BACHELOR THESIS

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Electrical buses related to Pedestrian and cyclist safety

rijksuniversiteit groningen

Jordi van Kleef, s2976730

Supervisor: Efstatios Margaritis

Rijksuniversiteit Groningen

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Abstract

This study investigates how people in Groningen, especially pedestrians and cyclists, perceive the electric buses that are driving through the city. The research first points out that the silence of electrical vehicles, especially at low speed, can be dangerous for non-motorized road users and poses the question whether this influences the perception of electric buses in Groningen. Eight important locations along the electrified bus lines within Groningen, specific points where sight distances may not be optimal, were presented as a focus point of the study. Over 50 respondents in and around Groningen were presented with a survey in which they had to answer some questions about the importance of sound in traffic and assess the visibility and the security of each of the locations. The results were submitted to statistical analysis and tried for significant differences between groups of respondents as well as for significant correlations between the importance they gave to sound and to electrical vehicles and the grades they assigned to the locations. The major conclusion of the study is that there are three target groups that are particularly affected and worried by the silence of electrical buses. The first group consists of the female respondents. While they are not necessarily affected or worried as compared to the two other groups, the comparison to male respondents does lead to the conclusion that ladies are much more worried about traffic safety than men tend to be. The second group consists of people who rely more heavily on sound when moving through traffic. These people report to be much more worried about silent vehicles in general. Lastly, there are the elderly people. There are several reasons to suggest that older people are warier of silent vehicles. These reasons can be found in earlier research but also in the results of this study. The data of this survey however was not representative (enough) for elderly people which means that this study does not give any definite proof of their worries, but there are serious hints towards the issue this group of respondents may have and further research on them is recommended.

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Introduction

1.1 Background

European transport is 94% dependent on oil, of which 84.3% is imported, and faces increasing fuel supply insecurity as oil comes from increasingly unstable regions of the world, and a high and rising oil import bill (€ 1 billion per day in 2011) which causes a deficit in the balance of trade (around 2.5% of GDP). In order to solve these problems, In the Transport 2050 Strategy, the European commission proposes to halve the use of 'conventionally-fueled' cars in urban transport by 2030 and to phase them out in cities by 2050 (European Commission, 2019) alongside a number of other measures regarding different modes of transport. In practice this means that there will have to be a very large increase in share of electric vehicles.

Using electricity to power vehicles allows for a major change of energy supply towards the transport sector. Instead of a single energy source (oil), there would be a more diversified energy supply which, importantly, can be produced from much more diverse resources; thus reducing Europe's oil dependency. Moreover, electric vehicles will completely suppress local emission of polluting substances, particularly in cities. In consequence, electric vehicles are ideally suited to urban areas. (European Commission, 2019)

Over the last years, the numbers of electric cars have been steadily growing in the Netherlands. In January 2014, there were more than 4.6 thousand FEVs in the Netherlands. Over the course of five years, this has increased almost tenfold to a total number of 44 700 in 2019 (CBS, 2019).

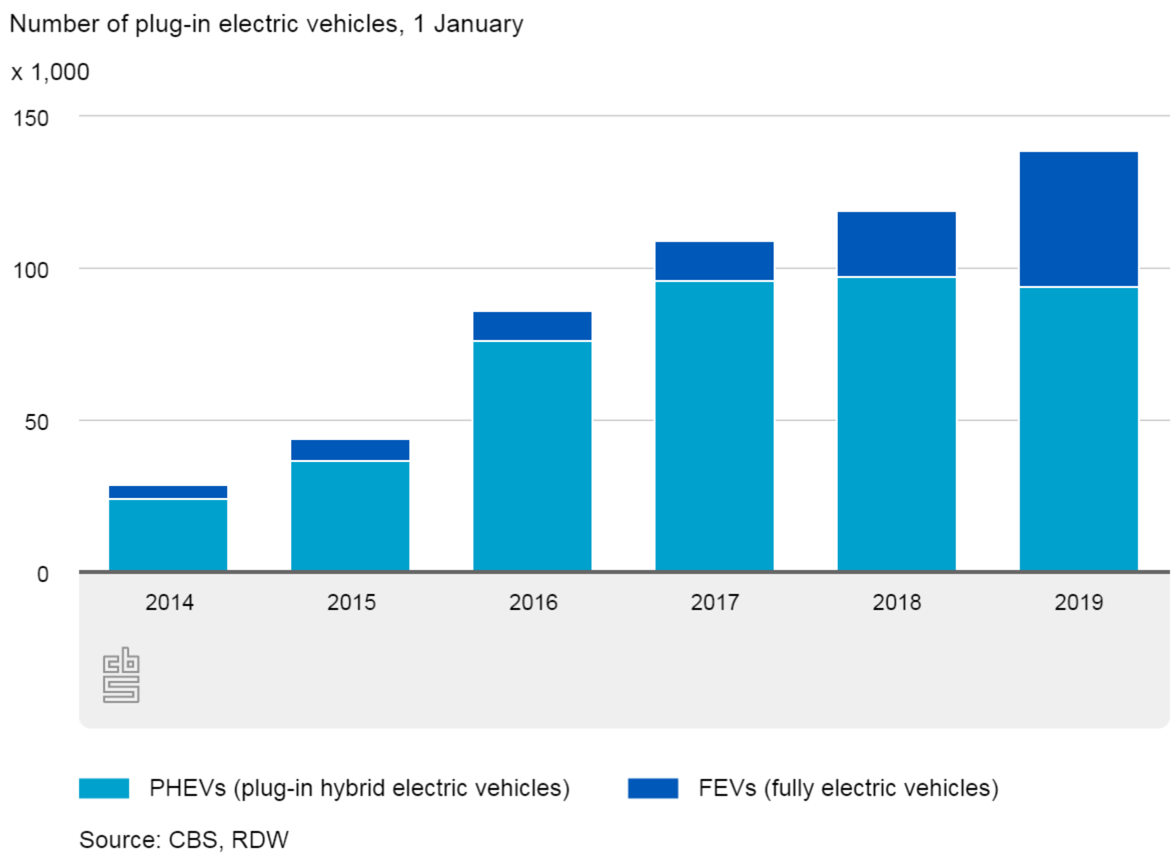

Figure 1: Numbers of hybrid and fully electrical vehicles in the Netherlands, CBS 2019

Increasing numbers of electrical vehicles are also sighted within the public sector, especially when it comes to bus-transport. Public transport in Groningen/Drenthe is pioneering with electrical vehicles: The provinces are replacing all their buses with electrical ones by December 2019 (Groninger Internet Courant, 2019). According to Newmobility news, the 164 vehicles will form the largest fleet of electrical buses in Europe (Newmobility news, 2019). Especially the city buses are affected by these transformations as those travel shorter distances and because Groningen intends to be a CO2-neutral municipality by 2035 (RVO, 2019).

However, there are some issues. For instance, Buses, require far more fuel or electricity charge than private cars typically do. Electrical propulsion offers a much shorter range than traditional fuel does however. Other problems include poor performance in steep terrain and with cold weather, lack of articulated electric buses and technically unfeasible rise in electricity demand if entire bus fleets are electrified and the great cost of charging infrastructure (Pagliaro & Meneguzzo, 2019). One more important problem is the quietness of electric vehicles.

1.2 Research Problem

The problem investigated in this paper is that, in given conditions and at low speed (10 km/h), an electrical vehicle can be detectable only from less than 5 meters whereas, in the same conditions, a traditionally fueled vehicle can be detected at a distance up to 50 meters (Pardo & Misdariis, 2018). This problem applies to both electrified cars and buses. In Groningen the problem appears to be present as well: "*Since the buses are so quiet, these buses also include a tram bell sound to alert pedestrians and bicyclists of the gigantic vehicle's approach."* (CleanTechinica, 2019). In this research we will focus specifically on buses as they drive on low speeds much more often and have more stopping moments than cars have and are also much more integrated in the Groningen traffic systems. This leads to the following question:

How do pedestrians and cyclists in Groningen perceive the quietness of electrical buses?

And sub-questions:

Is there significant difference between cyclists and pedestrians, between gender and between various age-groups?

How does visibility influence safety of (silent) electrical buses and do people more reliant on sound have more concerns about traffic security?

What is the (perceived) importance of electrical buses in traffic safety in Groningen and are people worried about the silence of electrical buses?

1.3 Theoretical Framework

This section will discuss the place of this research within broader academic context. Firstly, it stresses both the benefits and the relevance of electrically operated buses with regards to the sound environment, after which it points out the fact that there are also more negative aspects to the quietness of electrical vehicles in general and that these aspects are especially relevant when it comes to electrical buses. Finally, this section addresses the relevance of Groningen as a site to study these effects. A conceptual model has also been included in this section.

It is clear that electrical buses are an essential means to lower noise pollution within the urban environment by a significant amount. Noise reduction from electrical vehicles is significant mostly in urban environment and at low speed (under 50km/h), and buses are a large part of these traffic flows which makes them especially relevant with regards to the noise levels in cities (Campello-Vicente, 2017). Ashmead et al. (2012) conclude that, especially in urban environment and at low speed, electrical vehicles must be closer to a (blinded) pedestrian to be detected than traditional gasoline vehicles, making them potentially more dangerous.
While Sandberg et al. suggest that *"adding artificial sound to electrified vehicles would mean very little to improving possibilities to hear such vehicles when they approach a pedestrian*" (Sandberg et al. 2010), other studies (such as the studies by the NCSA and the studies by Pardo & Misdariis) have shown that, especially in urban centers which often boast high levels of noise additionally to traffic sound, electrical vehicles are often difficult to (audibly) detect for pedestrians and cyclists, with a significant difference in number of incidents between HEV (hybrid electrical vehicles) and ICE (Internal combustion engine cars) especially at intersections and during maneuvers at low speed (NCSA, 2014).

A number of studies have already been conducted on either perception of security, perception of sound levels, or visibility, all within different population groups. The three variables however were not yet put together to form a broader idea of how people perceive silent vehicles and were also not specific to buses. Two separate studies by Janoff et al. (1978) and by Vorko-Jović et al. (2006) found that visibility is a key issue in traffic security. Rifaat et al. also state the importance of sight distance when it comes to traffic security (Rifaat et al., 2012). Another study concluded that women were generally more concerned about traffic security (Andersson, 2011). One more research showed that older people do also have more concerns about traffic security (Chen and Chan, 2011). The results of this research will also be compared to these different previous studies.

The low levels of sound of electrified buses thus are both a benefit and a problem: a major conflict between quietness and safety arises (Genuit, 2013). This problem, as shown before, has been made clear by a number of earlier researches already, but further research is needed to find out how important the problem is and how it is perceived by pedestrians and cyclists in the Netherlands. A study by Wogalter et al. (2014) has investigated this in Raleigh, South Carolina and can serve as a basis for this research in that it also used a questionnaire in order to investigate this perception. Moreover, up to this point, the results have been collected for electrical vehicles in general, but not yet for buses in particular. In this research, we will focus on the perception of electrical buses' impact on safety (with emphasis on the safety problem) by pedestrians in Groningen. Groningen already has two bus lines that are fully electrified (lines 1 and 2), and buses have the particularity of stopping a lot along their lines and then starting to drive again, which mean that they have a high potential to cause safety issues in line with what Pardo & Misdariis describe in their paper. Moreover, Groningen, especially in the city center, but also at some other places along the electrified bus lines, has a lot of cyclists and pedestrians which offer ample opportunities for research.

1.4 Conceptual Model

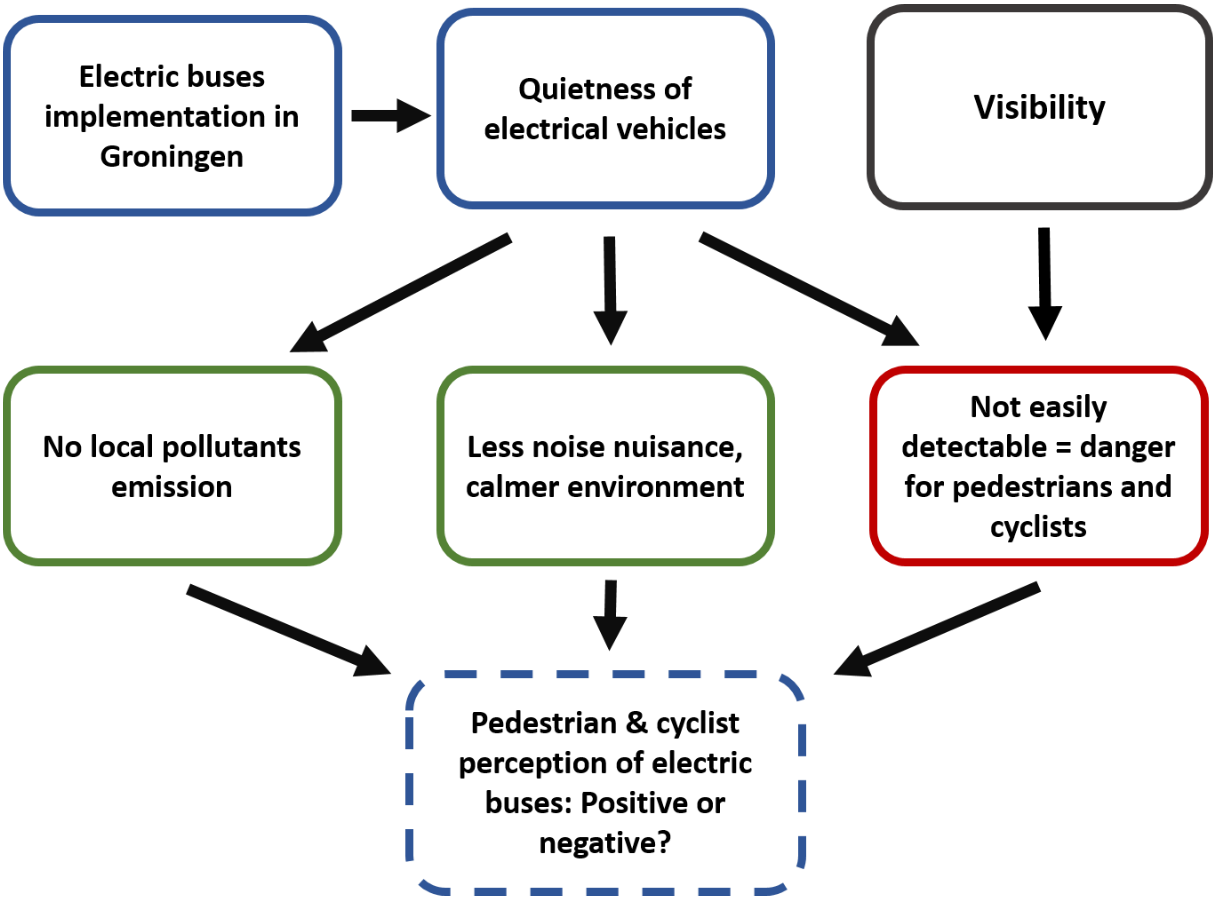

Figure 2: Conceptual model, depicts the general concepts used in this research and their relationships.

1.5 Hypothesis

The hypothesis derived from the research problem is that the quietness of electrical buses has a negative effect on pedestrian safety along the bus lines 1 and 2 in Groningen which are fully electrified at this point. Moreover, the research will investigate whether pedestrians and cyclists in Groningen have a positive or a negative perception of electric buses.

Methodology

This section describes the methods employed to gather data which answers the proposed research question. It tries to explain how the data was obtained, which tools were used and what the limitation of the employed tools have been. Then it proposes a discussion on the quality of the data that was obtained. At last, there is an explanation on the methods of analysis used to extract the relevant answers of the data.

2.1 Data Collection Method

The data collection for this research consisted of an online survey targeting pedestrians and cyclists, and asking them how they perceive electric buses with questions about both safety of electric vehicles and about the role of sound in the awareness in traffic. The survey used in Wogalter et al. (2014) has provided a basis for the questionnaire involved in this research, however with a number of modifications to adapt it to the context of this research. The questionnaire has been handed out mainly in Dutch, as the majority of the population was expected to prefer answering in Dutch rather than in English, but for some locations an English version was available. The survey contained a consent form in order to insure that every respondent was a voluntary participant.

The English version of the questionnaire is linked below and included in appendix 1.

https://docs.google.com/forms/d/1iMVSZ5IiH9BBqk5hcAnDWrb2n6hDNS3DmovaYNSoa7s/edit

Printed invitations to this questionnaire (see figure 3) have been handed out at different locations in the city, delivered in a number of mailboxes in Groningen and posted at several important locations in the city (a number of spots at Zernike Campus and several supermarkets for instance). The larger invitations contain 2 QR-codes (one for the Dutch version of the survey and one for the English version) which allow the participants to get access to the survey with their phone. The smaller invitations (which I used for manual distribution) only have the QR code which links to the survey in Dutch.

Figure 3: Invitation to online survey, own creation

2.2 Target Groups

The research investigated different target groups. First of all, the survey clearly differentiated pedestrians and cyclists. Secondly, a distinction has been made between regular cyclists and cyclists driving with e-bikes in order to search for any differences between their results. As the e-cyclists of interest are those that primarily drive within the city of Groningen, the survey was also handed out at the Thuisbezorgd office as well as different locations of both Domino's Pizza and New York Pizza where it was possible for the deliverers to fill it in themselves (without interview). Three Age-groups and gender were also differentiated and the results have been examined to find any differences between the various groups.

2.3 Locations of Interest

There are 8 points along the electrified bus lines which are of major interest for the research. All of these points are located along the shared trajectories of bus 1 and 2, or in the city center along line 1 (see figure):

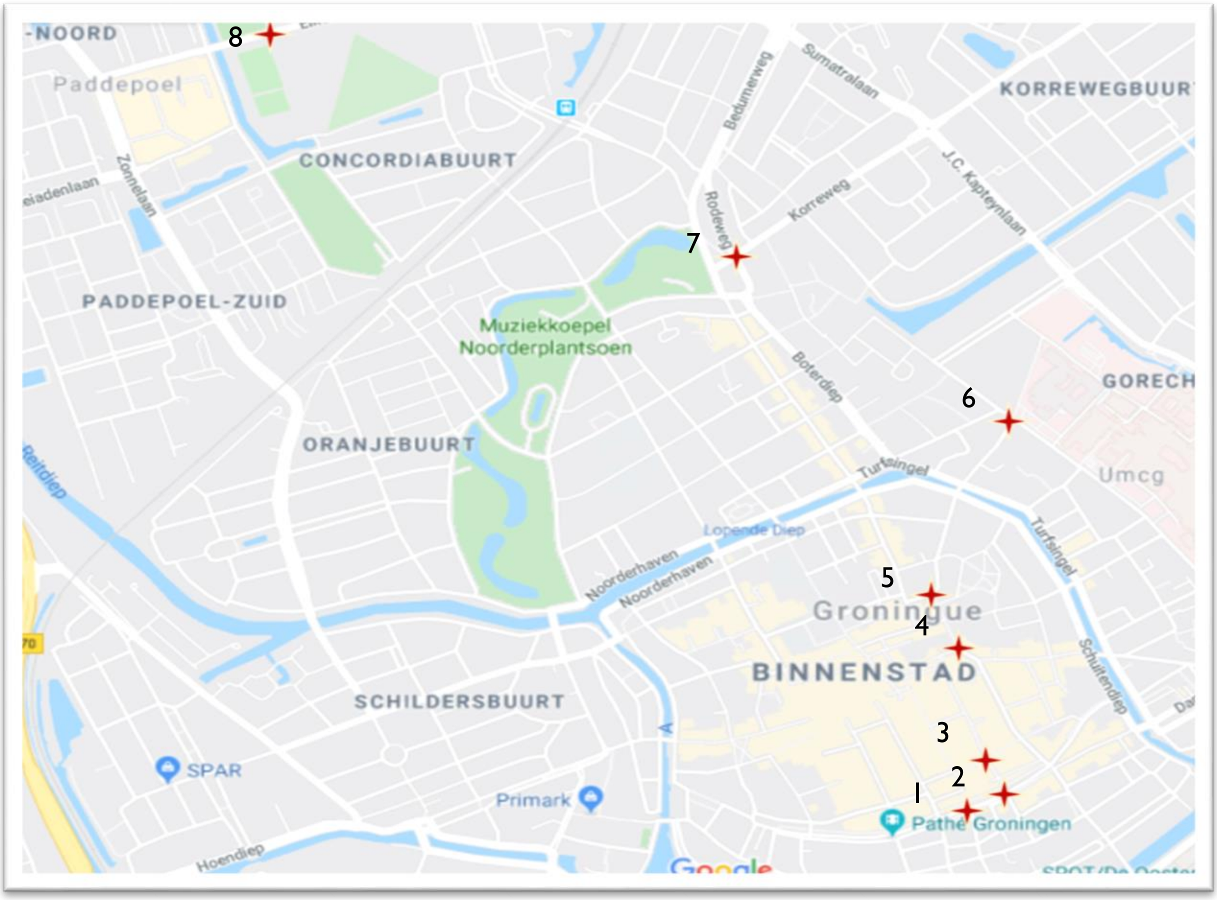

Figure 4: Map with the 8 locations of interest in Groningen, own creation

1	(the southern part of) The intersection of Zuiderdiep and Herestraat
2	The end of Gelkingestraat (on the edge of Zuiderdiep)
3	The intersection between Gelkingestraat and Carolieweg
4	Northern entrance of Oosterstraat

5 The intersection between Kwinkenplein and Kreupelstraat

6 The intersection at UMCG Noord

7 The eastern extremity of the Korreweg

8 Pedestrian and cyclist crossing in the Eikenlaan

Visibility is a prime issue when it comes to traffic accidents (Janoff et. Al, 1978). The exact points of survey have been chosen as all of them present a visibility problem to at least some degree for cyclists and pedestrians. Furthermore, Ashmead et Al. conclude that electrical vehicles must be closer to the listener (a pedestrian or cyclist crossing a road) in order to be audibly detected than gasoline vehicles (Ashmead et al., 2012). Kim et al. also conclude that, when a vehicle is turning around a corner it will be detected much later than when it is going straight on (Kim et al., in Ashmead et al., 2012). Therefor this research included a number of survey locations where the buses are turning (UMCG Noord, end of Gelkingestraat, intersection between Zuiderdiep and Herestraat) and where the pedestrian/cyclist crossings do not have traffic lights (as that limits the need for audio-perception).
Dai et al. found that pedestrian crashes are related to the build environment and occur more in road segments with strong street compactness and mixed land use and are significantly clustered in high-density zones (Dai et al., 2010). A number of the points of interest along bus line1 present mixed land use and are located in the city center of Groningen which is a high-density zone (This applies to all locations along the Korreweg, Kwinkenplein, Gelkingestraat, Oosterstraat and Zuiderdiep).
Additionally, one of the points of interest was located at the very busy cyclist (and pedestrian) crossing on the Eikenlaan which has already caused a number of accidents in the past and is a point of contestation with regards to safety (RTV Noord, 2017). The speed of the cyclists on this major bicycle path might severely limit their visibility and their capacity to oversee the crossing. Jo et al. conclude that there is a negative influence of speed on visual attention of drivers (Jo et al., 2014), which implies that cyclists can be expected to boast lower levels of visual attention than pedestrians do and in turn e-bikers would, on average, have lower levels of visual attention than regular cyclists. This makes the location on the Eikenlaan particularly interesting as it is in fact an intersection between a busy road and a very busy cyclist path where cyclists usually drive quite fast.
Respondents were to separately assess the visibility and the security of each location, giving grades between 1 and 5.

2.4 Data Collection Process

Data collection has started with the intention of interviewing about 50 persons, split (roughly) equally between cyclists and pedestrians, at every point of interest described above. Practice however learned that interviewing cyclists on said locations was close to impossible as it isn't doable to stop cyclists on their path, even at intersections. This problem became apparent already after the very first day of data collection. This called for an immediate revision of the data collection method. Instead of manually interviewing people, the option was taken to create an online questionnaire using Google Forms. The respondents were then to be linked to the formulary with printed invitations on flyers. These flyers included a QR code that, when scanned with a smartphone, linked to the online form, enabling the respondents to fill in the survey by themselves on mobile. In addition to enabling the research to reach cyclists (or at least people who were predominantly cycling their way through the city), it also made approaching people more comfortable as it would in fact not be a problem if they had no time in the immediate to respond to an interview, because they would then be able to fill in the survey at a later point in time by themselves.

Data has been gathered in various places throughout the city of Groningen. The flyers have been distributed in two different ways throughout the city, with one of the ways having been subject to variation. Firstly, around 400 flyers have been distributed in mailboxes in different parts of the city. 250 of those have been deposited in mailboxes of university staff in the Duisenberg and Mercator buildings. Another 50 flyers were distributed in the area between the city-center and the UMCG hospital. The rest has been distributed in mailboxes of homes around Paddepoel and Selwerd with the specific intent of reaching older people as these locations are inhabited predominantly by elderly people. The rate of response from this way of data-gathering has been very disappointing which has led to a change of approach.
Instead of distributing the flyers to mailboxes, it was decided to hand out the flyers manually to people at various busy locations in Groningen, while actively engaging the (potential) respondents and telling them how to fill in the questionnaire, what the survey was about and giving some additional information. A first day at Groningen Hoofdstation (central station) had encouraging results with a much higher response rate. After the central station, flyers were handed out the same way at the Paddepoel commercial center but, while a good number of flyers were distributed, at the end of the day only a single response was recorded online. This caused one more change in the way of distribution and the following days were spent to distribute the same flyers in and around the university campus without giving too much detail, except when asked for. After that, the deadline for the data collection, which I had initially set at the 22th of November but later extended to the 29th, was passed and the process of data collection was closed.

Adding to the surveys that were handed out throughout the city, an invitation to the online survey was deposed out at the Thuisbezorgd office, as well as at the Domino's Pizza location in Paddepoel and two New York Pizza locations in Groningen, in order to investigate their (e-)bike deliverers' perception of the electric buses. This same invitation has been cast out at several supermarkets in Groningen and on some of the information boards at Zernike Campus. I've also posted this invitation at the front door of the building where I live myself, and posted a digital link to the survey in its WhatsApp group so that my neighbors could fill it in as well. Finally, I've posted a link to the survey on my LinkedIn account as well.

2.5 Data Quality

The 2nd of December, the surveys have been closed and the data of both the English and the Dutch survey have been combined into a single excel file. In total there have been 55 valid responses which means that, while the sample of the population is quite small, it can be regarded as representative. The small number of respondents is due to several inconveniences throughout the data collection process. For instance, there has been a week with no data collection at all I was absent during that week. Moreover, a first round of printed invitations delivered in mailboxes has failed to produce any responses at all because the QR code proved to be faulty even though it had been tested beforehand. This also meant that deadline for the data collection had to be extended by a week in order to be assured of enough data, as well as a concentration of data-collection around the university campus in the last few days.

On the other hand, the way of collecting data has had an effect on the population of the survey as it has been easier to reach the younger target groups while older persons were either more reluctant or less able to fill in the online questionnaire on mobile. This can of course affect the outcome of the research and while there has been a small number of respondents over 60, I recommend further research on this topic among elderly people, especially as their senses, both visual and audio, can be less accurate than those of younger people, meaning that their perception of danger can be quite different, especially with silent vehicles. Moreover, in spite of the efforts that were made, it has proved much more difficult than expected to reach deliverers with the survey. In fact, the data only contains a single respondent that qualified herself as a deliverer. This means that deliverers will be left out from the research as a separate target group and regarded as regular cyclists instead.

The survey was constructed in a way that avoided collecting any personal data beyond age and gender. No address, e-mail, phone numbers or names have been collected at all. The excel file containing the data was stored on the researcher's personal computer and is not accessible to anyone else than to himself.

2.6 Method of analysis

The method of analysis is the search for relationship between different parameters and the evaluations of visibility and safety given by respondents for all eight locations in the survey, using SPSS. The following table gives a full overview of all variables used in this research and derived from the survey (excluding the individual grades of each location):

Variable name	Label	Independent/Dependent Variable	Measure
Age	Age categories: 18 – 35, 35 – 60, 60+	Independent	Ordinal
Gender	Male/Female	Independent	Binary
Modality	Mostly pedestrian or cyclist?	Independent	Binary
Impsound	How important do you think sound for traffic security is?	Independent	Scaled
Bothered	Are you worried about totally silent vehicles?	Independent	Binary
Impbus	How important do you think the role of electrical buses in traffic security is?	Independent AND dependent	Scaled
Addedvis	Average marks for visibility on all locations (per respondent)	Independent AND dependent	Scaled
Addedsec	Average marks for security on all locations (per respondent)	Dependent	Scaled

(Table 1, an overview of the variables)

The visibility assessments were used as both an independent variable, influencing the security assessment, and as a dependent variable (with regards to the importance people gave to electric buses when it comes to security) as it was expected that people that were more concerned with visibility would also be more concerned about the lack of sound inherent to electric buses. Similarly, the importance of buses was also used as both an independent and a dependent variable as it was tested whether people who gave more importance to electrical buses were also more concerned about their security, but it was also tested whether people who are more reliant on sound would mark electrical buses as more important than other people do.
The security and visibility assessments as dependent variables were used both individually and aggregated. In order to facilitate the use of both parameters, two separate new variables were created out of the 16 individual variables for each location, containing one average mark per location (Addedvis and Addedsec). These two variables were doubled averages: firstly, an average was made of the individual grades of all respondents for each location and after this, the 8 obtained averages (one per

location) were again put together to form one single average security grade which could then be done for each category of respondents separately, in order to compare the differences between groups.

Firstly, there were four binary variables: Gender, travel modality and the answers on questions no. 4 and 7 (yes or no). The binary parameters were tested for statistically significant differences between the security assessments of their two groups of respondents by means of independent T-tests.
For the age variable, which contained three possible categories, a one-way ANOVA was used to search for statistically significant differences between any of the age-categories.
All questions which required respondents to grade a specific aspect (importance, visibility, security…) have been treated as scaled variables as the most practical means to use these variables was to calculate the average grades of the respondents per subject, which mostly resulted in numbers with three decimals.
These scaled (independent) variables, the importance of sound in traffic, the importance of buses in security and the visibility assessments, were tested for correlation with the (averaged and scaled) security assessments with Pearson's correlation test and the importance people gave to both sound and buses within traffic was also compared to their visibility assessments. The importance of sound was also compared to the importance people allocated to buses. The visibility and security assessments were tested individually for each location, as well as aggregated with the average marks of each respondent in order to get a robust image of their possible correlation. The average marks were however easier to use while giving almost entirely the same results, so they have been used more extensively. Moreover, the importance respondents gave to buses in security was also checked for correlations with the average marks those respondents assigned to the locations in their visibility assessments. All SPSS output is included in Appendix II.

Results

This section describes the results that have been extracted from the data analysis. The section is divided in three subsections: he first one it gives an overview of the data, the second one reviews the results obtained from all questions of the survey that did not require the respondent to assign some grade (in other words, all binary, nominal and/or ordinal variables), and the third section gives the outcomes of all tests with scaled variables, mainly the assessments of both security and visibility (concerning the different locations of interest) and the assessments of importance (concerning the importance of sound and the position of electrical buses with regards the safety of traffic)

3.1 General Sample Characteristics

This section describes any particularities of the data as well as its main descriptive statistics.
The respondents were categorized according to their age, their gender and their travel modality.
As described earlier in this research, the total of 55 (valid) respondents was very unequally split between the age-categories. About two thirds of the respondents were under 35 (67,3% to be precise). Another 23,6% were middle-aged; between 35 and 60 years old. Only 9,1% of the respondents (that is 5 respondents in total) aged over 60. This distribution may well have had an effect on a number of the results described below.
Gender was more equally distributed: 56,4% of the respondents were male, with the remaining 43,6% were female.
Modality was not evenly split between Pedestrians and Cyclists as had been the initial goal of the research, but this has to do with the change in methods. The change in methods was very effective in reaching a larger number of cyclists, which had been a problem when interviewing passengers on the locations of interest. In fact, 63,6% of the respondents reported being predominantly cyclist. The other 36,4% saw themselves more as pedestrians. While this makes for a clear majority of cyclists, the results still include a consistent number of pedestrians.
An overwhelming majority of the respondents (83,6%) affirmed using sound as a clue that a vehicle is approaching when crossing a street. 76,4% of the respondents also recognized the silence of vehicles as to be a potential danger for pedestrians and cyclists. Nevertheless, the amount of respondents worried about this danger was far smaller: 34,5%.
A confidence interval of 95% was used for all tests used in the three following sections.

3.2 Statistical Differences between Various categories

This section describes the statistical differences that were found between pedestrians and cyclists, between male and female respondents, and between the three age groups.
A statistically significant difference was found between male and female respondents by means of a T-test. Male respondents gave considerably higher security grades on average (M = 3.40, SD = 0.70) than female respondents did (M = 2.80, SD = 0.77), $t(53)$ = 3.00, p = ,004. On average, women seem to be more worried about both visibility and security than men which is in line with what Henrik Andersson found in his research on perception of own death risk, where he concluded that "*males under-assess their road-mortality risk, whereas all females, […] over-assess their road-mortality risk*." (Andersson, 2011). Such difference was not found between pedestrians and cyclists. While the T-test showed that the average security grades somewhat surprisingly lay a bit higher with pedestrians (M = 3.06, SD = 0.80)

than with cyclists (*M* = 3.19, *SD* = 0.78), the difference was not statistically significant; *t*(53) = - 0.59, *p* = ,561.
Expected was that cyclists would have somewhat lower visibility scores (and thus lower security scores as well) because of their higher speed (Jo. et Al., 2014), but this wasn't the case.
A one-way ANOVA test was used to search for statistically significant differences between the average marks for the security assessments of respondents in different age-categories. Maybe as a result of the uneven distribution in these categories, combined with the small sample size, no significant difference was found *F*(2, 52) = 2.09, *p* = .134. Nevertheless, elderly respondents gave much lower average grades (*M* = 2.55, *SD* = 0,97) than the two other age groups (age 18 – 35: *M* = 3.26, *SD* = 0,78; age 35 – 60: *M* = 3.02, *SD* = 0,65). On average, elderly respondents also gave much more importance to sound in traffic (*M* = 4.00, *SD* = 1.23), which could have to do with fact that their visual abilities may be lesser than those of younger people (both other groups had *M* ~ 3,00), but this was again not a statistically significant difference *F*(2, 52) = 2.29, *p* = .111. Moreover, younger respondents gave less importance to electrical buses for security (*M* = 2.95, *SD* = 1.10) then older people did (*M* = 4.00, *SD* = 1,00), which could have to do with a higher technology acceptancy rate. Once more however, this result is not statistically significant, *F*(2, 52) = 2,28, *p* = .113. It is in concordance however with former research: In their review of technology acceptance by older adults, Chen and Chan concluded that *"older adults possess lower computer self-efficacy and a higher degree of anxiety about computers than younger adults"* (Chen and Chan, 2011).
However, even though their comparison seems to confirm existing theories, none of the results with regards to the three age categories show any statistically significant differences which means that no firm conclusions can be established based on this research with regards to differences in age.

3.3 The Importance of Visibility

This section describes the correlations that were found between visibility and security, but also between visibility and the importance respondents gave to sound within traffic security. The section also aims to assess whether people that are worried about the silence of electric vehicles are also more concerned about the safety of electrical buses and whether they see them as a more important factor in traffic security.
Firstly, the Pearson correlation test displayed a very strong correlation between the mean grades assigned by the respondents for each of the eight locations for visibility and the grades for security. Visibility appeared to be a very important factor itself when it comes to security. This is in accordance with several studies such as the Croatian study on Risk factors in urban road traffic accidents by A. Vorko-Jović et al. point to visibility as a major factor in traffic security in urban centers (Vorko-Jović et al., 2006). The results of the statistical analysis display a clear link between visibility and security since there is a very strong correlation between the average marks respondents assigned to the given locations for visibility and for security, *r*(53) = .82, *p* < .001. In general, the average marks for visibility and security of each respondent did not show large differences: the average mark for all respondents on all locations was 3,02 for visibility and 3,14 for security (these two grades are the result of adding up the average marks of each respondents before dividing that addition by the total number of respondents). This does imply that while visibility is not the only factor for security, it is probably the most important one. The same test has been applied to the grades of each location individually. Every single location showed a strong, statistically significant correlation between its visibility grades and its security grades, with the lowest correlation sitting at 0,62 and the highest at 0,80. This confirms the results of the first test with the average grades of each respondent.

The importance respondents assigned to the usefulness of sound was also correlated (moderately negative) to their visibility assessments, $r(53) = -.31$, $p = .020$. This means that people who are relying more heavily on sound (such as for instance persons with visual impairment), are more likely to be worried about the visibility of buses, which in turn would be a lesser problem if those buses emitted more sound. This corresponds the two T-tests that compared people who stated to be worried about the lack of sound on vehicles to people who stated not be worried: People worried about lack of sound gave much higher importance to electrical buses with regards to traffic security, $t(53) = 2.35$, $p = .023$. Moreover, the importance respondents assigned to sound within traffic was negatively correlated to their average security assessments, $r(53) = -.33$, $p = .015$. This means that respondents who see sound as an important clue in order to assert whether a vehicle is approaching, in other words, respondents who make more use of sound when crossing a street, such as for instance a visually impaired individual, give lower security scores in general and vice versa.

3.4 The Role of the Electrical Bus

This last section aims to assess the role that electrical buses are perceived to have in traffic security.
Statistically significant correlations have also been found between the importance assigned by respondents to electrical buses in security, and their average security assessments, which resulted in a moderate negative correlation, $r(53) = -.38$, $p = .005$: People with (on average) lower security scores perceive electrical buses as more important when it comes to security (and vice versa) which has to do with the fact that electrical vehicles, especially at low speed, emit much less sound then traditional vehicles.
A moderate negative correlation was also found between the importance respondents assigned to electrical buses in traffic safety and their visibility assessments $r(53) = -.43$, $p = .001$. This can be explained by the fact that the silence of electric vehicles is extra dangerous in places with low sight distances or turning points, as it was pointed out by Kim et al. (Kim et al., in Ashmead et al., 2012).

Expectedly, respondents that reported to be worried about totally silent vehicles gave much higher importance to electrical buses when it comes to safety, ($M = 3.63$, $SD = 0.96$) compared to people who reported not to be worried ($M = 2.89$, $SD = 1.19$), $t(53) = 2.35$, $p = .023$. This same group of respondents also gave significantly lower grades to the security assessments, $t(53) = -2.68$, $p = .010$.

Conclusion

This research has aimed to measure how pedestrians and cyclists in Groningen perceive the quietness of electrical vehicles, especially buses which are very common in the city, and the number of which will be largely expanded starting December 2019 already. An online survey was used to sample the perceptions of the population, formulating several questions concerning the importance of sound in traffic. The questionnaire also asked the respondents for their age, their gender and their preferred mode of (non-motorized) transport within the city. Finally, it made the respondents assess both visibility and security on eight locations of interest along the already electrified bus line 1 in Groningen.

4.1 Summary of the Results

It was found that there is a significant difference on the perception of security between male respondents and female respondents, with female respondents being warier about traffic safety. No large differences were found between pedestrians and cyclists. In contrast, the average security grades varied considerably between the age-categories, with the category 60+ seeming to be especially worried about security in traffic and low sound levels. This could not be statistically verified within the 95% confidence interval, but former literature does indicate that it would be reasonable to think that elderly people have more concerns with silent vehicles.

Visibility was identified as a very major factor when it comes to security, which coincides with earlier findings. Moreover, this study found that there is a clear negative correlation between the respondent's assessments of visibility and the importance that people assign to electrical vehicles for traffic safety as well as the importance people assign to the usefulness of sound in traffic: the more people are reliant on sound, the more worried they are about visibility. The usefulness of sound in traffic is also linked positively with the importance that people assign to electrical vehicles and people worried about the silence of electrical vehicles gave much higher importance to electric buses with regards to traffic safety.

Overall, this research leads to the conclusion that there are several categories of people who are more concerned about the safety of silent buses in Groningen:

Firstly, ladies are, in general, more concerned than men. Secondly, people that are more reliant on sound (such as for example people with visual impairments), are very much worried about the development. Finally, elderly people also seem to worry about the silence of electrical buses but this cannot be statistically verified from this research.

4.2 Limitations of the Study and Recommendation for Further Research

This research was bound to a number of limitations. For instance, the overall sample was quite small, with a total sample population of 55 valid cases. This had to do with problems during the data collection process. It also has to do with a limitation in budget, as a larger budget would have allowed to spread more invitations to the survey. Another limitation was the timeframe which caused the data collection process to last for only several weeks, which also limited the number of respondents. Lastly, the age-distribution was very unevenly split, containing much less elderly people then intended. This may well have to do with the digital nature of the survey and with the fact that elderly people may have less access to digital devices, especially smartphones, that are able to scan the QR-code which gave access to the survey. As a consequence, however, the results that this study obtained with regards to the age-categories could not be seen as statistically significant (although they were largely within a confidence interval of 85%). Former researches have investigated the technology-acceptance of older people, but not specifically with regards to transportation modes or vehicles. Further research on how elderly people perceive electric buses, or electric vehicles in general is needed to establish the seriousness of the apprehension hinted by this study.

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Appendix I - Questionnaire (source: own creation, Google Forms)

(The security assessments have largely been left out because of space constraints. However, they are included in the link and are set up exactly the same way as the visibility assessments)

Electrical buses related to Pedestrian and cyclist safety in Groningen

The survey consists of 4 parts: A consent form, 7 short Introductory questions, 8 visibility assessments and 8 safety assessments, with a final question to conclude.

*Obligatoire

rijksuniversiteit groningen

Consent to participation *

This research is being carried out by Jordi van Kleef, undergraduate student from the Faculty of Spatial Planning in Groningen University, Netherlands. The aim of the findings is to write a Bachelor project dissertation for assessment purposes. The Bachelor project contributes to the third year of our degrees. The research will not be circulated beyond the normal examination and assessment processes within the Faculty of Spatial Planning. Participation in this study is voluntary. You are free to withdraw at any point. All data collected will be kept confidential and used for research purposes only. All primary data will be destroyed after the end of this project.

- I Accept
- I do not accept (in this case, quite this page manually)

SUIVANT

Page 1 sur 4

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Google Forms

Electrical buses related to Pedestrian and cyclist safety in Groningen

*Obligatoire

Introductory questions

Age-group: *

- ○ 18-30
- ○ 35-60
- ○ 60

Gender

- ○ male
- ○ female

How do you move within the city most often? By bike or walking? *

- ○ By bike
- ○ Walking
- ○ I'm a deliveroo on e-bike or scooter

When crossing a street, do you (sometimes) use the sound of vehicles as a clue that the vehicle is approaching? *

- ○ Yes
- ○ No

How important is the sound emitted from a moving vehicle in making you aware of the vehicle's location and of the direction from which it approaches? *

	1	2	3	4	5	
Not important at all	○	○	○	○	○	Very important

Hybrid and Electric buses are quieter than traditional gasoline engine-powered buses. Would this lack of noise pose any threat to pedestrians or cyclists (with or without e-bikes)? *

- ○ Yes
- ○ No

As a pedestrian or cyclist, when a moving vehicle is totally silent does that worry you? *

- ○ Yes
- ○ No

RETOUR SUIVANT Page 2 sur 4

Electrical buses related to Pedestrian and cyclist safety in Groningen

Sight-assessment

What do you think about the visibility on this location? Can you see coming buses well enough? Please give an
assessment mark to the visibility for each of these locations. You can base your evaluations on both the photos and your own experience with the locations.

Intersection Zuiderdiep and Heerestraat

southern side

The buses come from the left

	1	2	3	4	5	
Very limited	○	○	○	○	○	Excellent

Intersection Zuiderdiep and Gelkingestraat

northern side

The buses come from the right

	1	2	3	4	5	
Very limited	○	○	○	○	○	Excellent

Intersection Gelkingestraat and Carolieweg

The buses come from the left

	1	2	3	4	5	
Very limited	○	○	○	○	○	Excellent

Entrance Oosterstraat

At the Grote Markt

The buses come from the right

	1	2	3	4	5	
Very limited	○	○	○	○	○	Excellent

Intersection Kwinkenplein and Kreupelstraat

At the Grote Markt

The buses come from the left

	1	2	3	4	5	
Very limited	○	○	○	○	○	Excellent

Very limited	◯	◯	◯	◯	◯	Excellent

UMCG Noord

The buses come from the right

	1	2	3	4	5	
Very limited	◯	◯	◯	◯	◯	Excellent

Intersection Korreweg and Damsterdiep
(buslane)

The buses come from the right, on the first lane

	1	2	3	4	5	
Very limited	◯	◯	◯	◯	◯	Excellent

Crossing Eikenlaan
Crossing with the Zernike route for cyclists (cyclists drive fast here)

The buses come from both sides

	1	2	3	4	5	
Very limited	◯	◯	◯	◯	◯	Excellent

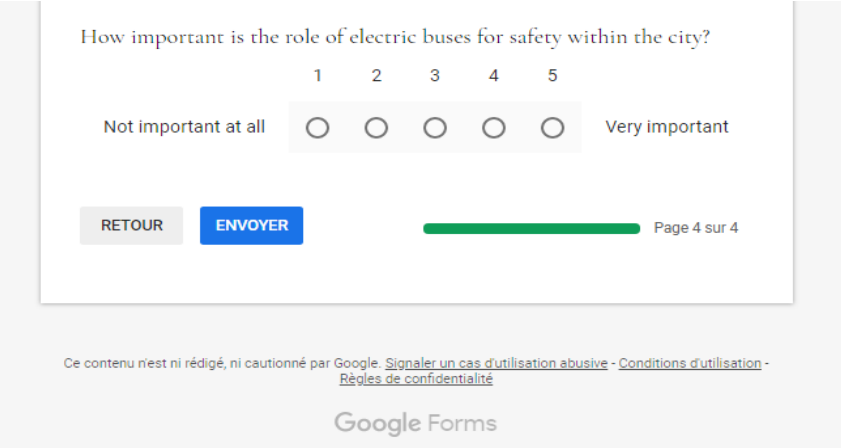
RETOUR SUIVANT Page 3 sur 4

Electrical buses related to Pedestrian and cyclist safety in Groningen

Safety Assessment

Please assess the pedestrian/cyclist safety of this place with one of the following assessment marks:

[..]



How important is the role of electric buses for safety within the city?

	1	2	3	4	5	
Not important at all	○	○	○	○	○	Very important

RETOUR ENVOYER Page 4 sur 4

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Google Forms

Appendix 2 – SPSS Output (Source, SPSS output)

One-way ANOVA: Age groups/Average security grades

Descriptives

addedsec

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
18-35	37	3,26014	,780835	,128368	2,99979	3,52048	1,625	5,000
35-60	13	3,01923	,645187	,178943	2,62935	3,40911	2,125	4,625
60+	5	2,55000	,970663	,434094	1,34476	3,75524	1,125	3,500
Total	55	3,13864	,783833	,105692	2,92674	3,35054	1,125	5,000

ANOVA

addedsec

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2,464	2	1,232	2,086	,134
Within Groups	30,713	52	,591		
Total	33,177	54			

One-way ANOVA: Age groups/Importance of sound in traffic

Descriptives

impnoise

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
18-35	37	3,05	,880	,145	2,76	3,35	2	5
35-60	13	3,00	1,080	,300	2,35	3,65	1	5
60+	5	4,00	1,225	,548	2,48	5,52	2	5
Total	55	3,13	,982	,132	2,86	3,39	1	5

ANOVA

impnoise

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4,217	2	2,109	2,289	,111
Within Groups	47,892	52	,921		
Total	52,109	54			

One-way ANOVA: Age groups/Importance of Electrical buses in traffic safety

Descriptives

ImpEB

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
18-35	37	2,95	1,104	,182	2,58	3,31	1	5
35-60	13	3,38	1,261	,350	2,62	4,15	1	5
60+	5	4,00	1,000	,447	2,76	5,24	3	5
Total	55	3,15	1,161	,157	2,83	3,46	1	5

ANOVA

ImpEB

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5,868	2	2,934	2,278	,113
Within Groups	66,969	52	1,288		
Total	72,836	54			

T-test: Gender/Average security grades

Group Statistics

	Genre	N	Mean	Std. Deviation	Std. Error Mean
addedsec	Masculin	31	3,39919	,702984	,126260
	Feminin	24	2,80208	,766943	,156552

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
addedsec	Equal variances assumed	,135	,715	3,003	53	,004	,597110	,198869	,198230	,995990
	Equal variances not assumed			2,969	47,307	,005	,597110	,201122	,192575	1,001646

T-test: Transport modality/Average security grades

Group Statistics

	déplace	N	Mean	Std. Deviation	Std. Error Mean
addedsec	Pedestrian	20	3,05625	,798307	,178507
	Cyclist	35	3,18571	,783194	,132384

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
addedsec	Equal variances assumed	,003	,957	-,586	53	,561	-,129464	,221062	-,572858	,313930
	Equal variances not assumed			-,583	39,047	,564	-,129464	,222239	-,578968	,320040

T-test: Worried by silent vehicles?/Average security grades

Group Statistics

	bothered	N	Mean	Std. Deviation	Std. Error Mean
addedsec	Yes	19	2,76974	,764062	,175288
	No	36	3,33333	,731315	,121886

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
addedsec	Equal variances assumed	,012	,912	-2,676	53	,010	-,563596	,210575	-,985957	-,141236
	Equal variances not assumed			-2,640	35,363	,012	-,563596	,213499	-,996864	-,130329

T-test: Worried by silent vehicles?/Importance of electrical buses in traffic safety

Group Statistics

	bothered	N	Mean	Std. Deviation	Std. Error Mean
ImpEB	Yes	19	3,63	,955	,219
	No	36	2,89	1,190	,198

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
ImpEB	Equal variances assumed	,351	,556	2,347	53	,023	,743	,316	,108	1,377
	Equal variances not assumed			2,513	44,285	,016	,743	,296	,147	1,338

Pearson's correlation: Importance of sound in traffic/Importance of electrical buses in traffic safety

Descriptive Statistics

	Mean	Std. Deviation	N
impnoise	3,13	,982	55
ImpEB	3,15	1,161	55

Correlations

		impnoise	ImpEB
impnoise	Pearson Correlation	1	,422**
	Sig. (2-tailed)		,001
	N	55	55
ImpEB	Pearson Correlation	,422**	1
	Sig. (2-tailed)	,001	
	N	55	55

**. Correlation is significant at the 0.01 level (2-tailed).

Pearson's correlation: Importance of sound in traffic/Average security grades

Descriptive Statistics

	Mean	Std. Deviation	N
addedsec	3,13864	,783833	55
impnoise	3,13	,982	55

Correlations

		addedsec	impnoise
addedsec	Pearson Correlation	1	-,327*
	Sig. (2-tailed)		,015
	N	55	55
impnoise	Pearson Correlation	-,327*	1
	Sig. (2-tailed)	,015	
	N	55	55

*. Correlation is significant at the 0.05 level (2-tailed).

Pearson's correlation: Importance of sound in traffic/Average visibility grades

Descriptive Statistics

	Mean	Std. Deviation	N
impnoise	3,13	,982	55
addedvis	3,02273	,708370	55

Correlations

		impnoise	addedvis
impnoise	Pearson Correlation	1	-,314*
	Sig. (2-tailed)		,020
	N	55	55
addedvis	Pearson Correlation	-,314*	1
	Sig. (2-tailed)	,020	
	N	55	55

*. Correlation is significant at the 0.05 level (2-tailed).

Pearson's correlation: Importance electrical buses in traffic safety/Average security grades

Descriptive Statistics

	Mean	Std. Deviation	N
addedsec	3,13864	,783833	55
ImpEB	3,15	1,161	55

Correlations

		addedsec	ImpEB
addedsec	Pearson Correlation	1	-,376**
	Sig. (2-tailed)		,005
	N	55	55
ImpEB	Pearson Correlation	-,376**	1
	Sig. (2-tailed)	,005	
	N	55	55

**. Correlation is significant at the 0.01 level (2-tailed).

Pearson's correlation: Importance of electrical buses in traffic safety/Average visibility grades

Descriptive Statistics

	Mean	Std. Deviation	N
addedvis	3,02273	,708370	55
ImpEB	3,15	1,161	55

Correlations

		addedvis	ImpEB
addedvis	Pearson Correlation	1	-,426**
	Sig. (2-tailed)		,001
	N	55	55
ImpEB	Pearson Correlation	-,426**	1
	Sig. (2-tailed)	,001	
	N	55	55

**. Correlation is significant at the 0.01 level (2-tailed).

Pearson's correlation: Average visibility grades/Average security grades*

Descriptive Statistics

	Mean	Std. Deviation	N
addedsec	3,13864	,783833	55
addedvis	3,02273	,708370	55

Correlations

		addedsec	addedvis
addedsec	Pearson Correlation	1	,819**
	Sig. (2-tailed)		,000
	N	55	55
addedvis	Pearson Correlation	,819**	1
	Sig. (2-tailed)	,000	
	N	55	55

**. Correlation is significant at the 0.01 level (2-tailed).

*The output of the bivariate tests for each individual location are not included in the appendix.