what we learn will most definitely shape the selection of our chosen mockup. We will take the input of the focus groups, select our final design, and then make any improvements to it suggested by the focus groups.

3.3.5 Presenting to Sponsor

After we have narrowed down our choices and made a prototype from our mockup, we will present our dynamic sign to our sponsor. We hope to present a sign that is universally understandable and has the proper dynamic properties to become a talking point, something that will not just become part of the background to people's daily lives. The creation and implementation our dynamic signage will help Miljøpunkt Nørrebro show the people of both Nørrebro and Copenhagen as a whole the dangers of noise and air pollution, and get them interested in the benefits of the daylighting project.

APPENDIX A: PROPOSED SURVEY QUESTIONS

1. What do you think of the levels of air pollution in Nørrebro?
2. What do you think of the levels of noise pollution in Nørrebro?
3. How do you feel about the level of pollution where you live from 1-10, where 1 is perfectly clean air, free of pollutants, and 10 is highly polluted, almost unbreathable air
4. How would you rate Copenhagen's efforts in reducing pollution?
5. Have you heard of the Ladegård Daylighting project?
    a. If so, do you have any opinions about it?
6. Would you be interested in participating in a focus group about displaying pollution levels around Nørrebro?
    a. Can you please provide us with your name, email, phone number and your preferred method of contact?

APPENDIX B: PROPOSED FOCUS GROUP QUESTIONS

For each design:

1. What are your thoughts on this design?
2. What do you like about this design?
3. What do you not like about this design?
4. Is there anything you would change about this design?
5. Who do you think is most likely to notice this design?

For all designs at once:

1. Which one of these designs most clearly shows that the level of pollution is high?
2. Which design did you like the most?
3. Which design did you like the least?
4. What would be a good location for a sign of this type?

APPENDIX C: ANNOTATED BIBLIOGRAPHY FOR RESEARCH CASE

Air quality guidance note - Construction Sites. from http://www.environment.nsw.gov.au/resources/air/mod3p3construc07268.pdf

- Pollution from demolition can be controlled with water sprays and paying attention to strength and direction of wind
- Filtration systems to control pollution from sanding, grinding, and welding
- Enclose and properly cover all solid and liquid waste
- Diesel engine exhaust managed by properly maintaining engines, catalytic converters, and limiting idle time
- Remove all asbestos carefully before any deconstruction begins
- Screen area periodically to remove pollution and particulate matter

Belivacqua, M. (2014). End of the Roads: When Highway Removal Works. from http://nextcity.org/daily/entry/end-of-the-roads-when-highway-removal-works

- Removing and renovating highways can be difficult when they serve thousands of cars a day
- Possible to remove highways without drastically changing things
- Embarcadero highway destroyed in 1989 earthquake, renovated in 1991 as large boulevard with lots of walkways, plazas, trees, homes, and businesses
- Plan for Woodall Rodgers Freeway to be capped with 5.2 acres green space

Chen, Z., Li, H., Wong, C. T. C., & Love, P. E. D. (2002). Integrating construction pollution control with construction schedule: An experimental approach. *Enivornmental Management and Health, 13.2/3*, 142.

- Studied pollution around major roads in Greater Manchester and Warrington
- Industry accounts for 44% of pollution in the area, road traffic is 40%
- Pollution is collected very densely near road, much lower a short distance away

Gray, J. (2013). Pollution From Construction. from

http://www.sustainablebuild.co.uk/pollutionfromconstruction.html

- Construction dust is PM10 (particulate matter, less than 10 microns in diameter)
- PM10 comes from dust during excavation as well as diesel vehicle exhaust
- Lots of respiratory illnesses, cancer, bronchitis, asthma
- Noxious fumes from various chemicals used on construction sites mix with pollutants
- All of this pollution also goes into ground water
- Ground water much more difficult to treat than surface water
- Heavy noise pollution from construction equipment, vehicles, workers shouting and playing music
- Fine water spraying of land can keep soil from dusting up and polluting air
- Use fine mesh screening to prevent dust from spreading outside construction site
- Rubble should be covered, spillage should be regularly checked for to prevent anything from running off into ground water
- Use non-toxic chemicals whenever possible, keep a check on all possible sources of contamination
- Use low sulphur diesel oil in all vehicles

Havlick, D. (2002). Removing Roads. ***Conservation - The Source for Environmental Intelligence*****.**

- Mike Sanders, removing roads from Redwood National Park since 1995
- Science and engineering only used to improve construction
- Recently gone into studying long term effects of roads on ecology
- Redwood National Park reserved in 1968 by Congress to preserve some of the tallest trees in the world
- Doubled in 1978, though the extra land added had mostly been logged and had roads built to transport lumber
- $33 million road removal allocated for 300km of road
- Leaves soil very loose and difficult, always leaves some debris that gets into crossing streams
- Cost $750k to remove 2.5k road, 150k m^3 of soil

- Rain during road removal destroyed already soft soil
- Difficult to keep land from shifting around and causing damage, but landscaping it is a breeze

ITDP. (2014). The Life and Death of Urban Highways. from https://go.itdp.org/display/live/The+Life+and+Death+of+Urban+Highways

- US cities built highways in 40's and 50's to compete with clean and clear roadways of suburbs
- Had poor impact on communities
- Jane Jacobs brought displaced communities, environmental degradation, and severing of communities through poor land use in 1961, all unintended consequences
- Increased economic growth but physically and environmentally destroyed communities
- Many cities are finding that it is better to tear down highways or turn them into boulevards

Peace, H., Owem, B., & Raper, D. W. (2008). Air Quality in and Around Traddic Tunnels. from http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/eh42.pdf

- Page 84
- Lots of very concrete, quantitative data on tunnels

Peace, H., Owen, B., & Raper, D. W. (2004). Identifying the contribution of different urban highway air pollution sources. *Volumes 334–335,* 347–357. doi: 10.1016/j.scitotenv.2004.04.057

- Provides a method of scheduling construction to optimize construction time while lowering pollution
- Need to take several factors into account such as Construction Pollution Index (CPI), biological thresholds for noise and air pollution, and factors of a genetic algorithm

- Before use of scheduling algorithm, there were multiple weeks of unhealthy levels of pollution
- After scheduling algorithm, it always stayed at a tolerable level, and only added two weeks of construction time to a 20-week project
- Instead of a week of zero activity, reduce activity on certain weeks and don't take break weeks
- Move specific high-pollution activities as far away from each other as possible so as to allow pollution to disperse or be filtered out and not build up

Vernick, C. (2009). The Big Dig: new greenspace for The City of Boston. from https://courses.cit.cornell.edu/crp384/2009reports/Vernick_New%20Green%20Spae%20for%20Boston.pdf

- Poorly planned, went billions of dollars overbudget
- Central Artery destroyed 900 businesses, 100 residences
- 10 hour traffic jams
- Created room for multiple green spaces
- Rose Kennedy Greenway 26 acres of new green space
- Spectacle Island 105 acre area created entirely by land dug out of Boston for Big Dig
- West Roxbury Millennium Park created from capping landfill with land dug out for Big Dig, 100 acres

Zhou, X., & Rana, M. M. P. (2012). Social benefits of urban green space: A conceptual framework of valuation and accessibility measurements. *Management of Environmental Quality: An International Journal*. doi: 10.1108/14777831211204921

- Green space refreshes people by increasing contact with nature
- Gives people great aesthetic enjoyment due to its changing beauty
- Promotes recreation and physical health while relieving mental and physical stress
- Green settings can lower blood pressure and risk of cardiovascular disease
- Reduces particulate and noise pollution, collects rainwater, creates microclimate

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