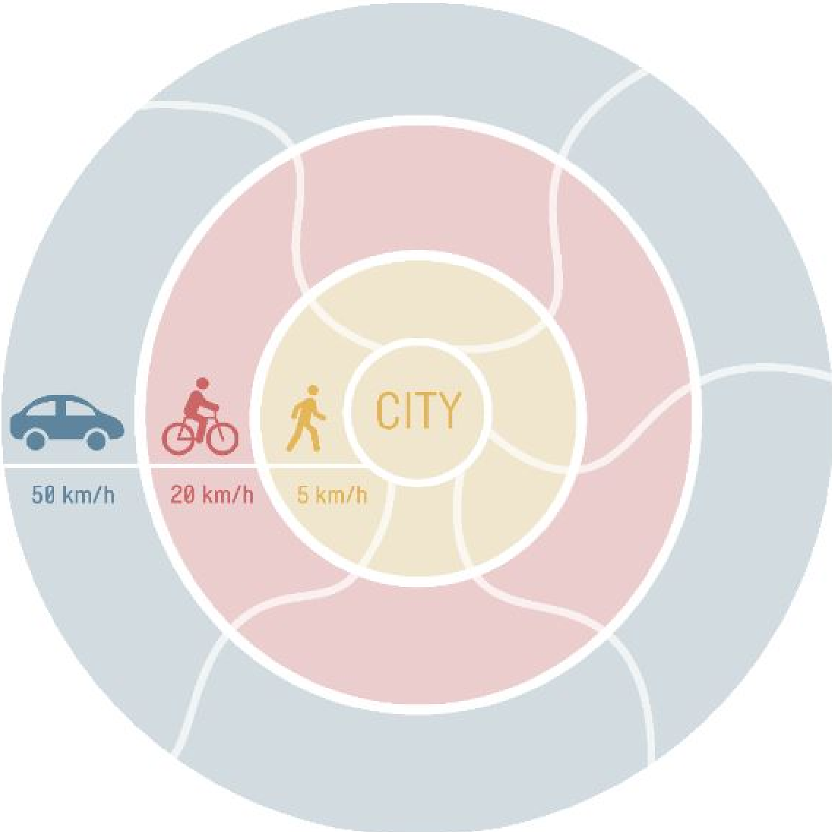

Shared speed for safe transportation and sustainable cities

A study from a cyclist perspective on how traffic design can promote shared speed and the acceptance of mixed traffic

Master's thesis in Infrastructure and Environmental Engineering

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DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2020

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Master's Thesis ACEX30

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Abstract

This study has aimed towards evaluating the speed difference between transport modes and investigating what can be done to approach shared speed and reach a sustainable transport system. The research has been conducted through literature studies with the support of a questionnaire and interviews to complement the literature. The purpose of the questionnaire was to understand what design elements in the urban streetscape would help establish shared speed and mixed traffic cycling as well as find out the acceptance of mixed traffic cycling. The questionnaire was distributed to two sample groups, one with traffic engineers and the other with dedicated civilian cyclists. The questionnaire consisted of 20 questions where the respondents were asked about their cycling characteristics, their willingness for mixed traffic cycling, and to compare drawings of design elements in urban streetscapes. The results of the questionnaire show that there is a willingness for mixed traffic cycling, and particularly among faster cyclists. Slower cyclists have a lower acceptance yet are not totally against it. The design elements that would give the best possible conditions for shared speed and mixed traffic cycling was found to be road marking bicycle symbols, a *Cars are guests* sign, lane width, pavement and central divider. There are existing and up-and-coming speed-reducing methods that can help establish shared speed. Also, mixed traffic solutions such as bicycle streets and $2-1$-roads are being tested in Sweden and could be functional on urban streets. Concluding the findings, the study reveals that there is already plenty of knowledge about creating a functional and attractive bicycle infrastructure. To reclaim the lost human perspective, planning should strive for accessibility and mobility for pedestrians and cyclists. A prerequisite for increased accessibility is to improve safety, which likely is improved with mixed traffic cycling. Further, the safety can be improved by increasing the share of active travelers which has great potential in Gothenburg. By using the efficient motor traffic infrastructure and invite cyclists into the roadway, it will also state that cyclists have equal rights to the street. In urban areas, cyclists share speed with motor vehicles and not pedestrians. Consequently, the distribution of space in urban streetscapes should be reallocated based on speed. However, cyclists are a very heterogeneous group, and therefore, the bicycle infrastructure must provide solutions that are attractive for all types of users. Traffic regulations need to be adapted for mixed traffic cycling and in general to suit cyclists better. Conclusively, shared speed can secure sustainable development by distributing more space to the active transport modes, whereas that would benefit efficiency, air quality, noise, and public health, as well as creating attractive and sustainable cities.

Keywords: Shared speed, cycling, mixed traffic, urban planning, design elements, geofencing

Delad hastighet för säker transport och hållbara städer
En studie från en cyklists perspektiv på hur trafikutformning kan främja delad hastighet och acceptansen för blandtrafik
Examensarbete inom masterprogrammet Infrastruktur och Miljöteknik
PONTUS JÖRGENSEN
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Chalmers Tekniska Högskola

Sammanfattning

Syftet med denna studien har varit att utvärdera hastighetsskillnaden mellan transportmedel samt utreda vad som kan göras för att närma sig delad hastighet och nå ett hållbart transport system. Studien har gjorts genom litteraturstudier med stöd av en enkät samt intervjuer för att komplettera literaturen. Målet med enkäten var att förstå vilka utformningselement i urbana gaturum som skulle kunna hjälpa till för att etablera delad hastighet och cykling i blandtrafik samt förstå acceptansen för cykling i blandtrafik. Enkäten gavs ut till två provgrupper där en bestod av trafikingenjörer och den andra gruppen av hängivna civila cyklister. Enkäten bestod av 20 frågor där de svarande ombads svara på frågor rörande deras karaktärsdrag som cyklist, deras acceptans för att cykla i blandtrafik samt att jämföra teckningar av utformningselement i urbana gaturum. Resultaten från enkäten visar att det finns en villighet för cykling i blandtrafik och framförallt bland snabbare cyklister. Långsammare cyklister har en lägre acceptans men är heller inte helt emot. De utformningselement som skulle ge bäst förutsättningar för delad hastighet och cykling i blandtrafik visade sig vara vägmålade cykelsymboler, en Bilar är gäster vägskylt, körfältsbredd, ytskikt och mittrefug. Det finns lovande hastighetsreducerande åtgärder som hjälpa till med att etablera delad hastighet. Dessutom testas lösningar för blandtrafik i Sverige i form av cykelfartsgata och bygdegata (2-1-väg) och kan vara funktionella på urbana gator.
För att sammanfatta resultaten finns det redan mycket bra kunskap för att skapa funktionell och attraktiv infrastruktur för cykling. För att återkalla the förlorade mänskliga perspektivet bör planering sträva efter tillgänglighet och framkomlighet för fotgängare och cyklister. En förutsättning för ökad tillgänlighet är att förbättra säkerheten som troligen förbättras med cykling i blandtrafik. Vidare så kan säkerheten förbättras med en ökad andel aktiva trafikanter vilket det också finns stor potential för i Göteborg. Genom att använda motortrafikens effektiva infrastruktur och bjuda in cyklister i körbanan, kommer det också sända signaler om att cyklister har samma rätt till gatan. I tättbebyggda områden delar cyklister hastighet med motorfordon och inte gående. Därför bör utrymmet i urbana gaturum fördelas om baserat på hastighet. Cyklister är dock en mycket heterogen grupp och cykelinfrastrukturen måste därför tillhandahålla lösningar som är attraktiva för alla typer av användare. Trafikreglerna behöver anpassas till cykling i blandtrafik samt överlag för att passa cyklister bättre. Avslutningsvis kan delad hastighet säkerställa hållbar utveckling genom att fördela mer utrymme till aktiva färdmedel då det gynnar effektivitet, luftkvalitet, buller och folkhälsa samt att det skapar attraktiva och hållbara städer.

Nyckelord: Shared speed, delad hastighet, cykling, blandtrafik, stadsplanering, utformningselement, geofencing

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Firstly, I would like to thank my supervisors at Sweco, Charlotte Berglund and Roger Johansson, for all the great inputs and the long time expertise they have shared with me. A special thanks to Roger for coming up with the idea of shared speed.

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Lastly, I would like to thank everyone that responded to the questionnaire.

Pontus Jörgensen, Gothenburg, June 2020

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1 | Introduction

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The quote comes from the Brundtland Report in 1987. Today 2020, we still have not reached sustainable development. Future generations are more than ever compromised (WHO, 2020a).

Sustainable development includes social, economic, and environmental aspects. In 2015 the UN introduced 17 sustainable development goals that all member states agreed to work with to tackle poverty, improve health, and preserve the environment. This study will focus on the development connected to traffic and urban planning. Therefore, as figure 1 shows, the development goals of interest are:

- 3. Good health and well-being
- 9. Industry, innovation and infrastructure
- 11. Sustainable cities and communities
- 12. Responsible consumption and production
- 13. Climate action

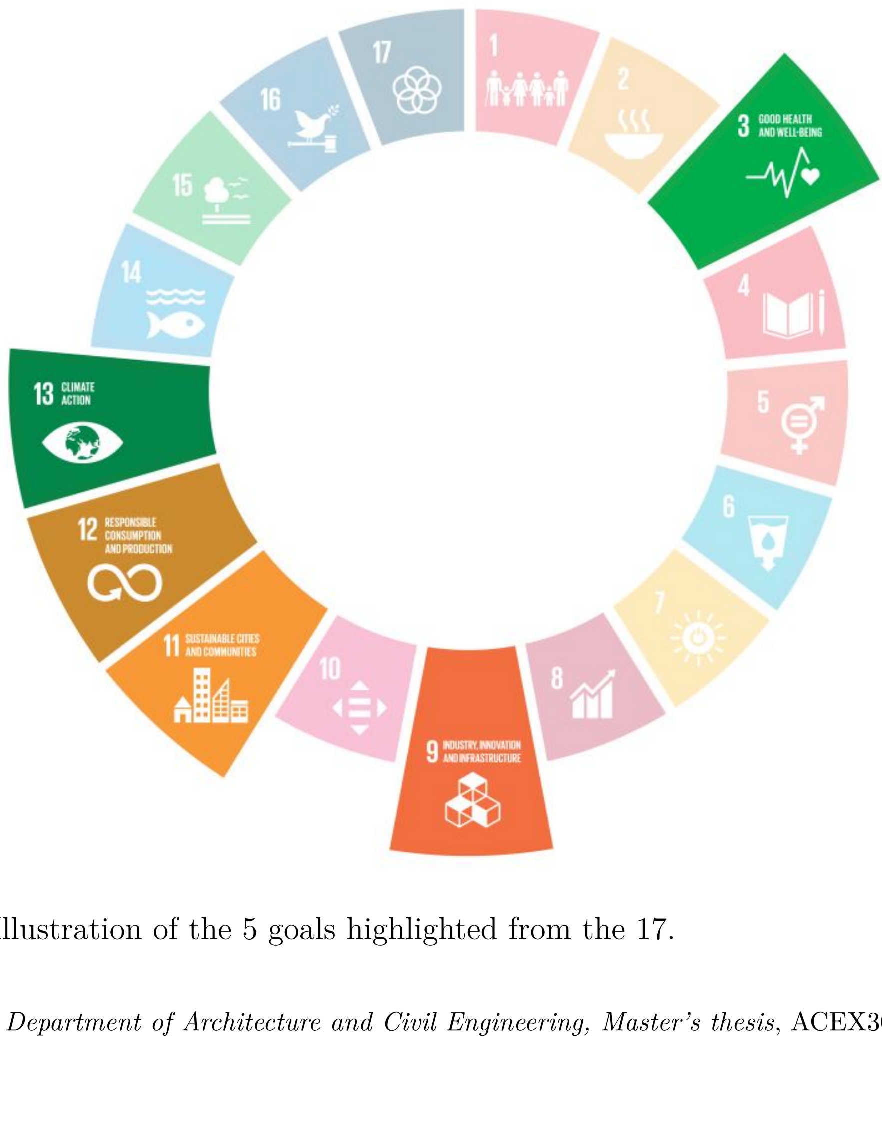


Figure 1.1: Illustration of the 5 goals highlighted from the 17.

Each goal is broad and includes several targets. Therefore, here follows a few that are connected to traffic and urban planning.

3. Health and well-being can be secured by focusing on improving traffic safety and pollution, causing deaths and illnesses (UN, 2014).

9. Investing in qualitative and sustainable infrastructure with inclusive access can boost human well-being (UN, n.d.-a).

11. Challenges brought by urbanization are typically traffic congestions and air pollution. To handle these and additional challenges, integrated and sustainable urban planning is required. Sustainable transportation and public spaces should be accessible, affordable, and safe for everyone (UN, 2018).

12. Promote sustainable infrastructure and management of natural resources such as fossil-fuels (UN, 2015a).

13. Adaptation efforts must be taken to integrate climate change measures. (UN, 2015b).

Road accidents are one of the biggest reasons for death globally. Over 1.3 million people die every year from road accidents. More than half are pedestrians, cyclists and motorcyclists (WHO, 2020b). The Swedish Transport Administration (2016) acknowledges the UN sustainable development goals that a sustainable development requires safe traffic and that the traffic safety in turn must development hand in hand with sustainable development connected to physical activity and public transport. Sweden is one of the greatest countries when it comes to traffic safety (SKL & Swedish Transport Administration, 2013). Yet, Sweden is not best in all aspects. Swedish drivers are not very good at complying with the speed limit (Swedish Transport Administration, 2020b, 0:53) and speed is the most fundamental parameter in traffic safety (Swedish Transport Administration, 2020b, 0:52).

Motor vehicles are almost exclusively involved in road fatalities. In a road fatality a person has either been hit by a motor vehicle or self been driving one. High speeds and motor vehicles are strongly connected since pedestrians and most cyclists cannot travel with high speeds due to physical abilities. Approximately 75 percent of all fatalities and seriously injured in traffic happen in urban areas (SKL & Swedish Transport Administration, 2013).

With consideration to all transport modes that exist, with all their individual needs and speeds, the best solution would be to give them all their own physically separated travel lanes. One for pedestrians, one for runners, one for slow cyclists, one for fast cyclists, one for mopeds and another one for motor vehicles. Maybe there should be one for skateboards as well? Still, where should one rollerski? The whole thing becomes infeasible.

In order to bring light to the issue each transport mode need to be treated as its own. However, today streetscapes are divided into spaces of two groups (pedestrians, bicycles and mopeds as one and motor vehicles as the other) when in fact they are at least four major groups (pedestrians, bicycles, mopeds and motor vehicles). Instead, should not the space be divided based on speed and which modes share the speed?

The author has over some time observed the effect of the uphill/downhill movement at the bicycle street at Redbergsvägen, Gothenburg. The author's observations have acknowledged that downhill the bicycle street works well and as intended. The motor vehicles give the bicycles priority and do not overtake. However, on the uphill side the bicycles are not given priority. Motor vehicles tend to overtake and bicyclists therefore place themselves to be overtaken. The main reason for this behaviour the author believes is due to the difference in speed. Uphill the cyclists can not maintain the speed while the motor vehicles have no problem to continue with the same speed. However, downhill cyclists can without problem keep the same speed as the vehicles or even faster.

Concluding this section, when the speed is close to the same, the bicycle street works well and as intended. This leads to the idea of shared speed.

1.1 | Objective

This thesis does not try to exclude motor vehicles from the streetscape of urban streets yet instead collect well-defined ideas for urban planning and street design in an attempt to conclude them into recommendations for sustainable development. Plenty of research and governmental documents state ways to reach sustainable urban transportation, yet we have not seen those ideas been implemented to a large extent. Considering traffic safety, the Vision Zero in Sweden has more or less stagnated the last years, whereas, in order to move nearer zero fatalities and serious accidents in transport, these ideas have to be realized in new design and urban planning.

1.2 | Aim

The overall aim is to evaluate what speed difference between transport modes means for urban transport, and specifically for cycling. Also, to investigate what can be done to approach shared speed and reach a sustainable transport system.

1.3 | Research questions

In order to meet the aim of the study, the report will attempt to answer the following questions:

RQ 1 - What does the literature say about planning and designing for attractive bicycle infrastructure?

RQ 2 - Does mixed traffic cycling have acceptance from traffic engineers and cyclists?

RQ 3 - Who share speed, and what can it contribute to?

RQ 4 - Which design elements would give the best possible conditions for shared speed and mixed traffic cycling?

1.4 | Delimitations

This report briefly covers urban planning; however, it will not take into account how land use should be planned.

All transport modes are addressed; however, the focus is put on bicycle. The study is done with Gothenburg as the base, yet the study can possibly be used for other places in Sweden and maybe even globally. Public transportation is, in most cases, left out of the study because of its complexity.

The study builds upon how transportation looks today and does, therefore, not consider what urban and traffic planning might look like in the future. Whether autonomous vehicles will be implemented in the future has not been considered in this study. Additionally, current traffic flows and how changes in traffic planning would influence the flows are not included.

1.5 | Target Audience

This report targets both students of civil engineering and professionals with interest in traffic and urban planning. Therefore, the content presumes an elemental knowledge within the subject yet remains on a fundamental level.

2 | Theoretical Framework

2.1 | Sustainable development

The Swedish Government (2008) has set a main goal to secure a socioeconomically efficient and long term sustainable transport supply for the citizens in the whole country. The transport system should supply the demand in a way that creates good opportunities for solutions that are safer, more efficient and better for the climate. This includes that the climate friendly choices are to be attractive and accessible. Prerequisites for choosing walking, cycling and public transport should therefore increase. Additionally, the goal adds the possibility for the transport policy to have a positive impact on the citizens' health. Part from creating safe traffic, actions can be made to increase the health by striving for active travels and at the same time reduce illness due to pollution and noise. The fatalities in road transport were specified to halve from 2007 until 2020 and the number of seriously injured shall decrease by 25 percent. This goal has further been adopted for the work on traffic safety until 2030 (Swedish Transport Administration, 2020b, 1:18).

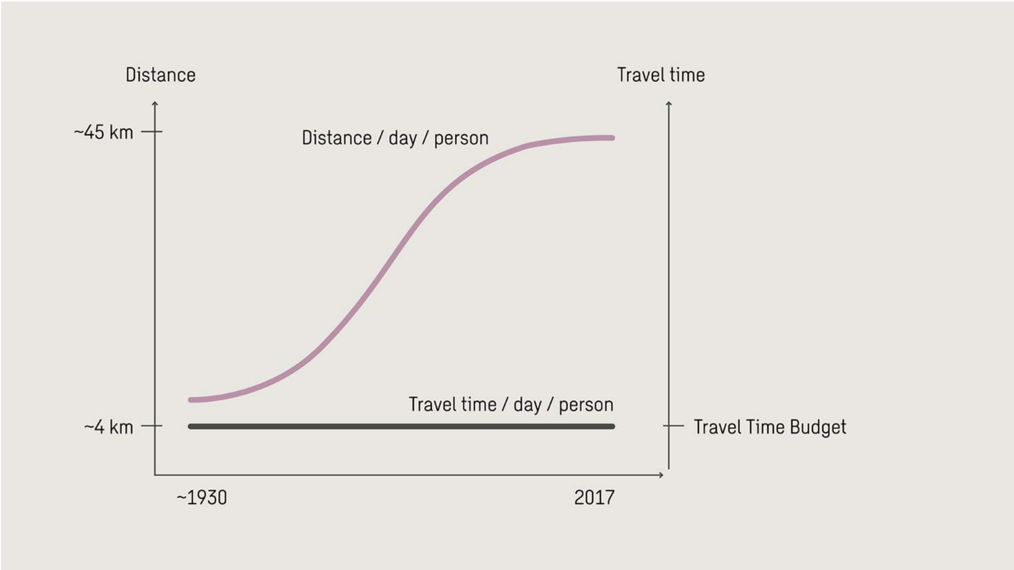
2.2 | Urban planning

In the mid 19th century, most cities were planned from the perspective of pedestrians and their moving speed (Lindelöw, 2018). Old cities and especially their city centers testify that far back the car did not have a place in the streetscape. The streets are narrow and millions of tourists yearly visit old European cities where the infrastructure is walkable and the environment is attractive. Before the car, for hundreds of years, integration and shared space was the common thing (Hamilton-Baillie, 2003). However, walkable attractive European cities have changed (Hamilton-Baillie, 2003), (Ahlgren, Robson, & Houthaeve, 2018). Since the mid 20th century the car has dominated urban planning and changed how cities look (Ahlgren et al., 2018).

The car in the transport system is relatively new, yet it is the norm for all traveling and urban planning. The separation of transport modes became modern (Hamilton-Baillie, 2003) and the car made it possible for cities to expand and spread the mixed land use (Lindelöw, 2018). Car dependency has caused streets to be spaces for cars and public spaces have become spaces for parking (Ahlgren et al., 2018). Walking and cycling have lost its place in urban space (Lindelöw, 2018) and streets have lost their significance as attractive points for social meeting (Ahlgren et al., 2018).

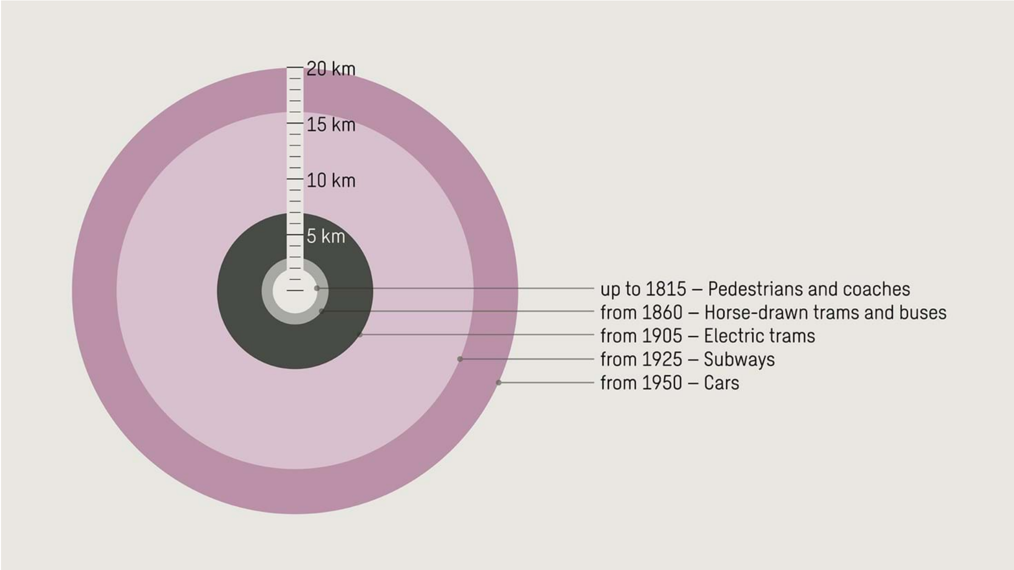
Although, the car made cities spread, travel time has not changed over time. Which can be seen in figure 2.1, new faster transport modes have not particularly shortened travelers' daily time spent on traveling. Travel time to close destinations decreased, however the distance that one accepts to travel also increased. Ahlgren et al. (2018) explains that adaptation and de-densification have caused destinations to move further apart, hence increasing car dependency further. Speed took over for accessibility whereas accessibility became dependant on fast travels (Lindelöw, 2018) & (Ahlgren et al., 2018). Consequently, citizens need to travel long distances which bound and even excludes walking and cycling since they for physiological reasons, have a shorter radius of action (Lindelöw, 2018).

“Moreover, the focus on minimizing travel time almost automatically excludes pedestrians and cyclists, whose options for increasing speeds is naturally limited.“ (Lindelöw, 2018)



Source: (Lindelöw, 2018)
Figure 2.1: The graph shows a simplistic illustration of how travel time and distance per day and person transformed in the 20th century. Travel time budget, the time accepted for traveling per day, has remained the same. Yet, the distance accepted for traveling per day has increased with newer faster transport modes. For instance, in Sweden the daily distance per person increased from around 4 km in 1930 to 45 km after 2010, yet the travel time per day and person remained the same.

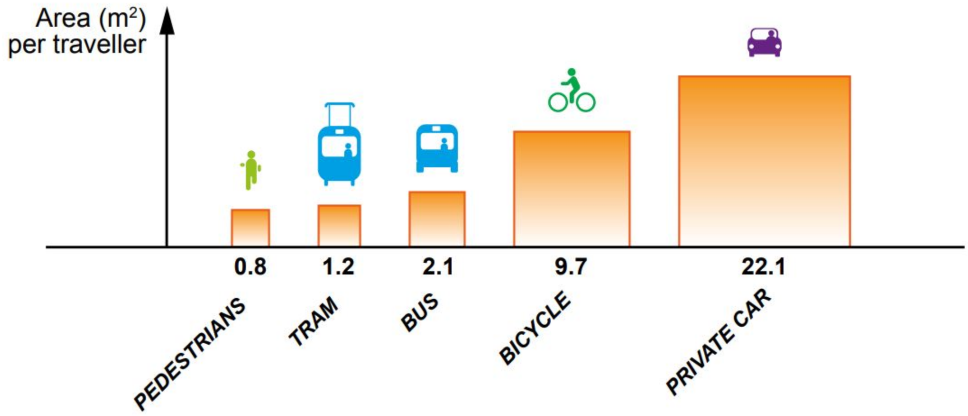
Transport has great influence on a city’s spread and characteristics. The accepted distance and time for travling per day implicate that a city is 70 minutes in diameter. Hence, the distance citizens can travel during 70 minutes with the city’s main transport mode (Lindelöw, 2018). ”Put differently, a city is as big as the speed allowed by its transport system.” (Lindelöw, 2018) Figure 2.2 shows how cities have spread over time with newer faster transport modes.



Source: (Lindelöw, 2018)
Figure 2.2: The illustration shows how cities' size is often largely a result of the average speed of their transport systems.

The road transport system has already reached a level that implies problems of accessibility (SKL & Swedish Transport Administration, 2015). Yet, prognoses from the Swedish Transport Administration (2018c) shows that the car travels in Sweden are predicted to increase with approximately 30 percent from 2014 to 2040. To create longterm sustainable traveling, new thinking is required. Urban planning should be characterized by the naturality of walking and cycling which require these alternatives to the car to be easier and more attractive. An increase of car traffic is counteracting sustainability. If car travels are to increase, infrastructure most like will have to claim more unsettled space. For pedestrians and cyclists that means substantial barriers which makes it difficult to move around. At the same time car drivers suffer in city centers where the mobility is reduced. Urban planning becomes affected because businesses tend to move away from the city centers. Further problems of accessibility is the result for those without cars. Therefore, now it is time not to design for the car and instead design for the alternative modes as walking, cycling and public transport (SKL & Swedish Transport Administration, 2015).

The car is a flexible transport mode, however it is not the most efficient one. The car dominating urban life creates traffic congestions resulting in loss of time and inefficient use of urban space (Ahlgren et al., 2018). We have seen it before, see figure 2.3, the comparison of space allocated by different modes of transport. This comparison is often used by public transport administrations to lure car drivers over to public transport. Bicycle is not the most space efficient mode either, however less space allocated by cyclists is not the only benefit. Traffic flow is improved, pollutions are reduced and travelers' health is improved with an active lifestyle (Quee & Bijlsma, 2018) & (Ahlgren et al., 2018).



Source: Norheim, Bård and Stangeby, Ingunn: Fakta om kollektivtrafikk. Transportøkonomisk institutt, Oslo, 1995.
Figure 2.3: Space claimed per traveller of different transport modes.

There are great health benefits to gain by planning for pedestrians and cyclists. An inactive person that drive his/her car for work, instead start to walk or cycle, will experience an increased well-being. The risk for cardiovascular disease will decrease by 50 percent thanks to walking or cycling 5 kilometers every day. The risk of injury when walking and cycling compared to driving is however higher, which will be covered later in the report. Yet, in the big picture the positive benefits outweigh the negative health losses from accidents. With improved safety for pedestrians and cyclists the benefits can be even greater (SKL & Swedish Transport Administration, 2013).

Today, in urban areas, the car is starting to lose its superiority in the transport system (Polle & Gidske Naper, 2018). A modern strategy in urban planning is to reclaim space from cars and give it to pedestrians and cyclists (Quee & Bijlsma, 2018). Walking and cycling have for many years been underestimated transport modes and now with all the beneficial contributions they can bring, they can have a major role in sustainable development (Quee & Bijlsma, 2018). (Ahlgren et al., 2018) argues that choosing sustainable transport modes become easier with holistic urban planning. Sustainable cities have a connected transport infrastructure creating urban spaces that are safe and lively, where people interact. If urban space is designed from a human perspective it can improve people's well-being (Ahlgren et al., 2018). Quee and Bijlsma (2018) think we may see these modes have a central role in future urban planning.

2.2.1 | A model for sustainable transportation

There is a place in the Netherlands that exhibit how effectful great urban planning can be for sustainable urban life and transport. Foletta (2014) made a case study for The Institute for Transportation and Development Policy (ITDP) on Houten because of its sustainable transport system. Houten was a small village that in the late 1960's was estimated to have high population growth over the coming years. A master plan was developed with the great intention to design the city for pedestrians and cyclists. The street layout of Houten consist of a dense network of bicycle lanes and a ring road for motor vehicles surrounding the city. The bicycle lanes are sometimes for cyclists only and sometimes shared with either pedestrians or motor vehicles. The residential neighbourhoods are connected to the ring road with narrow local streets, prioritized for cyclists, however not connected to each other. Consequently, using the ring road is the only way to access another neighbourhood by car. Cycling is therefore often the fastest transport mode having much more direct access than the car (Foletta, 2014).

Entering the local low speed streets the pavement changes from asphalt to bricks and traffic calming measures are used to bring vehicle speeds down. In the residential areas cars and bicycles are sharing the street on the premise of cyclists. The mixed use streets are secured to low speeds and signs inform road users that cars are guests. Where the bicycle lanes intersect the ring road and the train tracks, grade separation has been used to create safe links for pedestrians and cyclists. Consequently, the accessibility for pedestrians and cyclists is secured to outside the ring road while mobility is maintained for both motor vehicles and cyclists (Foletta, 2014).

In Houten ownership of bicycles is fairly high (3.4 per household) while car ownership is not as low as one can imagine. There are 415 cars per 1,000 residents in Houten compared to 530 in Zeist, another suburb at approximately the same distance from Utrecht. Still, which can be seen in table 2.1, numbers from a travel behaviour survey released 2008 reveal 55 percent of the trips made by Houten residents are non-motorized compared to 43 percent by Zeist residents. Furthermore, the share of trips by car are lower, 34 percent and 46 percent respectively. Many Houten residents work in the city of Utrecht. Commuting to work by bicycle is provided with dedicated lanes between the two cities and 31 percent of the work trips are made by bicycle. Public transport create a fast alternative to bicycle and car. There are two train stations located in Houten, each with less than 2 kilometers to the ring road, providing accessibility for all residents. Still, 53 percent of the work trips are made by car. When traveling out of the city, trips made by car are still common however within the city active transport modes are by far the most popular. Trips by Houten residents shorter than 7.5 kilometers are by 42 percent made by bicycle and 21 percent by walk. When residents visit family and friends or make errands they use active transport modes to a very high degree (Foletta, 2014). The mode splits in Houten and Zeist were quite similar, much because the Netherlands has a great bicycle culture. Therefore, in the case study Houten was also compared to the city of Milton Keynes in the UK. Milton Keynes was also designed in the 1960's however which can been seen in table 2.1, residents of Milton Keynes are much more dependent on their cars. 70 percent of all trips are made by car and only 2 percent are by bicycle.

Table 2.1: Distribution among transport modes for residents of Houten, Zeist and Milton Keynes. (Created with data from Foletta 2014)

Mode split	Houten	Zeist	Milton Keynes (UK)
All trips			
Walk	27%	14%	18%
Bicycle	28%	29%	2%
Public transport	11%	11%	10%
Car	34%	46%	70%
Work trips			
Walk	6%		10%
Bicycle	31%		4%
Public transport	10%		13%
Car	53%		73%

The city's design has resulted in high use of active transport modes with great safety and great accessibility. Additionally, activity level among Houten residents is high. Besides the higher use of active transport modes than residents of comparable places, they also tend to cycle for recreational purpose more. The city's transport system seem to encourage cycling outside necessary traveling. One can understand that maintaining and improving sustainable transport has high priority for the municipality (Foletta, 2014).

2.2.2 | Travel behaviour in Gothenburg and the West Sweden region

Travel behaviour surveys (The West Swedish Agreement, 2018) reveal that in the Gothenburg region 47 percent of the work trips (see figure 2.4) are made by car compared to 31 percent by public transport while 10 and 11 percent are made by walk and bicycle respectively. Furthermore, 49 percent of all work trips are shorter than 10 kilometers. Looking at weekday trips, 39 percent of all weekday trips shorter than 5 kilometers are made by car compared to 14 percent by bicycle. As seen in figure 2.5, on trips shorter than 2 kilometers, still 23 percent are made by car and even less 12 percent by bicycle. Walking is increasing from 35 percent to 59 percent, taking shares from all other modes. Within the whole West Sweden region the car drivers are by majority men and women travel more frequent by walk, bicycle and public transport. On the contrary, men use bicycle over longer distances. The median distance for men is 3 kilometers and respectively 2.5 kilometers for women. In comparison, the median value for car trips within the Gothenburg region is 10 kilometers. The median value indicate that half of the trips made by car are shorter than 10 kilometers.

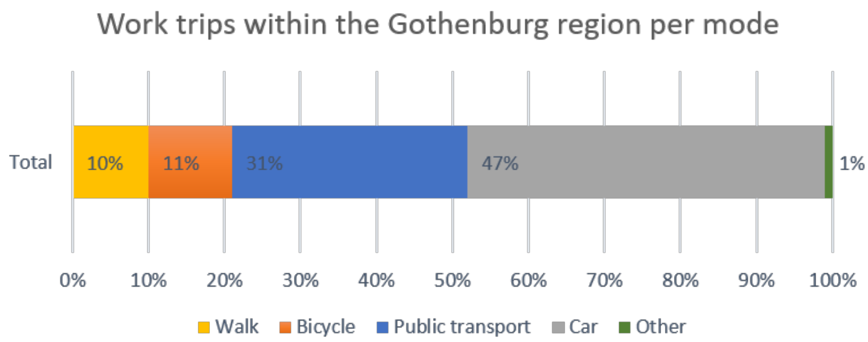


Figure 2.4: Graph showing the mode split for work trips made within the Gothenburg region. Created with data from The West Swedish Agreement

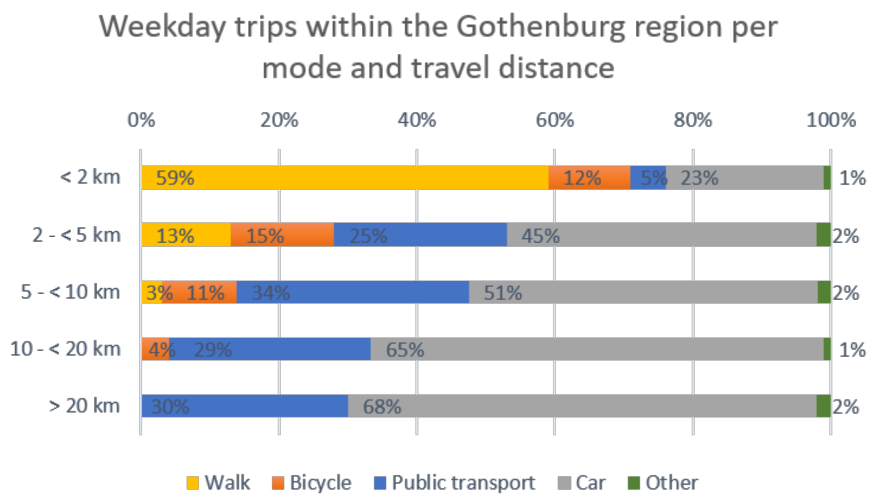


Figure 2.5: Graph showing the mode split for work trips over different travel distances. Created with data from The West Swedish Agreement

2.3 | Traffic planning and design

It is a national goal that society shall be accessible to everyone. Traffic planning must consider every road user conclusively and its abilities. Those that are most exposed need special consideration. Elderly, children and people with disabilities are among those road users and also in need of the possibility to walk and cycle (SKL & Swedish Transport Administration, 2015). Public spaces such as parks, squares and streets are sometimes referred to as the *living rooms* of the city. Streets together with buildings make the streetscapes where the building facades and trees make the *walls* of the *room* while the street inbetween makes the *floor* (see figure 2.6). These *living rooms* are to be accessible for all, regardless of age, gender and physical abilities. A prerequisite for increased accessibility is to improve the safety (SKL & Swedish Transport Administration, 2015).

Integration and separation are each other opposite, yet both fundamental in traffic planning. With integration of traffic, all or several transport modes are mixed within the streetscape and come more natural close to city centers. In order to make integration work, the speed needs to be well adopted, and the urban transport planning is of absolute importance (SKL & Swedish Transport Administration, 2015). Sharing space expresses the need for shared speed. When integration is not suitable, separation comes handy and is achieved by dividing the transport modes into time and space (SKL & Swedish Transport Administration, 2015). Separation by space can be in the form of a tunnel or bridge, and with traffic signals, the modes are separated in time. Typical for separated streetscapes include a high flow of vehicle traffic and high speeds. In order to create safe and secure solutions for pedestrians and cyclists, the streetscape is distributed among each or several of the transport modes (SKL & Swedish Transport Administration, 2015). Often pedestrians and cyclists share the space yet are occasionally separated as well. However, separation often create wide streetscapes which further encourage higher speeds and large barriers for pedestrians and cyclists (SKL & Swedish Transport Administration, 2015).

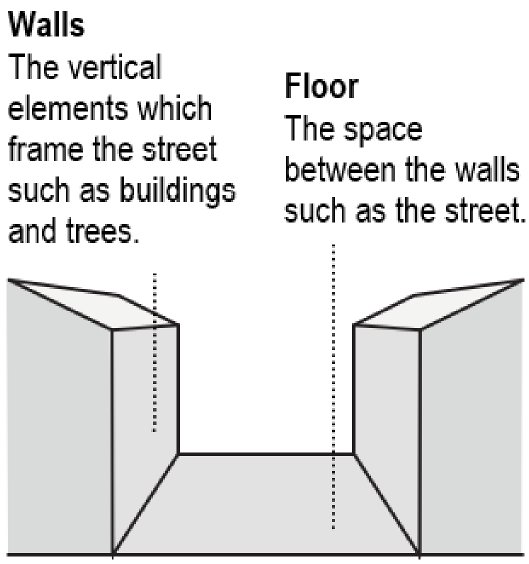


Figure 2.6: Simplistic illustration of a streetscape or so-called *living room.*

The SKL and Swedish Transport Administration (2015), divides the street network into three types of streetscapes or *living rooms.* These textitrooms are spaces where traffic and urban life interplay in different ways. At one end of the scale, the *free area* is for pedestrians and cyclists. In the *free area*, motor vehicles are seldom allowed and design is to be on a human scale with low speeds on cyclists and sporadic motor vehicles. In most streetscapes all road users are to share the space in so-called *integrated traffic space.* Cyclists and pedestrians are with road design given space whereas the space for motor vehicles is limited as much as possible. At the other end of the scale, transport is prioritized in so-called *separated traffic space.* Mobility for commercial transports as well as personal transport is of importance. Speed and design are important to establish the three types of streetscapes. With poor design the intended function of the street is compromised. The correct speed is to be secured in order to accomplish the function. Eventually, distinct self-explanatory design can make it easy for all road users to distinguish the borders between the different *rooms* as well as between areas intended for each group of road users within the streetscape (SKL & Swedish Transport Administration, 2015). Available street space shall be divided between the transport modes with regard to their demand on mobility and who is to be prioritized. Walking and cycling should be prioritized before motor vehicles in urban areas (Brandberg, Johansson, & Gustafsson, 1998).

Results from the study made by Warner et al. (2018) shows that streetscapes need to adapt. Likewise, the traffic regulations need to be better acclimatized to pedestrians and cyclists (Warner et al., 2018). Bicycles also being vehicles are not always clear. Still, the rules that apply for cyclists are often the same as for motor vehicles. On the contrary, they are often shoved to the bicycle lanes on the side of the street (Kircher, Ihlström, Nygårdhs, & Ahlstrom, 2018). In order to create safe cycling, in existing streetscapes developed for motor vehicles, it is not enough to make small adjustments in favor of pedestrians and cyclists. Today's needs are not the same as they were before when cars were in focus. Traffic planning and design need to promote and facilitate the heterogeneous group of cyclists. The main ambition shall focus on creating a safe environment for all transport modes and strive for accessibility and mobility for pedestrians and cyclists (Warner et al., 2018). The mobility of motor vehicles has often been prioritized in traffic planning, giving them direct and fast options. Letting cyclists use the same network would imply that the mobility of bicycles would increase (Nilsson, 2003).

The Government Offices of Sweden (2016) recognizes that even though traffic safety has increased, the road infrastructure is not always compatible with the needs of pedestrians and cyclists. Furthermore, their opinion is that design and maintenance should be better adapted for pedestrians and cyclists. In order to strengthen the position of cycling and its competitiveness, actions that increase flow and security must be prioritized (City of Gothenburg, 2015).

An attractive environment for active transport modes is accomplished with small blocks and a fine-grained network of streets. Wide streets create difficulties for pedestrians and cyclists as well as potentially dangerous long crossings. Furthermore, with more direct links, vehicle kilometers traveled can be reduced, creating better air and less noise. A network with many interconnected streets can consist of smaller, less wide streetscapes. Vehicle flow can be improved as well as the comfort and safety of pedestrians and cyclists (UPC, 2014).

For every street, the design should provide clear and unambiguous information about the function of the street and its requested behavior. With a self-explanatory design, the safety increase. The detailed design on the street, as well as in intersections, signalize how road users should behave (Brandberg et al., 1998), and the design must express cooperation between the road users. For a sustainable transport system, the transport modes shall coordinate and complement each other (SKL & Swedish Transport Administration, 2015). The setting, the dimensions, widths, and standard of the street indicate what speed and precaution are needed. The signal of attention can be narrowing, entrance, changed surface, speed bumps, vegetation, and so on. With colors, form, and structure, the *floor* of the streets can increase the clarity in the street infrastructure. These attributes can call for attention to all road users. Additionally, the street can be more visually attractive (Brandberg et al., 1998).

2.3.1 | SCAFT

In 1967 a research group at Chalmers University of Technology released a document of guidelines for urban planning concerning traffic safety and are commonly known within the business sector as SCAFT-guidelines. One of the major reasons for the guidelines was that the number of road accidents had increased threefold from 1950 to 1965. Additionally, most accidents happened within urban areas, and in 1965 1,270 people were killed (Nordqvist, Gunnarsson, & Lindström, 1967).

The general principle of the guidelines to obtain safe traffic was to reduce the number of conflicts between road users. The principles were suggested to be accomplished through strict separation of transport modes and homogeneous traffic flows. Especially the *hard* and fast motor traffic and the *soft* pedestrians must be given two completely separated networks. Further, cyclists should be separated from both pedestrians and motor vehicles. The bicycle lanes should be parallel to the street network, however, placed 5 meters from the street. Pedestrian paths should likewise be placed at a separation of 10 meters. Where conflicts still occur, grade separation or signalization should be used. Simplicity, predictable and uniform design could, therefore, ease the road users and avoid surprises (Nordqvist et al., 1967).

The work with separation and limited use of mixed traffic solutions created large streetscapes and large barriers for pedestrians and cyclists. The large-scaled infrastructure lost the human perspective, which reduced the attractiveness of urban space. Wide streetscapes and grade separations created safe passages for pedestrians and cyclists, however, lost in attractiveness. Insecure areas and indirect travel routes became the result. Since the SCAFT-principles were established during the time period where urban planning was focused on traveling by car, travel distances were allowed to increase (SKL & Swedish Transport Administration, 2013) and not considered for walking and cycling. Mobility for cars was important, and neither did the principles try to reduce vehicle speeds.

2.3.2 | Traffic safety

Traffic safety has had a significant impact on traffic planning over time and is essential for sustainable development. Urban space and urban life are also affected by traffic safety, which can be a catalyst for more attractive cities. The great design of urban space and a speed that is appropriately adapted to the area can help create beautiful, secure, and living urban environments (SKL & Swedish Transport Administration, 2013). Speed is crucial for traffic safety yet also has strong connections to traffic's impact on the environment. In urban areas, driving behavior has a decisive role in fuel consumption and emission release. Furthermore, higher speeds wear the pavement more quickly, releasing more particles to the air as well as increasing the maintenance needed (Transport Analysis, 2017). Noise is important for the environment and living quality, which will be improved as well with reduced speeds. Reduced speeds together with sustainable urban planning can have impacts on the mode split where the car's competitiveness is weakened, which in turn can reduce car flows (SKL & Swedish Transport Administration, 2013).

Which is illustrated in figure 2.7, the hard work with the SCAFT-principles of separation and homogeneous traffic networks had positive effects on traffic safety. From 1970 to 2019, the fatalities in road accidents decreased from 1,307 to 223. The greatest improvements were seen among killed pedestrians and cyclists, whereas 308 pedestrians were killed in 1970, and in 2019 only 27 pedestrians were killed. For cyclists the fatalities decreased from 141 in 1970 to 17 in 2019 (Swedish Transport Agency, 2020).

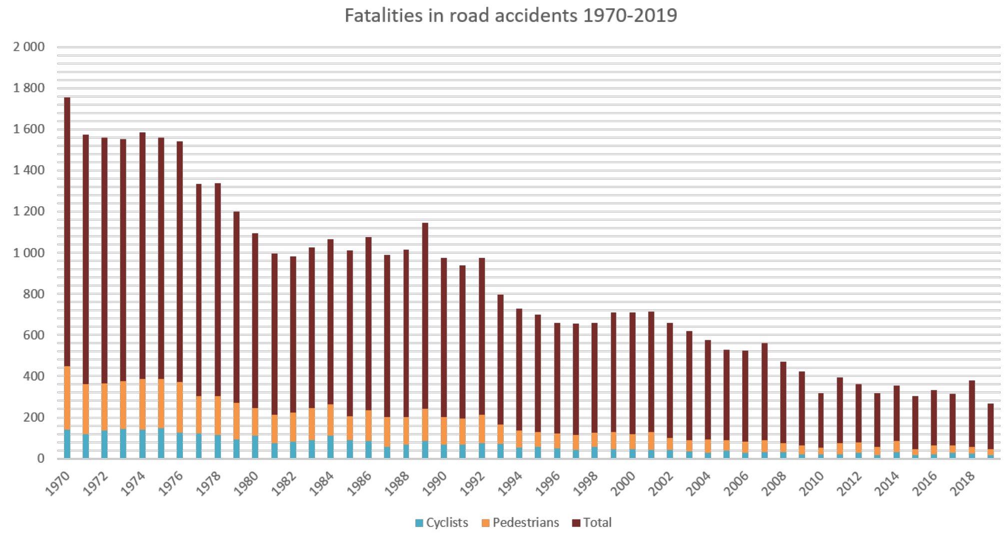
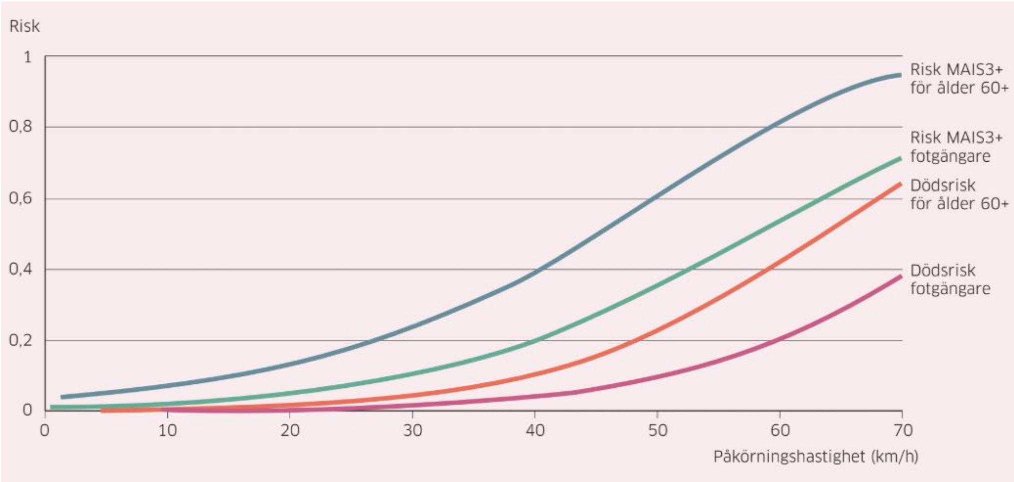


Figure 2.7: The graph shows the total number of fatalities in road accidents as well as fatalities of pedestrians and cyclists between the years 1970 and 1997 in Sweden. (Created with data from the Swedish Transport Agency)

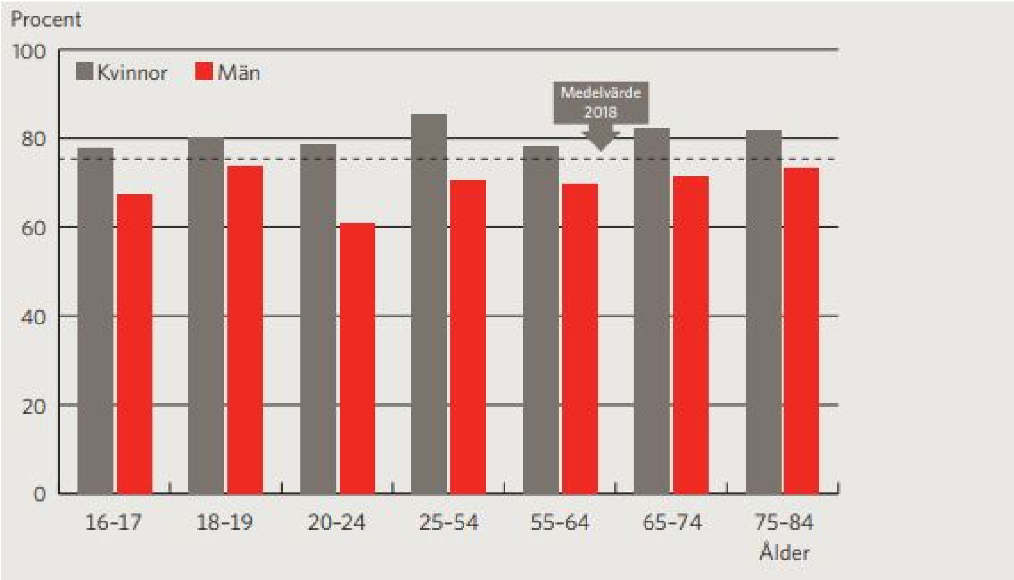
2.3.3 | Vision Zero

When the Swedish Parliament adopted Vision Zero in 1997, it was a totally new approach to traffic safety. The goal of Vision Zero is that no one should be killed or seriously injured through a road accident. Prior, traffic safety was directed at preventing accidents and that the drivers were responsible for accidents happening. With the new approach, the focus was shifted to design a transport system that will not cause serious consequences when accidents happen. The new approach accepts that humans will make mistakes, and the road users' responsibility stretch to follow laws and regulations. Instead, the responsibility lies at the stakeholders, which design the streets and vehicles as well as form the regulations. With this vision, new approaches need to be taken when designing the transport system. Human life and health are the decisive conditions and the violence the human body can tolerate without being seriously injured or killed, is the basic parameter. Consequently, when an accident happens, human tolerance should not be exceeded (Johansson, 2009). Figure 2.8 shows the risk of serious injury and death related to speed and is decisive when designing. In the absence of studies regarding the risk for cyclists, they are treated with the same model (SKL & Swedish Transport Administration, 2013). It is not the accident that kills; it is the kinetic energy and, therefore, indirect the speed. Consequently, traffic design after Vision Zero focuses on managing kinetic energy. "Pedestrian crossings generally do not lead to a safer crossing for pedestrians; they facilitate crossing a street but provide no safety in themselves." (Johansson, 2009)



Source: SKL and Swedish Transport Administration
Figure 2.8: The curves show the risk for all pedestrians and pedestrians over 60 years of age of getting killed or seriously injured (e.g. MAIS3+) when hit at increasing speed. The top blue curve is the worst case scenario and should be the decisive condition when designing areas where vehicles and unprotected road users are present.

As figure 2.8 illustrates, most pedestrians will not fall victims for severe injuries if hit by a car traveling up to 30 km/h. However, if a car hits a pedestrian driving 50 km/h or faster, the risk of serious injury or even death is much higher. Therefore, traffic should be designed so that it will not happen. Johansson (2009) states that kinetic energy can be managed by integration and separation, where compatible road users are integrated and where incompatible they are separated physically (e.g. barrier). For pedestrians and cyclists, this means they should not be exposed to vehicle speeds higher than 30 km/h. Therefore, traffic calming measures became widely introduced where pedestrians and cyclists are present and especially crossing the street (Brandberg et al., 1998). In case speeds exceed 30 km/h, vehicles and unprotected road users should be separated. Today, in Sweden, the acceptance of securing 30 km/h on streets where many pedestrians and cyclists are present is high (see figure 2.9). In the same questionnaire conducted yearly by the Swedish Transport Administration (2018e), the acceptance of reducing speed limits in benefit for traffic safety, is just over 60 percent.



Source: Swedish Transport Administration (2018e)
Figure 2.9: Graph of acceptance in Sweden for securing 30 km/h on streets where many pedestrians and cyclists are present. Y-axis show percentage and the X-axis is divided between women (left grey staples) and men (right red staples) within different age groups.

2.3.4 | Fatalities and injuries

Fatalities due to a road accident are those who die within 30 days due to the accident. To fall within seriously injured in a road accident, a person has received an injury resulting in at least 1 percent medical disability. For the accident to be defined as a road accident, at least one moving vehicle must have taken part in causing personal injury on a road generally used for traffic with motor vehicles. Consequently, pedestrians falling accidents are not included in the statistics of road accidents (Swedish Transport Administration, 2018a).

Speed has a decisive role in what the consequences will be following an accident. According to (SKL & Swedish Transport Administration, 2015), cars pose the most serious risk of traffic safety for pedestrians and cyclists in urban areas, whereas approximately 65 people die on urban streets yearly (Transport Analysis, 2017).

As seen in figure 2.10, 2019 the number of deaths reached an all-time low in Sweden (Swedish Transport Agency, 2020). However, the number in 2018 was the highest since 2010. The trend is still positive; however, the trend has stagnated since 2013 (Swedish Transport Administration, 2018a). The number of killed cyclists in road accidents is low. Still, cyclists are killed, and two-thirds of the bicycle fatalities happen in urban areas (SKL & Swedish Transport Administration, 2013).

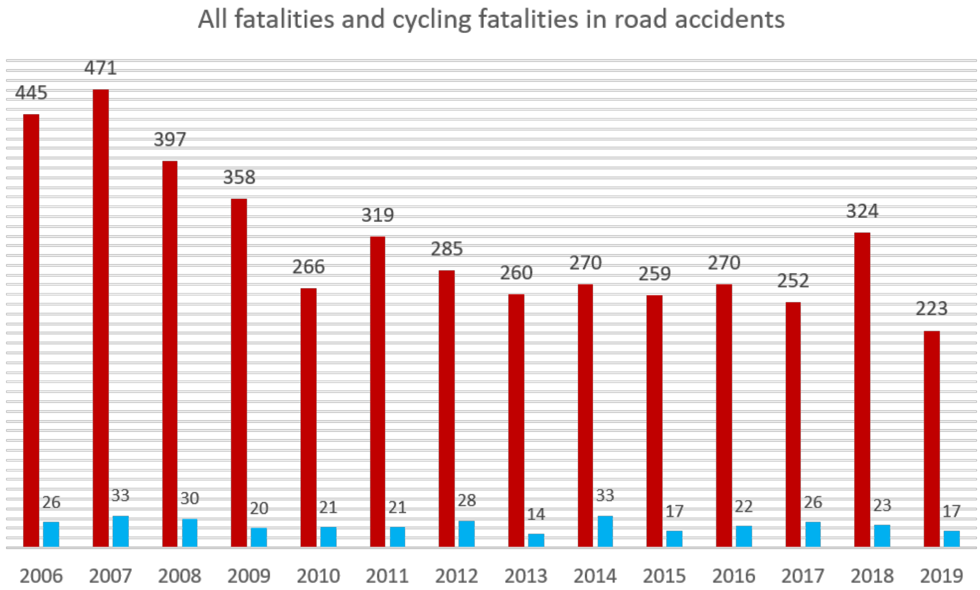


Figure 2.10: Graph illustrating with tall red staples the total fatalities and with blue staples killed cyclists. (Created with data from the Swedish Transport Agency)

The positive trend regarding fewer road accidents has, however, not affected all groups of road users as much as others (Government Offices of Sweden, 2016) (Swedish Transport Administration, 2018a). Pedestrians and cyclists are particularly vulnerable. The road infrastructure has become safer; however, it is not always designed for pedestrians and cyclists. Figure 2.11 shows that there is a negative trend with increasing numbers of injured cyclists. Seriously injured cyclists are not following any trend though, either negative or positive.

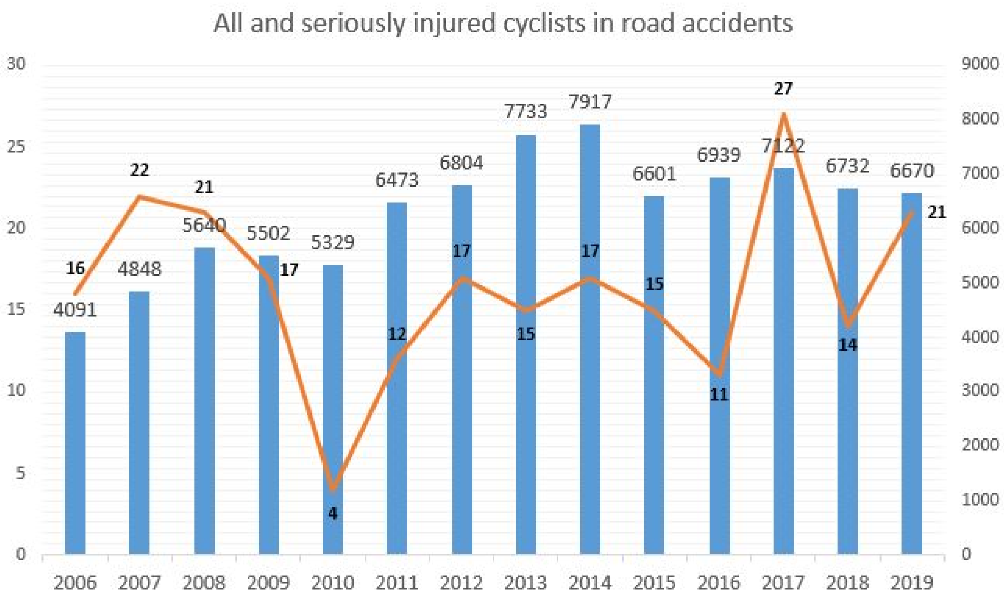
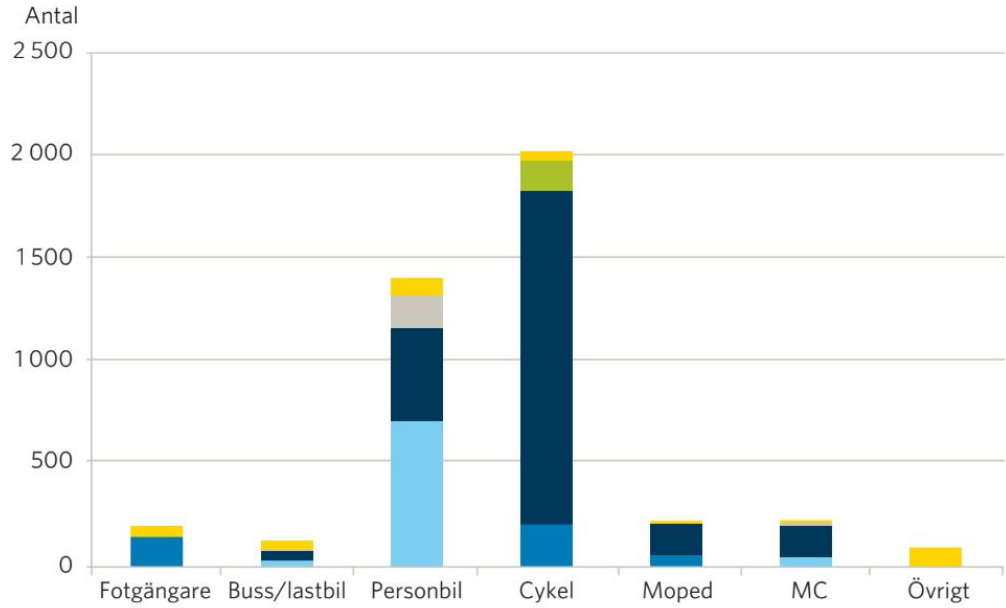


Figure 2.11: Graph illustrating with blue staples injured cyclists of all degrees and orange line seriously injured. Seriously injured are of degree ISS 9-. (Created with data from the Swedish Transport Agency)

The transport policy puts investments into improving the conditions and possibilities for active travels. In combination with an aging population, the number of accidents and its consequences can intensify, which is why pedestrians and cyclists need to be particularly addressed. Figure 2.12 shows that the vast majority of cycling accidents are single-vehicle accidents. Few are conflicts with other road users. The Swedish transport Administration (2020b, 0:40) revealed that the share of municipalities with good maintenance on bicycle infrastructure is very low, approximately 18 percent. Further, the maintenance must take greater consideration to the requirements two-wheeled vehicles have, whereas they are not as stable as four-wheeled vehicles (Government Offices of Sweden, 2016) & (SKL & Swedish Transport Administration, 2010).



Source: Swedish Transport Administration (2018a)
Figure 2.12: Graph illustrating for 2017 projected numbers of seriously injured within each transport mode. Categories from left to right: Pedestrian, Bus/truck, Car, Bicycle, Moped, Motorcycle, Other. Colors for bicycle staple: Green is indicating accident with cyclist, dark blue is single-vehicle accident, blue is accident with other road user and yellow is indicating other accidents. Seriously injured are of degree MAIS3+.

2.3.5 | Newer traffic safety

The latest effects on traffic safety have come from the vehicle industry (Berglund - personal communication April 23 2020). Safer vehicles have had a major positive impact and have removed about a third of the road accidents (Swedish Transport Administration, 2020b, 1:06). For example, Volvo cars' safety vision (Volvo Cars, 2015), set in 2008, is" that nobody should be seriously injured or killed in a new Volvo car.". As approximately 90 percent of all road accidents are due to human error (European Commission, 2015), much focus has been put into reducing the impact of drivers. New technology has made it possible to prevent accidents from happening and reduce human error. Autonomous vehicles are what most car manufacturers are working towards today. Even though the reality of those cars driving on the streets is distant, the development brings great technologies with it. Some of the technologies that are fundamental for vehicles to be self-driving are today common in newly produced everyday cars. So-called Driving Support Technologies or Driving Assist Systems can help drivers with e.g. keeping the vehicle within the lane, keeping a safe distance to vehicles in front, with blind-spot monitoring and also autonomously emergency brake if needed. Cruise control has been around for a while, and today the cruise control is also adaptive and can adjust the speed to a slower-moving vehicle in front (Euro NCAP, 2018a).

The list of technologies is long, and explaining them could not be part of this study due to time constraints. Those that are of greatest interest for this study are those assisting drivers with speed. Speed and acceleration is still very much optional for every driver. There are a couple of technologies that have attempted to limit drivers from speeding.

2.3.6 | ISA

Intelligent Speed Adaptation or Intelligent Speed Assistance or shortly used as ISA. The purpose of the technology is to help drivers not to exceed the speed limit. The system can be either passive or active, with different systems assisting the drivers. The Swedish National Road Administration (2002) conducted a trial in the early 21st century on a total of 5,000 private vehicles. The ISA anticipated the appropriate highest speed for the time and place, measured the vehicle's actual speed, and supported the drivers in different ways to adapt their speed. Three different systems were tested. The warning system gave the driver visual and auditory warning signals when exceeding the legal speed limit. With the informative system, a similar warning system was used, and in addition, a display informed the drivers of the local speed limit on the street. Also, an active system was tested where the accelerator gave a counter-pressure when the speed limit was reached.

The results of the trial showed that there was no significant difference between the three systems. All three gave speed reductions of approximately 3-4 km/h and had a positive influence on other drivers nearby. ISA was concluded to be able to help with traffic safety; however, the system needed development (Swedish National Road Administration, 2002). Today, ISA is more advanced and commonly applied in every vehicle, assisting and informing drivers of the local speed limit. The vehicles can identify the speed limit with preloaded digital map data and cameras on the vehicle (Euro NCAP, 2018a). The drivers are then informed about the speed limit, sometimes warned when speeding, and in rare cases prevented from exceeding the speed limit (Euro NCAP, 2018b).

The European Union (2019) decided on a proposal where new cars from 2022 must have ISA installed and active as default every time the car starts. The system should, however, be under the control of the driver. When given incorrect feedback or false alarms, it should still be easy to turn off and then back on again. There are, of course, those who will deactivate the system and even disconnect the system, yet the majority will drive cars that will not allow them to exceed the speed limit.

2.3.7 | Geofencing

Geofencing is a tool where a geographical area is created on a digital map (Swedish Transport Administration, 2018f) and is containing its coordinates and all parameters for the specific area (Bakhouya, Gaber, Wack, Nait-Sidi-Moh, & Nait-Sidi-Moh, 2013). The tool can be used towards all types of connected devices with a GPS, people with mobile phones, containers, and most important for this report: vehicles. Provided a vehicle is connected, it can be obstructed to enter the geographical area or when inside the area controlled by predefined rules. Vehicles being allowed into the area can be on the basis of size, weight, fuel, tire type, noise, etc. Once in the area, the predefined rules can automatically control the speed of the vehicle or what fuel it can be propelled on (provided that the vehicle has more than one fuel) (Swedish Transport Administration, 2018f).

Figure 2.13: Conceptual illustration of how geofencing can work. (Swedish Transport Administration, 2018f)

Research and development have been done on geofencing for several years in Sweden related to security and defense of the country. Geofencing against terror attacks has been a driving factor (Bakhouya et al., 2013). The terror attack in Stockholm 2017 caused the Swedish government to further invest in geofencing (Swedish Transport Administration, 2018f).

The geofence can have dynamic pre-definitions. Rules connected to the geographical area can differ with time and can, for example, be simple as day and night but also more advanced as current traffic situations. The geographic area can be controlled minute-to-minute on pre-known situations as events, roadworks as well as more unexpected events such as accidents and changed road conditions.

Even though (Bakhouya et al., 2013) did not foresee speed restriction as a possible application for geofencing, it is by Maria Krafft, Director of Traffic Safety at the Swedish Transport Administration, seen as the major win with the technology (Swedish Transport Administration, 2018d). Geofencing is estimated to help to realize Vision Zero by reducing speeds. Moreover, it ought to make vehicles move on the condition of people and being an efficient tool to create safe and sustainable cities. With today's complex urban transport systems, geofencing can benefit pedestrians and cyclists, especially. Furthermore, with the technology, cities can reduce noise and pollution locally by creating quiet and clean zones (Swedish Transport Administration, 2018f). The speed restrictions and clean zones are being tested in Gothenburg with geofencing implemented in the bus lines 16 and 55 (Swedish Transport Administration, 2018f). Figure 2.14 shows the route of bus line 55, and the speed controlled zone and zero-emission zones are illustrated. The low-speed zone is placed where the bus needs to collaborate with cyclists and pedestrians (ElectriCity, 2016).

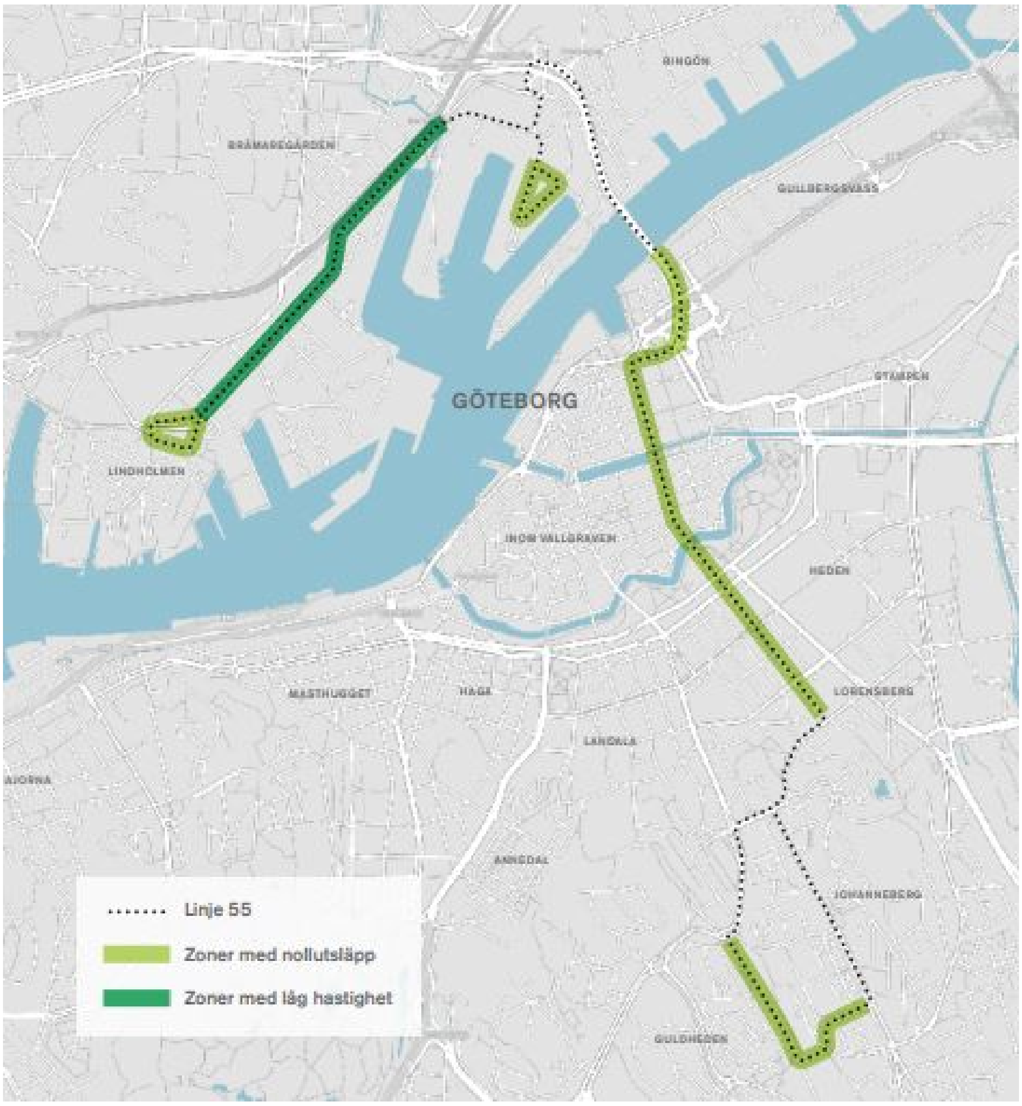


Figure 2.14: Illustration of the route of busline 55 in Gothenburg at its geofencing zones. Light green indicates zero emission zones and dark green indicates speed controlled zone. (ElectriCity, 2016)

In street design today, access to areas and the speed limit are controlled by physical measures and traffic regulations. Physical traffic calming measures and bollards restricting access seemingly fall unnecessary with geofencing in operation. Yet, Swedish Transport Administration (2018f) predicts the speeding vehicles off today to drive just under the speed limit with geofencing (see figure 2.15). In summary, geofencing will not affect the majority of cars that drive below the speed limit. Johansson (personal communication May 13 2020) however, believes in a herd effect where the distribution will be shifted, and all vehicles will drive slower. According to Swedish Transport Administration (2018f) the mean speeds are analyzed to drop

4-5 km/h on 30 km/h-streets and 2-3 km/h on 40 km/h-streets. The speed reductions will save two lives over three years and cause approximately 16 serious injuries less every year. The physical measure will still be needed in order to reduce the speed at crossings, letting pedestrians and cyclists cross the street safely. Also, the measures can fill a visual purpose for drivers to understand the speed limit. However, there is an interesting thought of how precise the geofencing technology can be applied and whether crossings always can be speed controlled with geofencing.

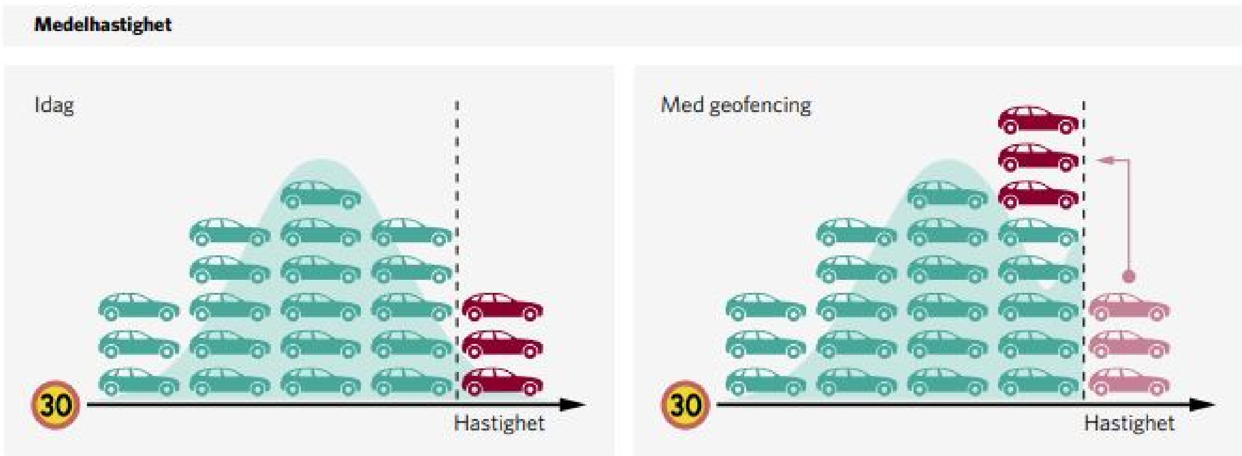


Figure 2.15: On the left, an illustration of the distribution of speeds today, where red cars are driving above the speed limit. On the right, geofencing has been implemented and the illustration shows what will happen with the distribution, assuming the affected cars will drive just under the speed limit. (Swedish Transport Administration, 2018f)

The technology has a long way to full implementation. First of all, vehicles need to be connected, and a digital infrastructure must be built. A digital infrastructure is a database with plenty of information and parameters. Also, regulations have to be looked over and if and how regulations could be forcing the technology on vehicles (Swedish Association of Transportation Planners, 2019). Important though, even if not all vehicles are equipped with geofencing technology, there is an indirect speed reduction on other vehicles as well. When one vehicle is moving slower, vehicles around must drive slower, causing the mean speed to decrease. Today, 2020, the Swedish Transport Administration (2020b, 1:22) claim that launching geofencing on a larger scale is only a matter of will since most of the work has been done. New buses use the technology, and in new cars, the technology is passive. Trucks are soon to be built with the technology. The technology exists, and now the Swedish government and the Swedish Transport Administration must coordinate how they want to use it.

2.3.8 | Outlook for traffic safety and challenges

The technology is promising; however, the effect will not occur in another 8-10 years since the technologies only exist in new newer vehicles (Swedish Transport Administration, 2020b, 0:56). The work on traffic safety must continue with more hands-on measures.

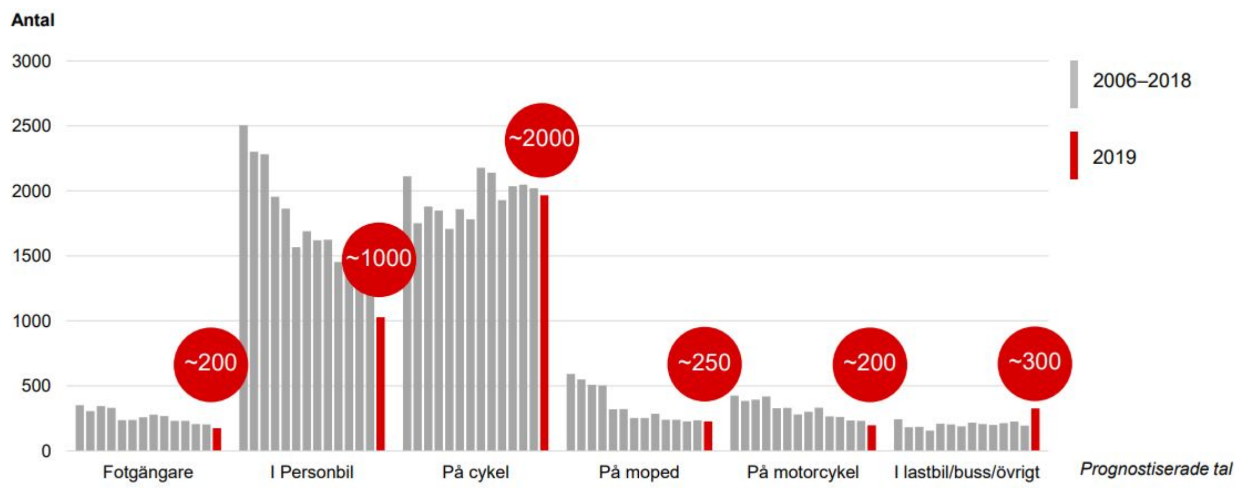
One of the latest intentions to create safer streets involve reducing the default speed limit in urban areas from 50 km/h to 40 km/h. A change that will have great impacts on traffic safety for pedestrians and cyclists and on the urban environment as a whole. The idea is still under investigation and in an analyzing stage (Transport Analysis, 2017).

Transport Analysis (2017) tested a scenario where 80 percent of the Swedish street network with the speed limit of 50 km/h was reduced to 40 km/h. The other 20 percent will remain 50 km/h to maintain motor vehicle mobility on essential thoroughfares. Based on prior knowledge, with a speed reduction from 50 to 40 km/h, the mean speed will decrease by 1-4 km/h. Therefore, the mean speed will decrease from 45.2 to 42.9 km/h. The prognoses show that a speed reduction of 2.3 km/h saves four people's lives yearly. Additionally, approximately 68 seriously injured and 10 very seriously injured will be prevented.

Lower default speed will have the greatest positive impacts on traffic safety but also security. The improvements will impact pedestrians and cyclists, especially. Reduced vehicle speeds will enable a higher portion of integrated streetscapes. Foremost, the possibility for cars and cyclists to share the roadway is greatly improved. Slow-moving traffic with mostly pedestrians and cyclists will increase social security, which will have the greatest impact on women who estimate risk higher than men. As mentioned before, speed also has strong connections to traffic's impact on the environment. A reduced default speed will have positive effects on fuel consumption, emissions, pavement wear, air particles, noise as well as the living quality and mode split. The positive effects will be even greater if the reduced speed motivates a shift from motorized travels to more walking and cycling (Transport Analysis, 2017).

In order to realize reduced speeds within the speed limit the (Swedish Transport Administration, 2020b, 0:54) is looking over the possibilities of using automatic traffic enforcement cameras on urban streets. Traffic enforcement is very effective for vehicle speed compliance.

New transport modes pose challenges for traffic safety and urban planning. E-scooters, for example, has only recently been launched yet have been immensely popular. However, these types of transport modes are not specifically included in traffic regulations, and infrastructure has not been planned and designed for them either. The Swedish Transport Administration (2020b, 0:44) reveals that seriously injured within the group *Other* has increased dramatically (see figure 2.16). Most of the increase is due to e-scooters, which stand for approximately 150 seriously injured during 2019.

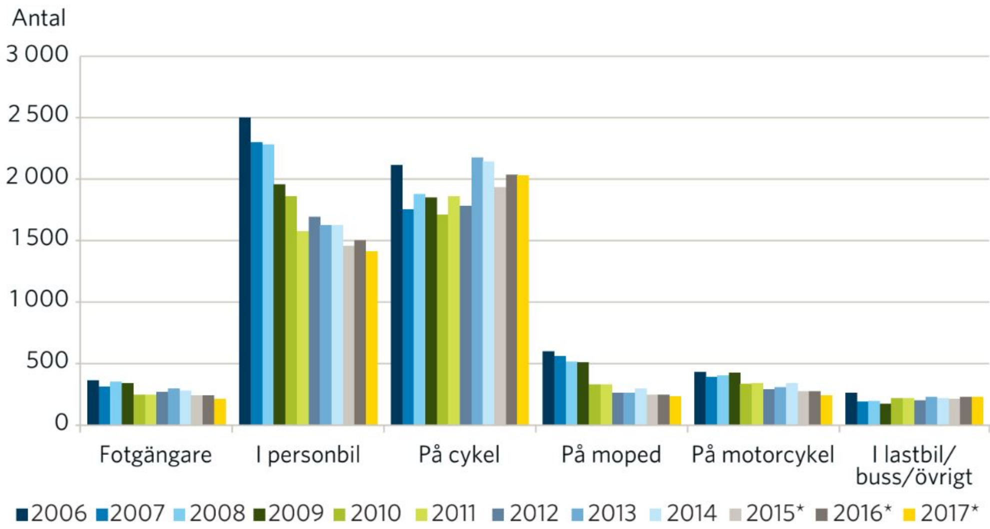


Source: (Swedish Transport Administration, 2020b)
Figure 2.16: Graph illustrating for 2019 projected numbers of seriously injured within each transport mode. Categories from left to right: Pedestrian, Car, Bicycle, Moped, Motorcycle, Truck/Bus/Other. Colors for bicycle staple: Green indicating accident with cyclist, dark blue single-vehicle accident, blue accident with other road user and yellow indicating other accidents.

2.3.9 | Cycling safety

In the study that Thulin & Nilsson (1994) did, they found that the risk for cyclists to be seriously injured (including death) is over seven times higher than for car drivers. The risk of dying is four times higher. To put in perspective, the numbers for pedestrians are eight and nine times the risk of dying as a car driver. These numbers are created upon distance traveled. However, since pedestrian and cyclists each have a shorter range (Lindelöw, 2018), (Warner et al., 2018) translated the numbers for cyclists into the risk to die per trip and per time traveled. Per trip, the risk to die is 1.3 times higher than for car drivers, and 2 per time traveled.

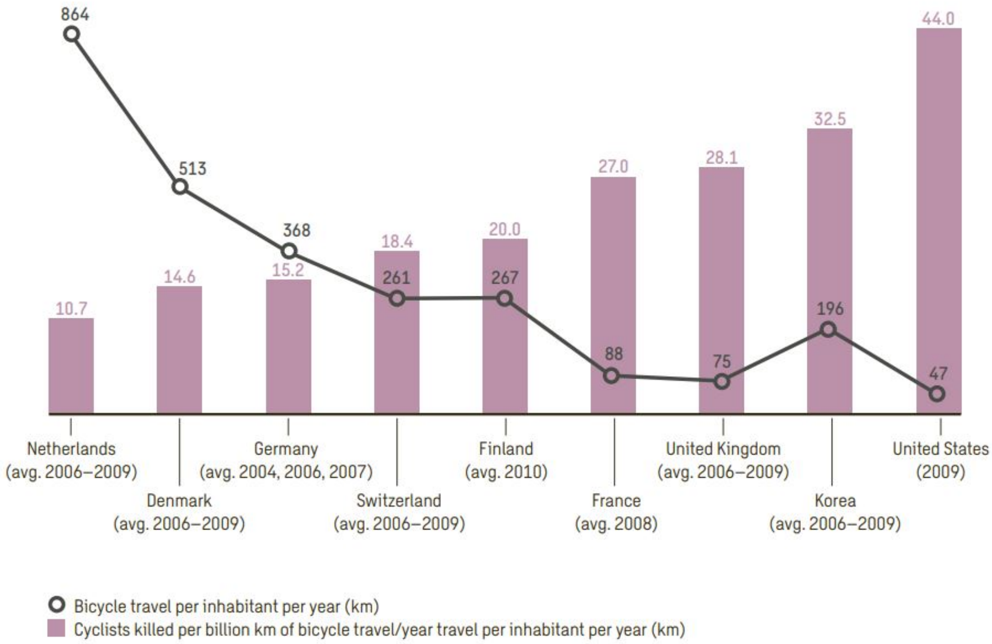
The Swedish Transport Administration (2016) points out that radical actions need to be taken to reduce the number of injured cyclists, especially single-vehicle accidents. The injured road users are dominated by the cyclists (Swedish Transport Administration, 2016) and are at 90 percent of the times wounded within urban areas (SKL & Swedish Transport Administration, 2013). As can be seen in figure 2.17, since 2011, cyclists are the group of road users suffering the highest number of serious accidents. Consequently, pedestrians and cyclists are those who suffer the largest health losses (SKL & Swedish Transport Administration, 2013).



Source: (Swedish Transport Administration, 2018a)
Figure 2.17: Graph illustrating for 2017 projected numbers of seriously injured within each transport mode. Categories from left to right: Pedestrian, Car, Bicycle, Moped, Motorcycle, Truck/buss/other.

Which was mentioned in section 2.3.2 Traffic safety; the number of killed cyclists has decreased since the 1960s. Warner et al. (2018) indicates that the reduction of seriously injured cyclists can be connected to the work on separation and speed reduction.

According to (Quee & Bijlsma, 2018) the best way to improve safety for cyclists is to increase the number of cyclists (and pedestrians). Figure 2.18 shows that the stronger position cycling has in its country's transport system, the fewer fatal accidents occur. Thus, more active travelers - greater safety, greater safety - more active travelers. This hypothesis is called "Safety in numbers".



Source: OECD Cycling Health and Safety
Figure 2.18: Graph illustrates an international comparison of bicycle fatalities and how they decrease with kilometers traveled

Logically, the more vulnerable road users on the street, the more crashes are assumed to occur. However, research claims that this is not the case. Tasic, Elvik, and Brewer (2017) conclude in their study that a safety in number effect is found and is consistent with previous research on the topic. An increased exposure would not proportionally increase the number of crashes. The crash rate per unit of exposure decreases with the increase of the exposure.

2.4 | Bicycle infrastructure

On a local level, the municipalities must coordinate with the national planning. It is foremost the municipalities that administer the great majority of pedestrians and cyclists on their local street infrastructure. Walking and cycling must be part of the master plan as well as the detailed design (SKL & Swedish Transport Administration, 2010).

In central parts of a city, the bicycle is often the fastest transport mode. Since travel time is important, Therefore, cycling has great opportunities to be a competitive way to travel (City of Gothenburg, 2015). Walking and cycling can reduce travel time and even be the most comfortable transport mode (SKL & Swedish Transport Administration, 2015). (City of Gothenburg, 2015) admit that the bicycle infrastructure in the city is inadequate. A common issue with bicycle infrastructure is that it is done afterward in existing vehicle infrastructure, leaving cyclists with badly connected infrastructure. Frequently, cyclists are expected to share the space with pedestrians, although their speeds and needs are not the same (Kircher et al., 2018). Cyclists have, for a long time, been paired together with pedestrians as a homogeneous group. Common names are *unprotected or vulnerable road users* and *active travelers* (Quee & Bijlsma, 2018). Unlike vehicle drivers and pedestrians, cyclists are a much more heterogeneous group and especially due to their different capabilities. The physical abilities and the purpose of the trip are important aspects. The need within the bicycle infrastructure varies among age, how often, and with what speed one cycle (Warner et al., 2018).

The difference in speed between pedestrians and cyclists makes mixing them unsafe. One issue with the safety and security of pedestrians that apply for all types of bicycle infrastructure includes the speed of cyclists, which is difficult if not impossible to reduce at crossings (Raja Ilijason, traffic engineer at the City of Gothenburg - personal communication April 29 2020). Further research is needed to find suitable traffic calming measures for cyclists. With new modes of transport such as electric bicycles and e-scooters as well as the changes in mode split and consequently increased mean speeds, increase the unsafe environment. (SKL & Swedish Transport Administration, 2010) recommends separating pedestrians from cyclists in existing urban space. The (City of Gothenburg, 2015) mentions the same thing as an important action in what they reckon will have positive impacts on the bicycle infrastructure. Bicycle lanes need to provide high quality and comfort. Pavement should be uniform and flat with high friction. Asphalt is good, providing all of those features. The flatness is of great importance due to bicycles generally have no suspension. Therefore, cobblestones are not a good solution for bicycles (City of Gothenburg, 2015). According to Michael Koucky, traffic engineer at Koucky & Partners (personal communication April 3 2020), cobblestones are not a good solution for anyone. The comfort on the uneven surface is bad for both pedestrians and vehicles. Pedestrians with strollers and rollators tend to avoid the walking lane paved with cobblestones if there is a bicycle lane paved with asphalt next to it. Eriksson, Niska, Sörensen, Gustafsson, and Forsman (2017) noted the same situation in their study that on shared walking and bicycle lanes separated with stone pavement for walking and asphalt for cycling pedestrians in higher degree used the bicycle dedicated lane where the comfort was higher. This was compared to other shared lanes where the pavement was the same over the whole path. As mentioned, cobblestones are not good for vehicles either. The comfort and speed are reduced. However, in some places, this can be used as an advantage where the presence of pedestrians and cyclists is high. Likewise, the use of pavement can help steer cyclists to where they are wanted since cyclists will choose the best pavement (SKL & Swedish Transport Administration, 2010).

Two-way bicycle traffic is the most common solution in Gothenburg and also nationally. However, in great cycling cities, one-way cycling is common. Accordingly, the City of Gothenburg (2015) suggests that the city should strive for mainly using one-way bicycle traffic in urban settings. There are, in fact, several advantages with one-way cycling in urban areas. Except for creating a uniform and continuous bicycle infrastructure that can easily switch between separated and integrated traffic, mobility, orientation, and traffic safety are improved (City of Gothenburg, 2015). Prior studies have shown that the safety is higher in intersections when cyclist are in mixed traffic or in on-road bicycle lanes (Nilsson, 2003), which are both infrastructural solutions for one-way cycling. Safest connection to the intersection was related to on-road bicycle lanes, then mixed traffic and last separated bicycle lanes (Nilsson, 2003). Correspondingly, (SKL & Swedish Transport Administration, 2010) states that on-road bicycle lanes and mixed traffic (Kircher et al., 2018) are safer solutions in intersections since they make cyclists visible for drivers but mostly because the bicycle traffic is one-way. The reason is that the number of conflicts with one-way cycling is much less than for two-way cycling. Figure 2.19 and figure 2.20 show the points of conflict in a four-way intersection for two-way cycling and one-way cycling, respectively.

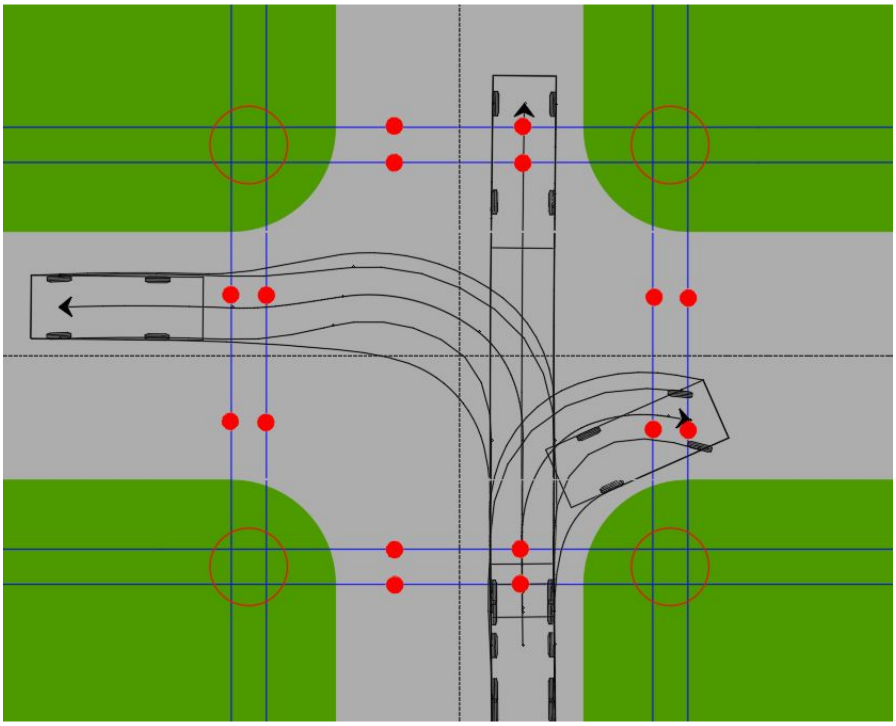


Figure 2.19: Simplistic illustration of conflict points between motor vehicles and bicycles in a typical four-way intersection with two-way bicycle lanes. Red dots on grey indicate conflicts vehicle-bicycle while red circles on green indicate each four conflicts bicycle-bicycle.

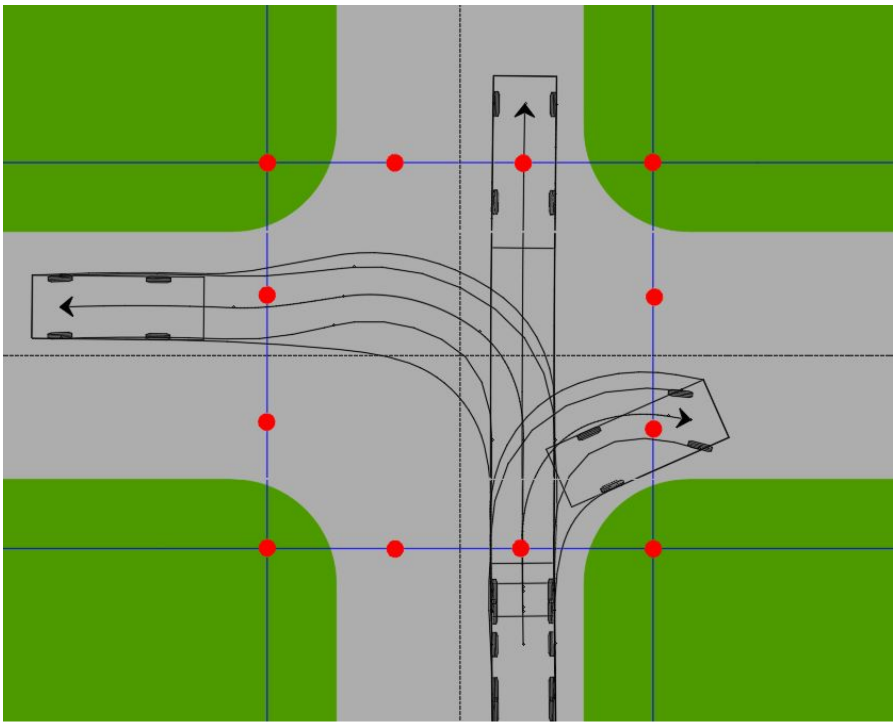


Figure 2.20: Simplistic illustration of conflict points between motor vehicles and bicycles in a typical four-way intersection with one-way bicycle lanes. Red dots on grey indicate conflicts vehicle-bicycle while red dots on green indicate conflicts bicycle-bicycle.

When using one-way cycling, it is important to provide it in both directions to prevent cyclists from using them in the wrong direction. However, to regulate the bicycle lanes for one-way cycling, changes in the regulations are needed. SKL and Swedish Transport Administration states that directional road markings are not enough. Furthermore, crossing the street should be uncomplicated, and vast distances between crossings must be avoided to maintain the accessibility (City of Gothenburg, 2015). In exceptional cases, one-way in only one direction can be implemented. Such exceptional cases include high demands of separating cyclists from pedestrians in e.g downhills, or when separation from motor traffic can only be made on one side. Only in such cases, the alternative can be useful.

Kircher et al. (2018) believe that the discussion around mixed traffic cycling must take into account the different types of cyclists, whereas the cyclists have varying comfort levels of mixed traffic cycling. It is often indicated that cyclists feel safer and more secure on separated bicycle lanes than in mixed traffic (SKL & Swedish Transport Administration, 2010). Hunt and Abraham (2007) found with their study that the willingness for cycling in mixed traffic increases with cycling experience. Kircher et al. (2018) could somewhat confirm that with their study, where fast cyclists used the roadway more frequently while comfort cyclists avoided mixed traffic. The comfort cyclists put security first at the expense of efficiency. This confirms that speed and experience (which is often assumed to be highly correlated with speed) have a significant role in the willingness to share the road. The conclusion that (Kaplan, Luria, & Prato, 2019) draw from their study is that cyclists and drivers sharing the street is more than physical changes. The social climate in traffic is of outright importance. The success to mixed traffic highly depends on mutual respect and empathy. How cyclists believe drivers see them and how they view themselves of drivers, affect the social climate. (Kaplan et al., 2019) suggest that "if cyclists believe that drivers perceive them as vulnerable, they are more likely to perceive themselves as vulnerable".

"Therefore, developing solutions that are efficient, yet safe, or providing several solutions, depending on personal preferences, are key to an infrastructure that is accepted by most and used as intended." (Kircher et al., 2018). Choices available have increased since two years back. The regulations regarding cyclists using the roadway changed in 2018 (Ilijason 2020-04-29 - personal communication) and now allow cyclists to do so even when separated bicycle lanes are present. When concluding, Kircher et al. point out the importance to further investigate why some cyclists within the heterogeneous group are disadvantaged when the national transport goal wants equal accessibility for everyone. (Kaplan et al., 2019) suggest that drivers should be given messages that cyclists have equal rights to the street. Disregarded the streetscape, bicycle symbols are essential since the symbols fulfill a purpose not only for cyclists yet also, and especially, for vehicle drivers who are alerted and reminded about where cyclists travel (SKL & Swedish Transport Administration, 2010). Colored pavement also increases the awareness of drivers, and cyclists perceive it as positive. The color does not affect the regulations that apply for the street, and in Sweden, colored bicycle lanes are typically red and almost exclusively used on crossings and in intersections. However, colored asphalt is usually more expensive than regular asphalt due to the use in smaller quantities. Furthermore, no studies related to colored bicycle lanes support the increased safety that cyclists perceive. Still, the color increases awareness and, consequently, also the traffic safety. Great design can not only provide a safe and efficient bicycle trip. Greenery can help create a colorful experience that gives recreational value and relaxation. Moreover, the trip will be perceived as shorter, the air quality can be improved, and the trip can be experienced as less noisy. Green elements such as trees and other vegetation can help create changes between open settings with sunlight and closed settings such as an allée of trees, to create shadows (SKL & Swedish Transport Administration, 2010).

2.4.1 | Cycling speed and retardation

Bai, Chan, Liu, and Xu (2017) found that there is a correlation between speed and rear-end conflicts on bicycle lanes. When the speed difference was higher between cyclists, rear-end conflicts increased. Higher speeds also increased the frequency. Except for speed, flow, and lane width correlated as well. Greater flows increased the number of conflicts, and wider lanes showed a reduction.

The correlation of rear-end conflicts between cyclists brings questions regarding the correlation between cyclists and cars. Swedish Transport Administration (2020a) estimates the reaction time of cyclists to be somewhere between 1.5-2 seconds. For car drivers, the time is estimated to be 1-2 seconds. Consequently, cyclists and car drivers travel about the same distance before they start to brake, provided they have the same speed. According to the Swedish Transport Administration, the retardation for cars decreases with speed. The same can be assumed for bicycles, however, to what extent is difficult to say. For speeds up to 60 km/h, the retardation for a car is 3.5-4.5 m/s2. For bicycles, the number is estimated to be 3 m/s2 (no speed correlation is given). Accordingly, car drivers can stop in a shorter distance than cyclists. Berg and Alf (2017) made a field study to analyze whether the numbers from the Swedish Transport Administration corresponds with reality. Their results showed that braking distance strongly correlates to the braking system the bicycle is equipped with. Nonetheless, the results also showed that stopping within the given distances were generally not a problem. Conclusively, more research is needed to be sure to say that stopping distance is shorter for car drivers than cyclists, or reversed.

The speed among cyclists vary. According to SKL & Swedish Transport Administration (2010), the mean speed is 16 km/h yet also state that speeds up to 40 km/h can occur. The dispersion of speed is greatest in uphill and downhill movements. Eriksson et al. (2017) questioned the mean speed of 16 km/h and made a study on cyclists' speeds. They could conclude that mean speeds depend on inclination and traffic composition, yet fall in the span of 15-25 km/h. Therefore, they recommend the mean speed of cyclists should be seen as 20 km/h. Eriksson et al. also discussed the impact of flow on the mean speed. It could be possible that with higher flows, every cyclist finds it more difficult to travel with the desired speed. The results show a tendency towards higher mean speeds with higher flows of bicycles. This is interesting since for vehicles being the opposite. The authors suggest that it has connections to commuting, where the share of fast cyclists is greater and the travelers being in a hurry.

Warner et al. (2018) believe that the use of electric bicycles will increase the coming years. Besides the positive benefits of electric bicycles, there might be a complexity regarding the type of cyclists and their speed since studies show that electric bicycles are most common among comfort cyclists. The electric assistance contributes to a higher cycling speed than comfort cyclists typically have. Still, the comfort cyclists use the bicycle infrastructure differently from e.g. fast cyclists. Suddenly, there is a group of cyclists that could be mentioned as fast comfort cyclists that demand the bicycle infrastructure to be designed for higher speeds yet provide a secure network, preferably separated from motor vehicles. Additionally, the increased weight and speed of the electric bicycles create further concerns regarding the stopping distance.

Warner et al. state that the brakes for regular bicycles do not create enough retardation for electric bicycles. Furthermore, tuning an electric bicycle is possible, allowing the motor to provide assistance above 25 km/h. There are, however, no indications of how common it is.

2.4.2 | Swedish traffic regulations related to cycling

Below a selection of traffic regulations related to cycling has been extracted from the Government Offices of Sweden's website (Government Offices of Sweden, 2001).

Chapter 3, paragraph 6 states that bicycles shall be operated on the bicycle lane if available. Cyclists are however with special precaution allowed to use the roadway instead of bicycle lane if
1. the cyclist is 15 years or older, and
2. the speed limit in the roadway is 50 km/h or lower and otherwise when more appropriate with regard to the location of the destination.

According to paragraph 7, when cycling in the roadway, bicycles shall be operated as close as possible to the right-hand side of the shoulder or lane that is used. According to paragraph 12, the shoulder shall be used when a separate bicycle lane is missing, provided that the shoulder is wide enough and suitable to use. Motor vehicles can momentarily use the shoulders to ease mobility for other traffic. Additionally, paragraph 12a states that children up to the age of 8 years are allowed to use sidewalks when a bicycle lane is missing.

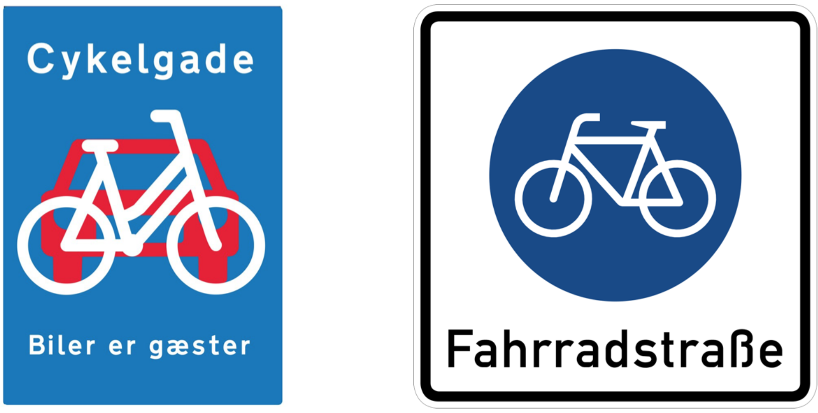
When in traffic, paragraph 14 states that speed shall be adapted to what the traffic safety demand. Consideration shall be taken to the road, terrain, weather and visibility conditions, the vehicle's condition and load, and traffic conditions in general. The speed is never allowed to be higher than the driver can remain control over the vehicle and stop within the distance ahead that the driver can overview before every obstruction that can be foreseen. Also, according to paragraph 15, low enough speed shall be used within urban areas and at crossings. Still, the default speed limit of 50 km/h within urban areas apply, according to paragraph 17.

According to Swedish regulations, electric assisted bicycles are limited to power assistance up to 25 km/h, and the motor is only allowed to assist when pedaling. A bicycle that exceeds these limitations, such as a motorized bicycle, is classified as a moped.

Under chapter 6, regulations for bicycle and moped traffic, paragraph 1 (Government Offices of Sweden, 1998) states that cyclists shall travel after each other. When it can be done without danger or obstruction to traffic, they are allowed to travel side by side.

2.4.3 | Bicycle street

The concept of bicycle street has in Sweden yet no legal basis. There are no traffic regulations and no road signs related to it. In Gothenburg the concept is being tested in order to evaluate whether it can work as a missing link in the bicycle infrastructure within the city center. Besides Gothenburg, the first try out was done in Linköping, and in countries such as the Netherlands, Denmark, and Germany, bicycle streets are quite common. In figure 2.21, typical bicycle street signs are illustrated.



Source: Flickr.com and wikipedia.org
Figure 2.21: Two types of road signs for bicycle street in Denmark and Germany respectively. Both translate to *Bicycle street* and the left also adds *Cars are guests*.

The objective of the bicycle street concept is to provide cyclists with higher accessibility. The cyclists are using the roadway together with the car drivers who are to yield for the cyclists and drive with their speed (Warner et al., 2018). Denvall and Johansson (2013) wrote in their thesis on bicycle streets in Gothenburg that the design should benefit the cyclists as much as possible. Consequently, the comfort and mobility of motor vehicles will be reduced, yet the accessibility is maintained. In order for the concept to work, the flow of bicycles must be expected to be greater than the flow of motor vehicles (City of Gothenburg, 2019). The SKL and Swedish Transport Administration (2010) states that bicycles are preferably twice as many, and the maximum number of motor vehicles is 500 per day.

The pavement of the bicycle street leads the cyclists into the middle of the driving lane. Therefore, the street design must be self-explanatory for both cyclists and drivers that cyclists have priority. As seen in figure 2.22, bicycle streets in Gothenburg are paved with an asphalt strip of approximately 1.5 meters with cobblestones on each side. The cobblestones are there to keep the cyclists within the asphalt strip intended for them (Ilijason - personal communication April 29 2020). Daniel Sjölund (personal communication April 29 2020) traffic planner at the City of Gothenburg explains that the width of the asphalt strip has been discussed considering cyclists to be able to overtake each other. Also, the width of the drive lane matter. Legally, the width could be 2.8 meters, but the City of Gothenburg has chosen a width of 3.5 meters with the explanation that maintenance is beneficial and that bicycle streets with this width achieve the positive effects wanted without obstructing motor traffic excessively (Ilijason - personal communication April 29 2020). The total width of the roadway should, according to (SKL & Swedish Transport Administration, 2010) be 4.5 meters to provide enough space for two cyclists in each direction.

Figure 2.22: Street view of bicycle street at Redbergsvägen, Göteborg.

Ilijason (personal communication April 29 2020) explains that the bicycle street in Gothenburg was implemented first and foremost as a measure in favor of pedestrians. The measure aims at giving priority to the transverse movement of pedestrians. An issue in the most central parts of Gothenburg was the lack of yielding from cyclists compared to drivers. The concept of bicycle streets was, therefore, interesting to try out on streets tailored for implementation. Ilijason strongly points out that bicycle streets are definitely not suitable everywhere. In fact, she says that very few places are appropriate and need to be carefully chosen and tailored for the task. The high presence of pedestrians and transverse movement are requirements in order to implement bicycle streets. It creates a natural traffic calming measure that appears logical for traffic on the bicycle street.

The safety and security of the cyclists require overtaking to be prevented. Consequently, the concept is not suitable for longer distances or on uphill stretches (City of Gothenburg, 2019). To secure no overtaking, Ilijason (personal communication April 29 2020) highlights that a central divider is essential to prevent it. She explains that the City of Gothenburg wants all cyclists to behave as brave cyclists. Hence, cyclists should take their place and not let drivers overtake. Cautious cyclists, however, tend to move aside. Furthermore, Ilijason believes that the traffic regulations are somewhat contradictory. It is always the vehicle in front that decides whether to be overtaken or not, yet at the same time shall cyclists keep to the side and not unnecessarily obstruct the traffic behind.

Collaboration between the cyclists and drivers is of great importance, and therefore speeds must be secured to be low, especially for motor vehicles. (SKL & Swedish Transport Administration, 2010) suggests that the actual speed should be 20 km/h. The street generally needs traffic calming measures to obtain the desired speed. The speed is absolutely crucial for traffic safety. Yet, Ilijason (personal communication April 29 2020) reveals that statistics show the safety to be a non-issue where bicycle streets are correctly implemented.

Evaluations of Västra Hamngatan (Lagerqvist, 2013) and Redbergsvägen (Wigeborn, 2016) after reconstruction show that the bicycle streets benefit cyclists much more than car drivers and pedestrians. The situation for cyclists has improved regarding most aspects, such as comfort, mobility, clarity, and perceived safety. Still, there are cyclists that believe that clarity and safety are not to satisfaction at all. Cars overtaking is what cyclists believe function least good. Both cyclists and car drivers are satisfied with mobility and pavement.

Even though the situation has clearly improved for cyclists, the attitude towards the concept is divided. Furthermore, pedestrians are disunited, and drivers are most critical to the concept. Drivers would not appreciate other reconstructions. They firmly believe that cyclists show no respect and behave recklessly. After reconstruction, the belief was stronger. More clear instructions and signage for cyclists are requested. Most of all, they would like separate bicycle lanes or wider drive lanes. Also, some cyclists would like separate bicycle lanes or wider streets and request better instructions and signage directed towards drivers. The number of cyclists requesting separate bicycle lanes has, however, decreased after the implementation of the bicycle streets. Likewise, fewer pedestrians request separate bicycle lanes when the cyclists, after construction, use the roadway. Generally, pedestrians believe cyclists use too high speeds and do not show respect.

2.4.4 | On-road bicycle lanes

When the flow is not dominated by cyclists, on-road bicycle lanes can work as another mixed traffic solution. On-road bicycle lanes are common on streets where space is limited. Space has often been the reason for constructing on-road bicycle lanes instead of separated bicycle lanes; however, it can also be a cheaper solution. Which can be seen in figure 2.23; the on-road bicycle lane is separated in the roadway from the driving lane with road markings. Bicycle traffic is one-way, and the width is often quite small, which does not support cyclists overtaking other cyclists. Leaving the dedicated bicycle lane can create a safety hazard from rearward motor vehicles. Usually, higher speeds, such as 40-50 km/h, are allowed on these streets. In a literature study made by Nilsson (2003) she evaluated on-road bicycle lanes' effect on cyclists' safety. The literature is not consistent whether on-road bicycle lanes are safer than mixed traffic regarding mid-block cycling. One study from the Netherlands showed higher risk with on-road bicycle lanes than mixed traffic. Another study from Denmark showed on-road bicycle lanes to have slightly fewer accidents than mixed traffic. Both types, however, had fewer accidents than separated bicycle lanes. Nilsson suggests that on-road bicycle lanes improve the safety of cyclists compared to mixed traffic solutions. The safety and attractiveness increase when the roadway is narrowed for the motorized vehicles, and the design clearly shows the intention of the street. SKL and Swedish Transport Administration (2010) states that on-road bicycle lanes are safer in intersections since they make cyclists more visible for drivers.

Source: Google maps
Figure 2.23: Street view of on-road bicycle lane at Lantbruksgatan, Mölndal.

Sanders (2016) found in her study that cycling car drivers are more positive to on-road bicycle lanes than non-cycling car drivers. Both groups also clearly agreed that the on-road bicycle lane facilities make cyclists more predictable on the roadway. Sander, therefore, states that on-road bicycle lanes are not only positive from the cyclists' perspective.

Mostly, on-road bicycle lanes suit adult cyclists, which request high mobility, whereas the solution benefits bicycle commuters foremost. Elder and children are not always comfortable using on-road bicycle lanes; hence sidewalks must be present as well. In cities with many bicycle commuters, the on-road bicycle lanes can be more attractive than shared walking and bicycle lanes thanks to the more homogeneous and faster cycling speed (SKL & Swedish Transport Administration, 2010).

The width is of importance since both too narrow and too wide lanes can be a problem. Wide lanes can be mistaken for driving lanes intended for motor vehicles. Too narrow on-road bicycle lanes can have a low comfort level and especially with poor maintenance of snow, leaves, and loose gravel (SKL & Swedish Transport Administration, 2010).

2.4.5 | 2 − 1-road

A similar version to the on-road bicycle lanes is being tested on roads outside urban areas. The concept of 2 − 1-road (2 minus 1-road) is not yet anchored with the Swedish traffic regulations; however, it resembles the design of a road with wide shoulders. Furthermore, the concept exists in e.g. Denmark and the Netherlands. The idea is that the road is two-way, with only one drive lane in the center of the roadway. The shoulders are dedicated to cyclists, and motor vehicles are only allowed to use them in oncoming traffic. The widths of both the drive lane and the shoulders can vary, and several design solutions have been tested. The goal with the 2 − 1-road is to provide cyclists with higher accessibility, give them more space in the roadscape, and create more efficient use of the infrastructure. Also, the safety and security of cyclists should be improved with a dedicated lane for cyclists (Visser van der Meulen & Berg, 2018). Stefan Berg at the Swedish Transport Administration states that 2 − 1-roads signalize cyclists' equal right to use the roads.

An evaluation after reconstruction showed that most cyclists were critical to the concept. They thought the idea of giving them more space was good; however, they did not feel safer or more secure (Visser van der Meulen & Berg, 2018). In a deeper evaluation made by Warner and Patten (2017) they found that despite all the disadvantages with the $2-1$-roads, the majority of respondents believed that the new design was better than the prior design. Still, separated bicycle lanes were highly requested. Visser van der Meulen and Berg (2018) discussed traffic calming measures to be tested to secure the correct speeds whereas, on $2-1$-roads, vehicle speeds should be held under 70 km/h. Visser van der Meulen and Berg (2018) suggested in their report that the drive lane should be between 3 and 3.5 meters wide, and the shoulders between 1 and 2 meters. Primarily, the widths depend on the total width of the existing road, and the distribution depends on the traffic flows. For the concept to work as intended, the flow of motor vehicles must be quite low.

Source: Google maps

Figure 2.24: Street view of $2-1$-road at Smedbyvägen, Kalmar.

3 | Methodology

The different approaches used to undertake the research questions in section 1.3 and fulfill the aim of the study is presented in the following chapter.

3.1 | Methodological approach

Primarily, this study has been conducted through qualitative research, where numerous papers of literature have been read through to gather as much information possible. A quantitative segment was used with the aid of a questionnaire to complement the literature. The questionnaire was anonymous and was seeing the respondents as a group and not individuals.

3.2 | Initial information gathering

In the early stages of the study, discussions were made with various traffic engineers at Sweco. Some of these persons are considered experts within traffic engineering and especially traffic safety. The discussions can be seen as informal, meaning no interviews were held, simply giving a basis for further research and what it should be focused on.

3.3 | Literature study

Initially, the literature of the most significant interest was governmental documents on urban planning and traffic safety. These documents are central to traffic engineering and were available at the Sweco office. The literature study was more or less continued through the reference list of every new document, report, and research article that was read. Keywords that were used searching Google, Google Scholar, and Chalmers Library to find complementing literature were: Shared Space, Shared speed, mixed traffic, on-street cycling, on-road cycling, mixed traffic cycling, mixed traffic safety, cycling safety, geofencing, and driving assist. Small variations of these keywords were also used.

3.4 | Personal communications

Except using the expertise possessed by the industrial supervisors, three other traffic engineers were used for their expertise. These persons were contacted through email and asked whether they would be interested in talking about their views on shared speed and mixed traffic cycling.

3.5 | Questionnaire

In order to answer research question 2 in section 1.3, a comparative questionnaire was used. The questionnaire was comparative in a double remark. Two groups of respondents were compared against each other; however, also the questionnaire itself consisted of comparative questions. The questionnaire will be further explained below in section 3.5.1, and the full questionnaire can also be found in Appendix A Shared Speed Questionnaire.

The purpose of the questionnaire was to understand what design elements in the urban streetscape would help establish shared speed and mixed traffic cycling as well as find out the acceptance of mixed traffic cycling. With support from the literature, several design elements were listed and showed to the industrial supervisors. After discussions, design elements were added as well as removed, and dimensions for streetscapes were agreed on. A first conceptual hand drawing was made to illustrate what it could look like. With AutoCAD, different streetscapes were prepared with supportive lines of the roadway and curb for different widths. The AutoCAD layouts were printed and then hand drawn on to give it "life" and an urban setting. For every painting, one design element was changed. All paintings were drawn to look as similar to each other as possible except the element change. This way, it would be easier to extinguish what caused the result from the response.

The questionnaire was distributed to two sample groups, which will be further mentioned as Alpha α and Beta β for simplicity. Alpha consists of traffic engineers in the Gothenburg region. The link was sent to people on Sweco Society, Partille municipality's traffic department, and the traffic department of the City of Gothenburg. Beta consists of cyclists of Gothenburg who are all members in the Facebook group "Cykla i Göteborg" [In English Cycle in Gothenburg]. The link to the questionnaire was available for approximately 5,000 members.

3.5.1 | Questionnaire explained

The questionnaire was made in Swedish to prevent the questions from being unnecessarily mistaken because of language borders. Also, special terms within traffic can be hard to translate and understand in another language. Below the questionnaire will be presented and described in English.

The questions are named after the section they belonged to in the questionnaire. Thereby, the first question is called Question 2.

Question 2 - *Do you have a driver's license of any kind?*
The first questions asked whether the respondent possesses a driver's license. The author assumes that holders of a driver's license might have a better knowledge of traffic rules and a better understanding of the other road users. This is mainly supposed for cyclists' understanding of drivers.

Question 3 - *With what transport mode do you travel the longest distance of your trip to work?*
The respondents were asked to answer what mode of transport they use the farthest part of their travel to work. One can assume that the answer to this question can affect the answers to other questions later in the questionnaire.

Question 4 - *When you cycle, what type of bicycle do you use? (Are you using more than one type? Choose the one you use the most)*
In this question, a few types of bicycles are listed, and the option *Other* as well. If the respondent never cycles, there is an option of *I never cycle*. This question is raised in order to see if there is any correlation between bicycle type and cycling speed. For example, electric bicycles help cyclists keep a higher speed.

Question 5 - *Regarding speed, what type of cyclist are you?*
Here four options are available all connected to a certain speed. The hypothesis is that faster cyclists might be more interested in sharing the street with cars than slower cyclists.

Question 6 - *Could you envision cars and bicycles to share the roadway provided they share speed?*

This question had a central role in the questionnaire to figure out to what degree the concept of mixed traffic cycling has acceptance. The respondents were asked if they could imagine cars and bicycles sharing the street, given they share speed. *Yes*, *No* and *Maybe* were available answers. The option of *Maybe* was included to give the respondents an option that was neither *Yes* or *No*.

Question 7 - *On your bicycle trip, who would you rather share the space with?*
Related to the prior question, the next question asks whom cyclists would rather share the space with. To some degree, this refers to the acceptance of sharing the roadway with cars. The result would be interesting to understand whether cyclists are satisfied with the most common existing bicycle infrastructure.

Question 8-20 - *You are driving. What speed would you drive in B compared to A? and You are cycling. Which streetscape would you rather cycle in?*
The next 14 questions asked the respondents to compare two hand-drawn illustrations of a street in an urban setting. Here the goal was to understand what changes in design elements affect driving speed and cyclists' attractiveness to the streetscape.

Question 21 - *If you would combine 3 design elements, which ones according to you would give the best conditions for cars and bicycles to share the roadway?*
The last questions asked what combination of design elements from the questionnaire that the respondents believe would create the best possibilities for cars and bicycles to share the roadway.

4 | Results

The following chapter will present the results obtained from the responses of the questionnaire distributed to professionals within traffic engineering and dedicated civilian cyclists.

4.1 | Sample groups

Alpha α consist of 40 responses from Sweco Society, 6 responses from Partille municipality and 1 response from the City of Gothenburg. A total amount of 47 responses from traffic engineers during the collection time.

The link to the questionnaire was available for approximately 5 000 members of the facebook group "Cykla i Göteborg" [In English Cycle in Gothenburg]. Beta β consists of 111 responses which was the amount recieved during the collection time.

4.2 | Results from questionnaire

Question 2

Do you have a driver's license of any kind?

Figure 4.1 shows that only one person in Alpha does not have a driver's license. Consequently, 98 percent do have a license of any kind. Figure 4.2 shows that only 14 percent from Beta do not have a driver's license of any kind while 86 percent have.

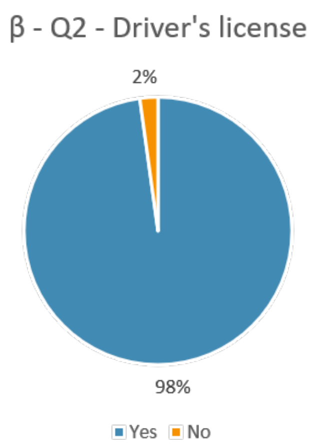


Figure 4.1: Diagram showing the distribution of Alpha's response on question 2

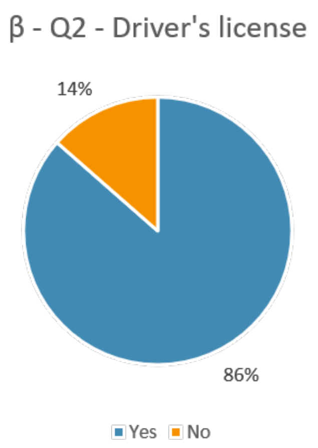


Figure 4.2: Diagram showing the distribution of Beta's response on question 2

Question 3

With what transport mode do you travel the longest distance of your trip to work?

Figure 4.3 shows that the most common transport mode in Alpha is public transport with 44 percent. With 36 percent, cycling is the second most common way to travel for work. No respondents are walking most of their work trip, nor using moped or motorcycle. Figure 4.4 shows that 85 percent of the Beta respondents use bicycle the longest distance of their trip to work. 6 percent use public transport, 5 percent drive car, one person use E-scooter or similar and one person added that he/she is running to work. 3 percent responded they are working at home and were therefore excluded from this question.

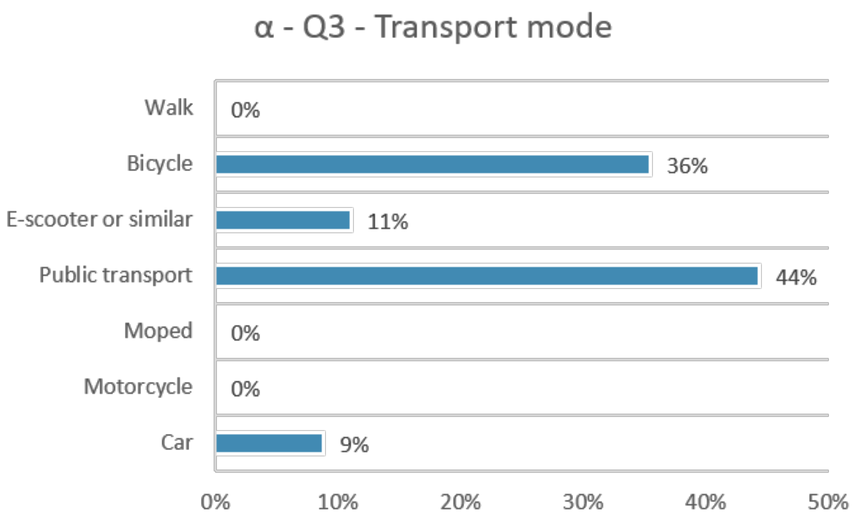


Figure 4.3: Diagram showing the distribution of Alpha's response on question 3

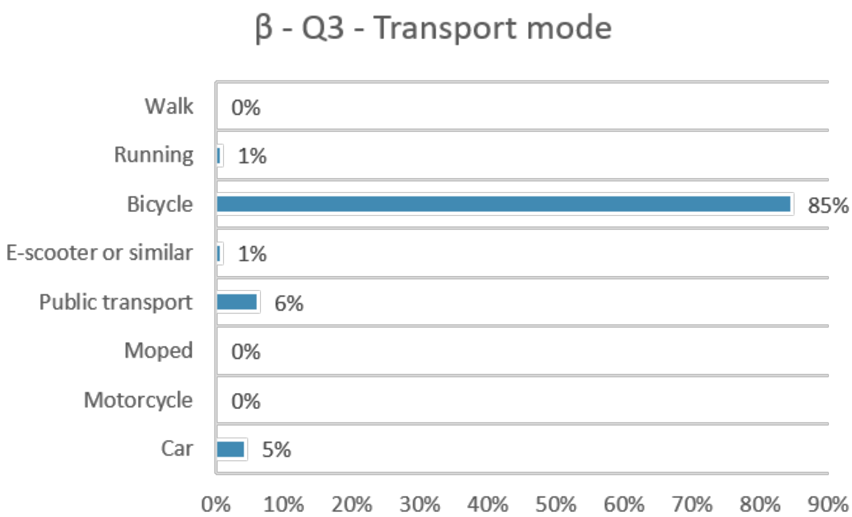


Figure 4.4: Diagram showing the distribution of Beta's response on question 3

Question 4

When you cycle, what type of bicycle do you use?

Figure 4.5 shows that the majority of Alpha (63 percent) are using regular bicycles. Electric bicycles count for 20 percent. No one uses cargo bike or lay down bicycle while road racer and mountainbike count for a few percent. 11 percent replied that they never cycle (not included in figure). Similarly, figure 4.6 shows that the majority of Beta (52 percent) use regular bicycles when cycling. Almost equally many, 19 and 18 percent respectively use road racers and electric bicycles. Mountainbike counts for 6 percent, cargo bike for 3 percent and no one responded they use lay down bicycle. One person added he/she uses a foldable bicycle.

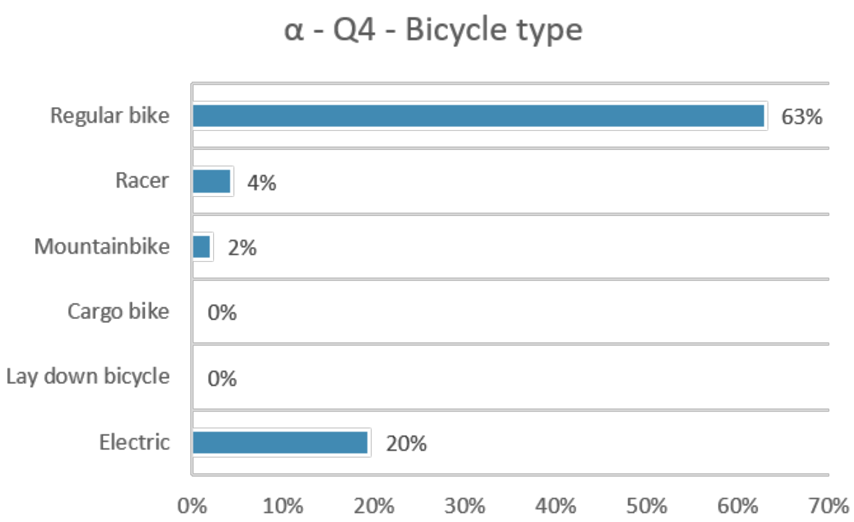


Figure 4.5: Diagram showing the distribution of Alpha's response on question 4

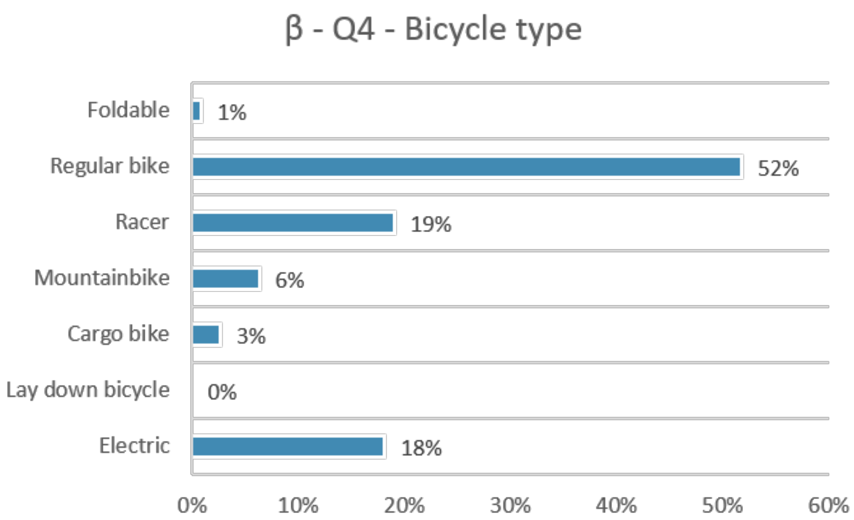


Figure 4.6: Diagram showing the distribution of Beta's response on question 4

Question 5

Regarding speed, what type of cyclist are you?

Figure 4.7 shows that almost everyone in Alpha are either comfort cyclists or fast cyclists, 49 percent each. Only 1 person responded he/she is a slow cyclist and no one responded racing cyclist. Figure 4.8 shows that the great majority of Beta (69 percent) see themselves as fast cyclists. 20 percent are comfort cyclists and 11 percent are racing cyclists. No one responded to be a slow cyclist.

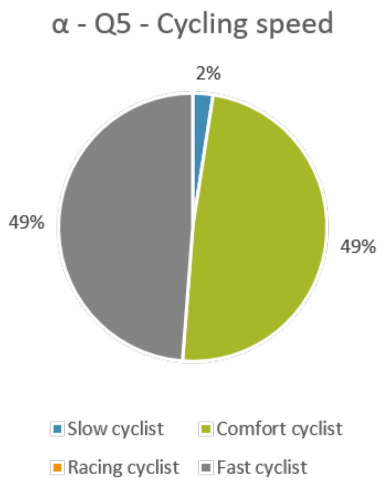


Figure 4.7: Diagram showing the distribution of Alpha's response on question 5

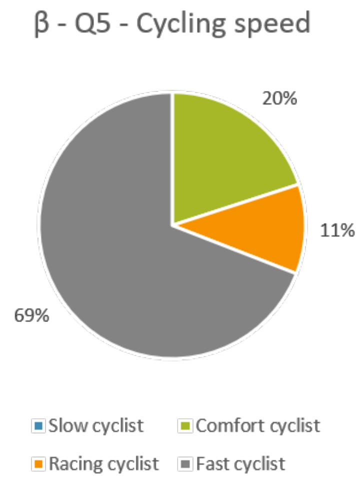


Figure 4.8: Diagram showing the distribution of Beta's response on question 5

Question 6

Could you envision cars and bicycles to share the roadway provided they share speed?

Figure 4.9 shows that a fifth of Alpha could not envision cars and bicycles to share the roadway. *No* and *Maybe* respondents make up almost 20 percent each. Over 60 percent of Alpha can envision cars and bicycles to share the road provided they share speed. Figure 4.10 shows that the majority of Beta (64 percent) could envision cars and bicycles sharing the roadway provided shared speed is secured. 23 percent responded maybe and only 13 percent do not envision it.

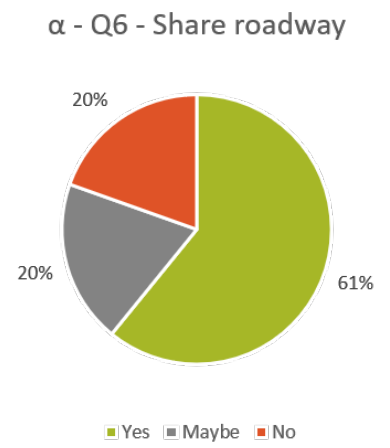


Figure 4.9: Diagram showing the distribution of Alpha's response on question 6

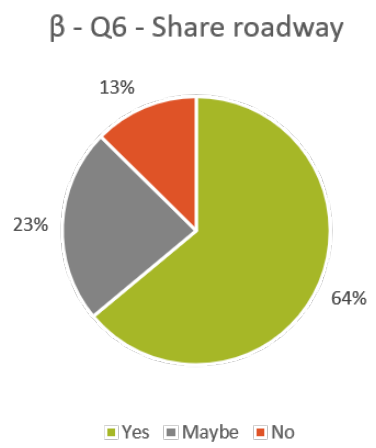


Figure 4.10: Diagram showing the distribution of Beta's response on question 6

Question 7

On your bicycle trip, who would you rather share the space with?

Figure 4.11 shows that the majority of Alpha (63 percent) would rather cycle together with car drivers than with pedestrians. Figure 4.12 shows that Beta would with 82 percent much rather share the space with car drivers.

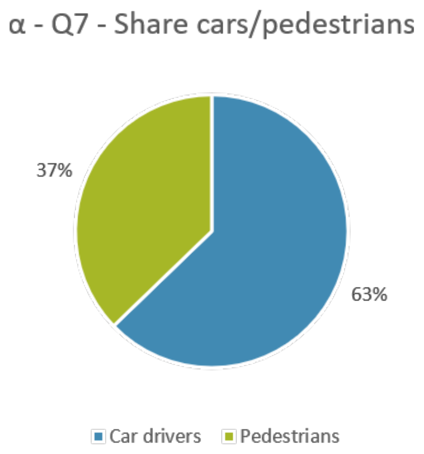


Figure 4.11: Diagram showing the distribution of Alpha's response on question 7

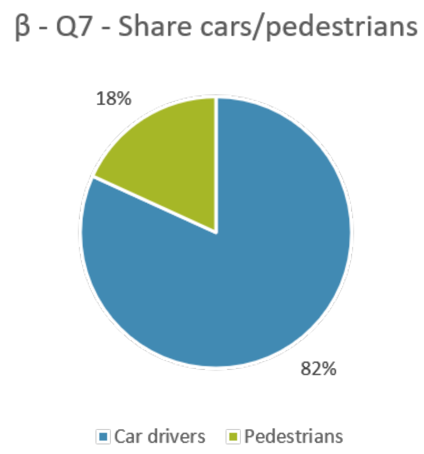
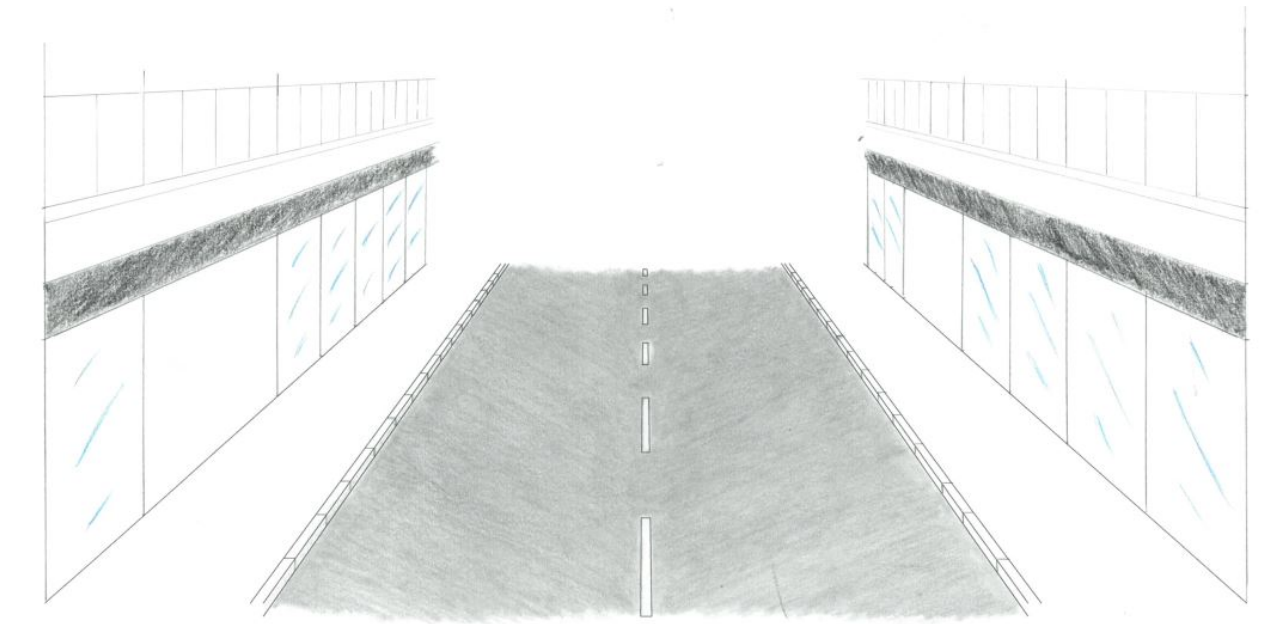
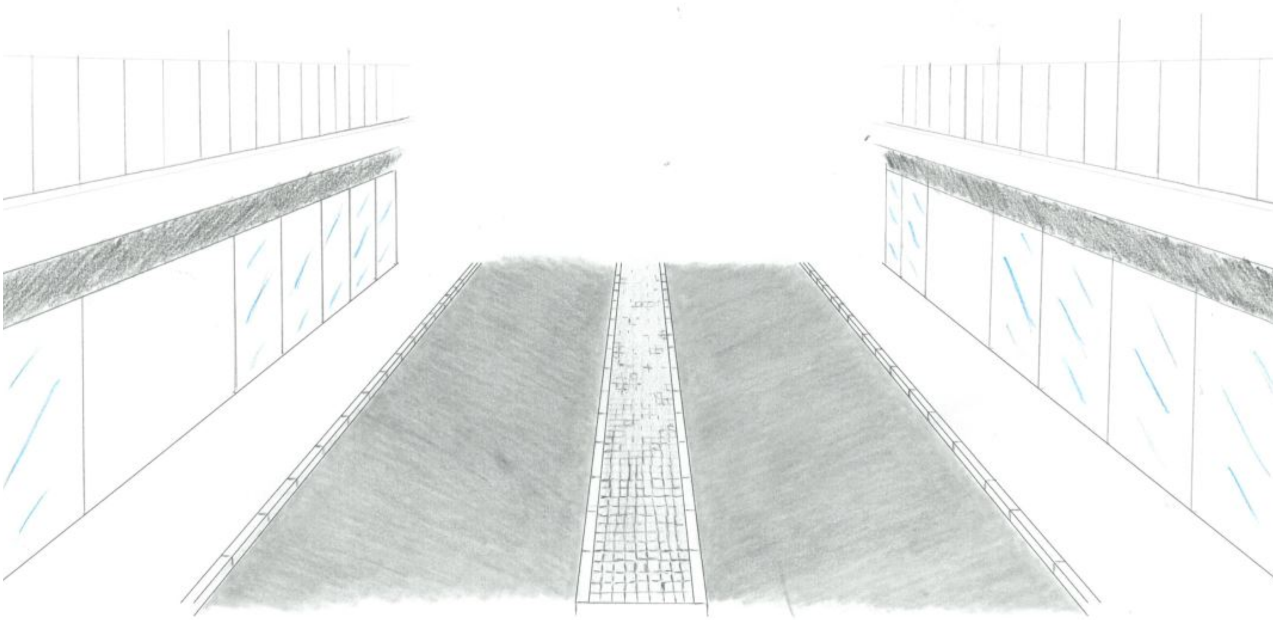


Figure 4.12: Diagram showing the distribution of Beta's response on question 7

Question 8

In streetscape B an elevated central divider has been added. The lane width is unchanged.





You are driving. What speed would you drive in B compared to A?
Figure 4.13 shows that a central divider would likely have a traffic calming effect on Alpha. 63 percent responded they would drive slower, 7 percent would drive faster and 30 percent would drive with the same speed. Figure 4.15 shows that a central divider would likely have a traffic calming effect on Beta. 68 percent responded they would drive slower, 4 percent would drive faster and 28 percent would drive with the same speed.

You are cycling. Which streetscape would you rather cycle in?
Figure 4.14 shows that the majority (57 percent) would prefer a central divider. For 13 percent of the respondents it does not matter and 30 percent would rather not have a central divider. Figure 4.16 shows a disunited response from Beta whether cyclists prefer a central divider or not. For 23 percent of the respondents it does not matter, 34 percent would rather not have a central divider and 43 percent do like it.

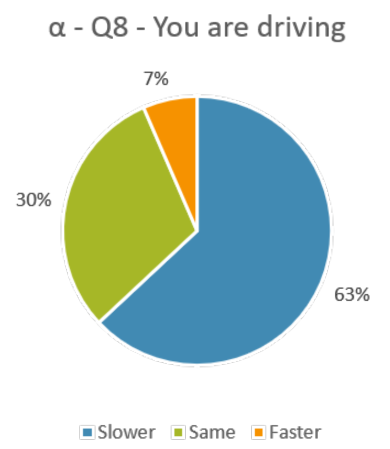


Figure 4.13: Diagram showing the distribution of Alpha's response on question 8

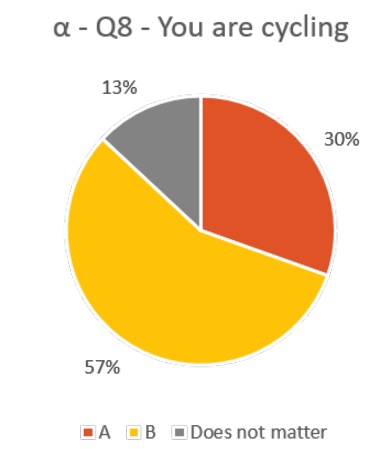


Figure 4.14: Diagram showing the distribution of Alpha's response on question 8

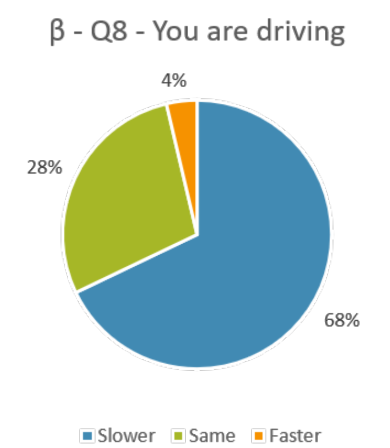


Figure 4.15: Diagram showing the distribution of Beta's response on question 8

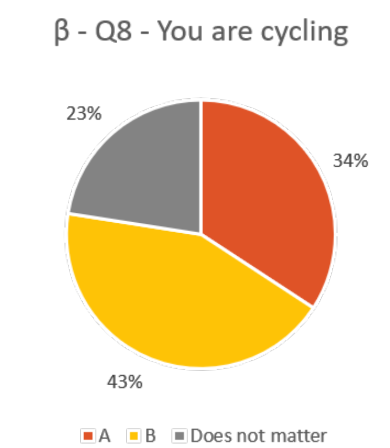
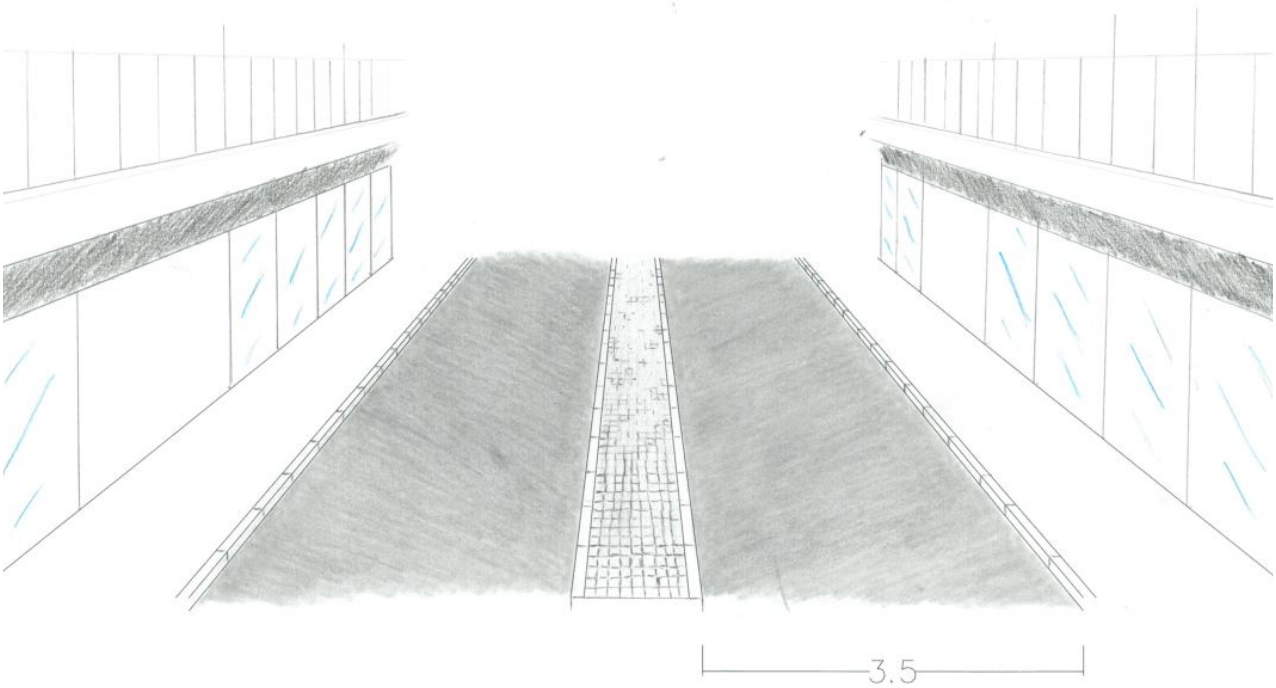
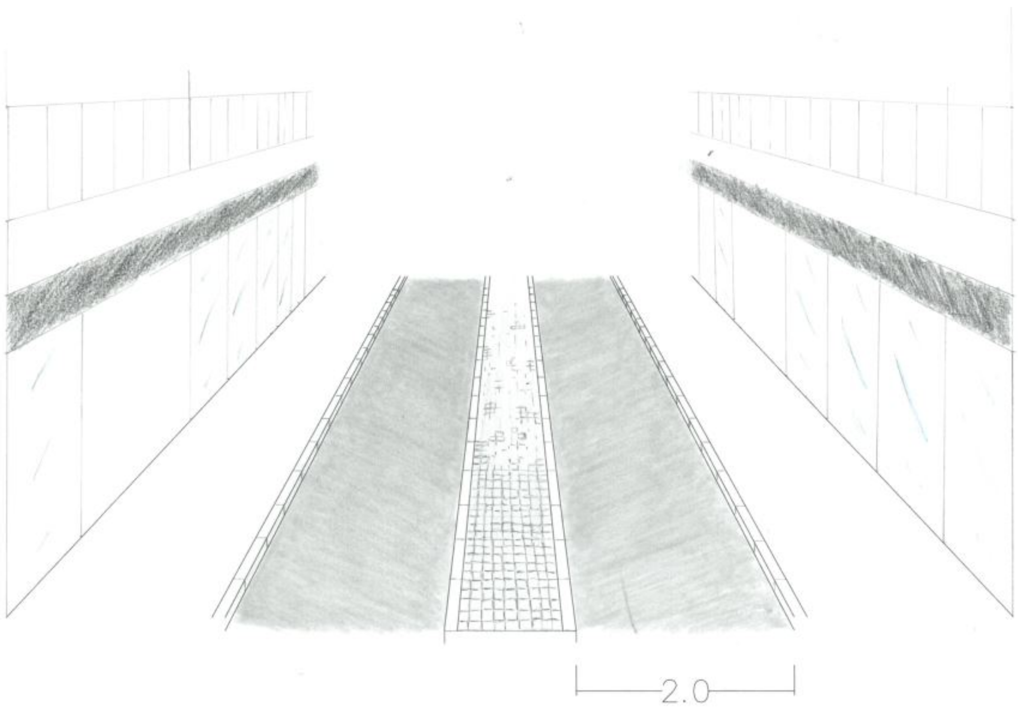


Figure 4.16: Diagram showing the distribution of Beta's response on question 8

Question 9

In streetscape B the lane width has been reduced to 2 meters.





You are driving. What speed would you drive in B compared to A?
Figure 4.17 shows that a narrowing of the road would very likely have a traffic calming effect on Alpha. 93 percent responded they would drive slower, 7 percent would drive with the same speed and one percent would driver faster. Figure 4.19 shows that a narrowing of the road would most likely have a traffic calming effect on Beta. 88 percent responded they would drive slower and 11 percent would drive with the same speed.

You are cycling. Which streetscape would you rather cycle in?
Figure 4.18 shows that the Alpha respondents would rather cycle in the wider driving lane. 59 percent did not prefer the narrower lane width, 26 percent did prefer it and for 15 percent it does not matter. Figure 4.20 shows that a not unanimous response whether Beta prefer narrower driving lanes or not. For 18 percent of the respondents it does not matter, 47 percent would rather not have a narrower drive lane and 35 percent do like it.

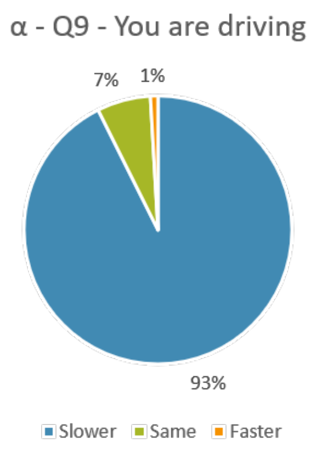


Figure 4.17: Diagram showing the distribution of Alpha's response on question 9

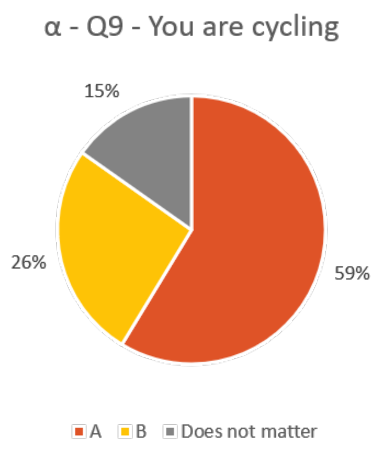


Figure 4.18: Diagram showing the distribution of Alpha's response on question 9

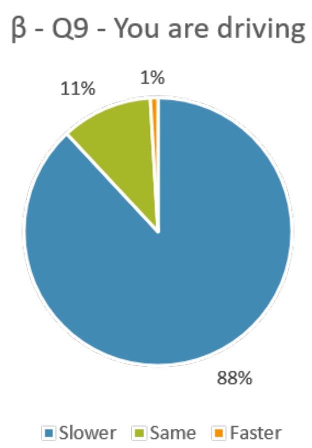


Figure 4.19: Diagram showing the distribution of Beta's response on question 9

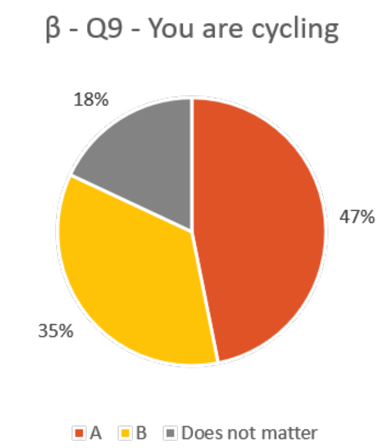
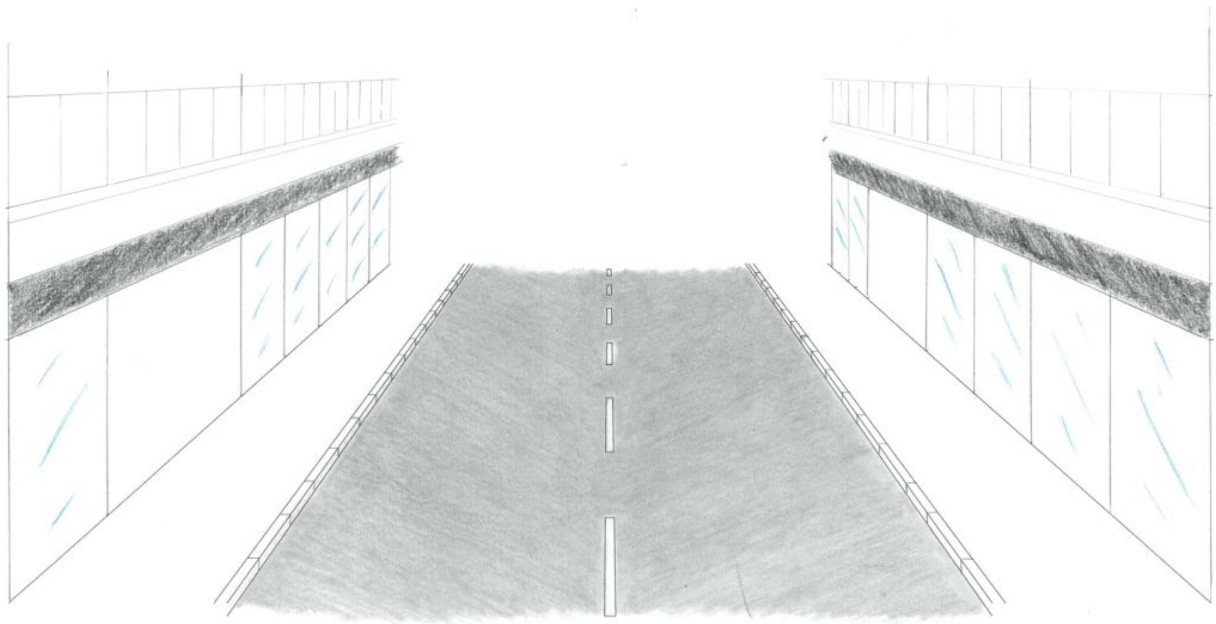
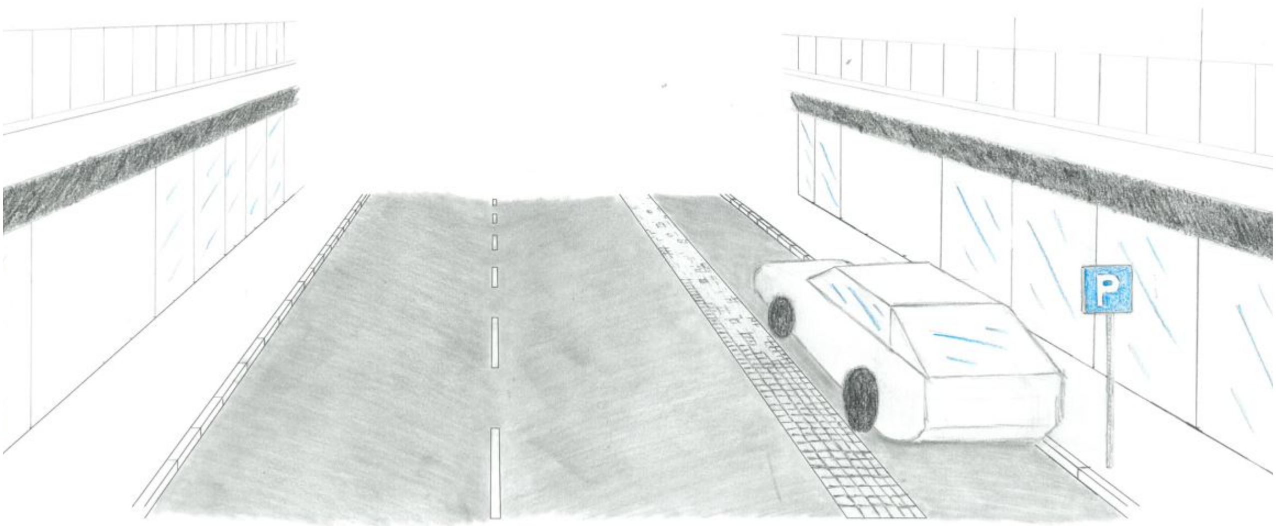


Figure 4.20: Diagram showing the distribution of Beta's response on question 9

Question 10

In streetscape B on street parking has been added on the right side in the driving direction. The lane width is unchanged.





You are driving. What speed would you drive in B compared to A?
Figure 4.21 show that on-street parking will have a traffic calming effect on Alpha. 4 percent of the respondents would drive faster, 24 percent responded they would drive with the same speed and 72 percent would drive slower. Figure 4.23 show that the great majority of Beta (63 percent) would drive slower. No respondents would drive faster and 37 percent responded they would drive with the same speed.

You are cycling. Which streetscape would you rather cycle in?
Figure 4.22 clearly shows that on-street parking is not preferred by Alpha. 83 percent do not want it, 9 percent want it and for 9 percent it does not matter. Figure 4.24 clearly shows that Beta do not prefer on-street parking when cycling. 85 percent do not want it, 5 percent want it and for 11 percent it does not matter.

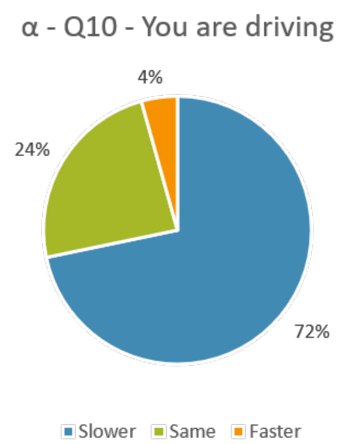


Figure 4.21: Diagram showing the distribution of Alpha's response on question 10

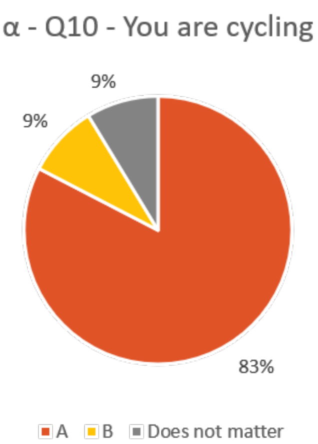


Figure 4.22: Diagram showing the distribution of Alpha's response on question 10

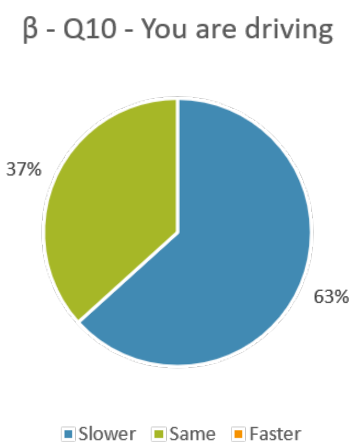


Figure 4.23: Diagram showing the distribution of Beta's response on question 10

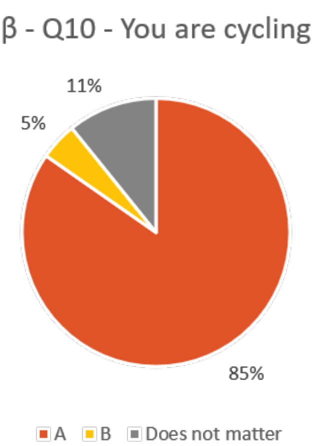
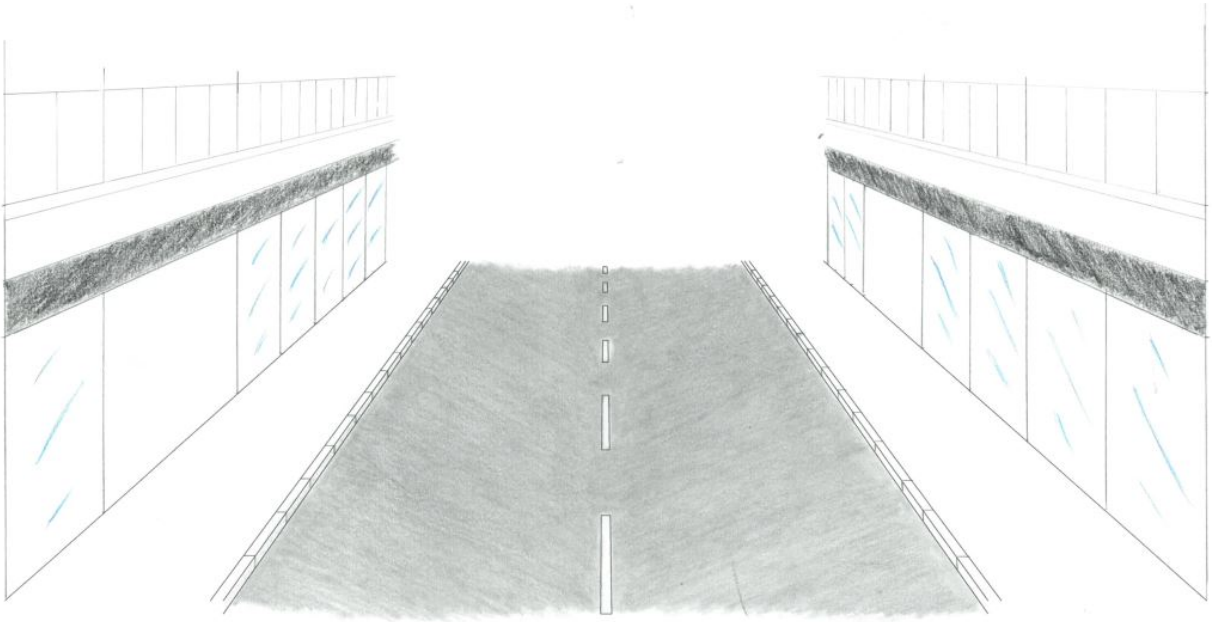
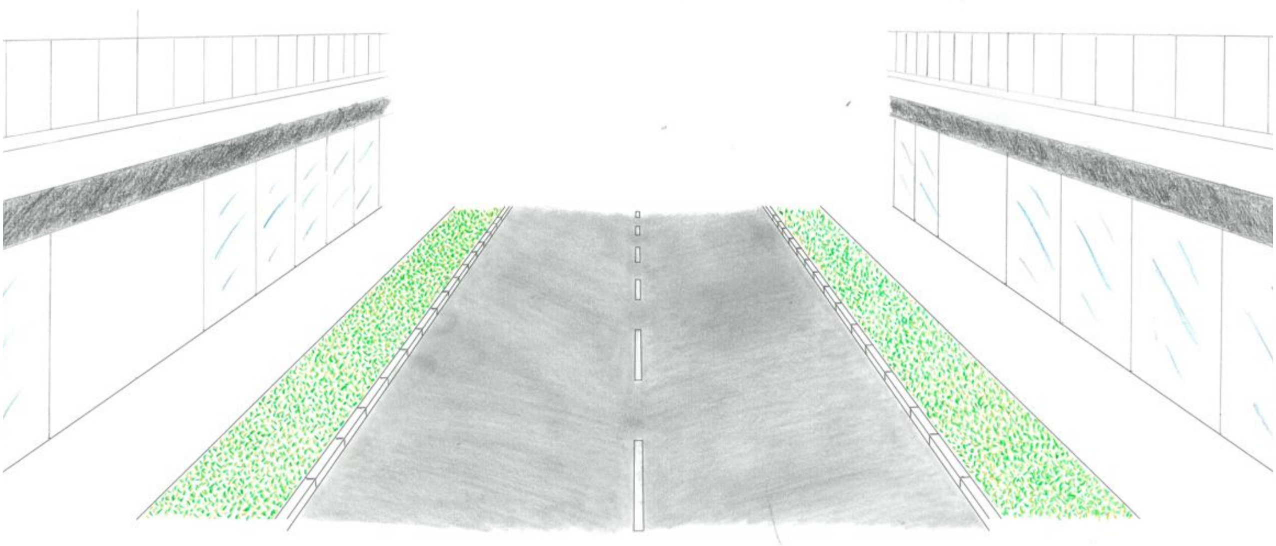


Figure 4.24: Diagram showing the distribution of Beta's response on question 10

Question 11

In streetscape B on street parking has been added on the right side in the driving direction. The lane width is unchanged.





You are driving. What speed would you drive in B compared to A?
Figure 4.26 shows that green barriers caused divided opinion about driving speed in Alpha. 41 percent responded they would drive with the same speed. 26 percent would drive faster and 33 percent would drive slower. Figure 4.27 shows that for Beta, green barriers might not have a significant traffic calming effect as 61 percent responded they would drive with the same speed. 25 percent would drive slower and 14 percent would drive faster.

You are cycling. Which streetscape would you rather cycle in?
Figure 4.26 shows that green barriers are strongly preferred by Alpha with 63 percent. 17 percent prefer without and for 20 percent it does not matter. Figure 4.28 shows that for Beta, when cycling green barriers are preferred. 53 percent prefer it while 16 percent do not prefer it. For 31 percent it does not matter.

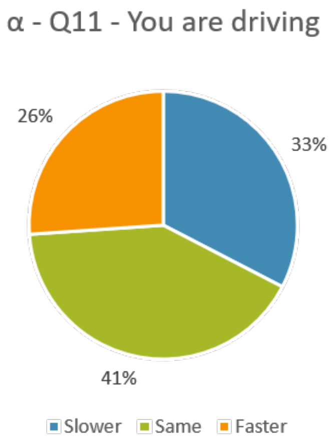


Figure 4.25: Diagram showing the distribution of Alpha's response on question 11

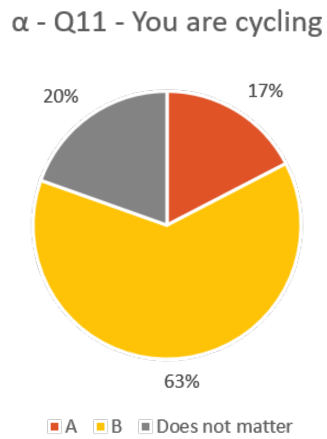


Figure 4.26: Diagram showing the distribution of Alpha's response on question 11

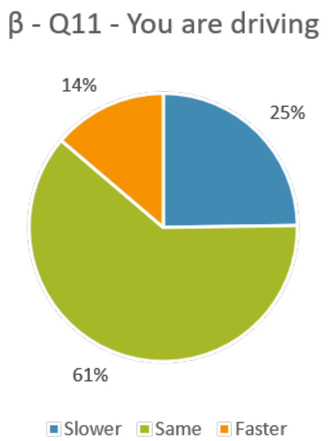


Figure 4.27: Diagram showing the distribution of Beta's response on question 11

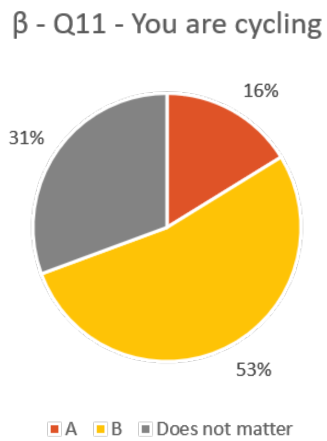
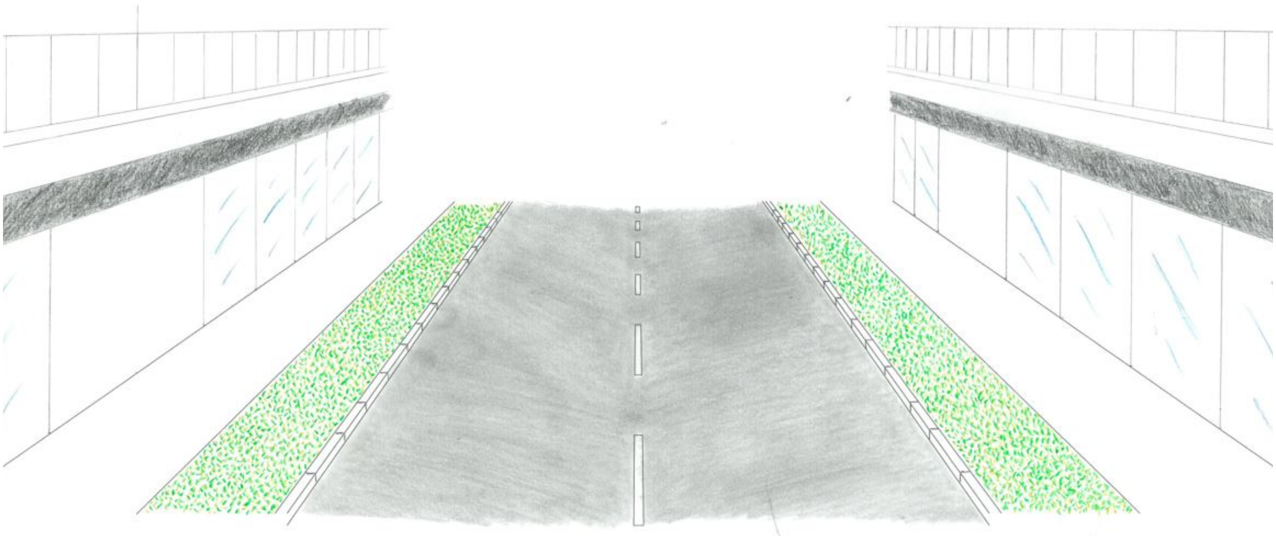


Figure 4.28: Diagram showing the distribution of Beta's response on question 11

Question 12

In streetscape B trees have been added on both sides. The lane width is unchanged.



You are driving. What speed would you drive in B compared to A?
Figure 4.29 shows that in Alpha trees in the green barriers would, with slightly more respondents, drive slower than with the same speed. 48 percent and 46 percent respectively. 7 percent responded they would drive faster. Figure 4.31 shows that Beta, with the additional trees in the green barriers, would drive with the same speed. 61 percent responded same speed, 34 percent would drive slower and 6 percent would drive faster.

You are cycling. Which streetscape would you rather cycle in?
Figure 4.30 shows that the majority of Alpha (59 percent) would prefer trees in the green barriers. For 30 percent it does not matter and 11 percent prefer no trees. Figure 4.32 shows a disunited response from Beta whether trees in addition to the green barriers are preferred. For 33 percent of the respondents it does not matter, 27 percent would rather not have trees and 40 percent do like it.

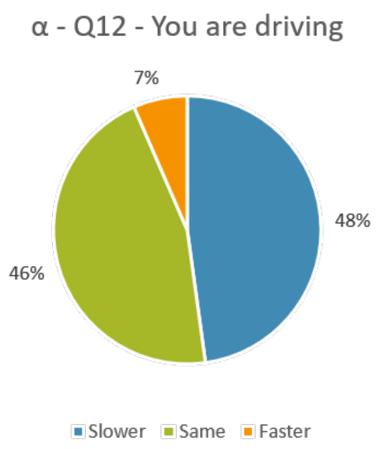


Figure 4.29: Diagram showing the distribution of Alpha's response on question 12

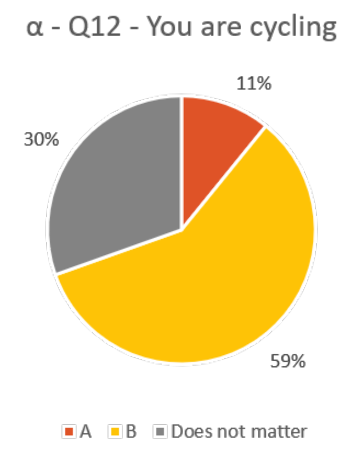


Figure 4.30: Diagram showing the distribution of Alpha's response on question 12

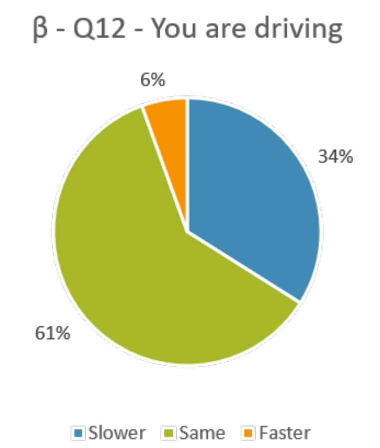


Figure 4.31: Diagram showing the distribution of Beta's response on question 12

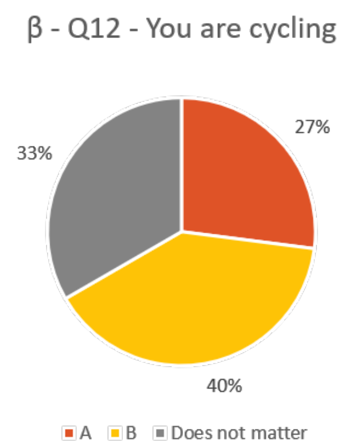
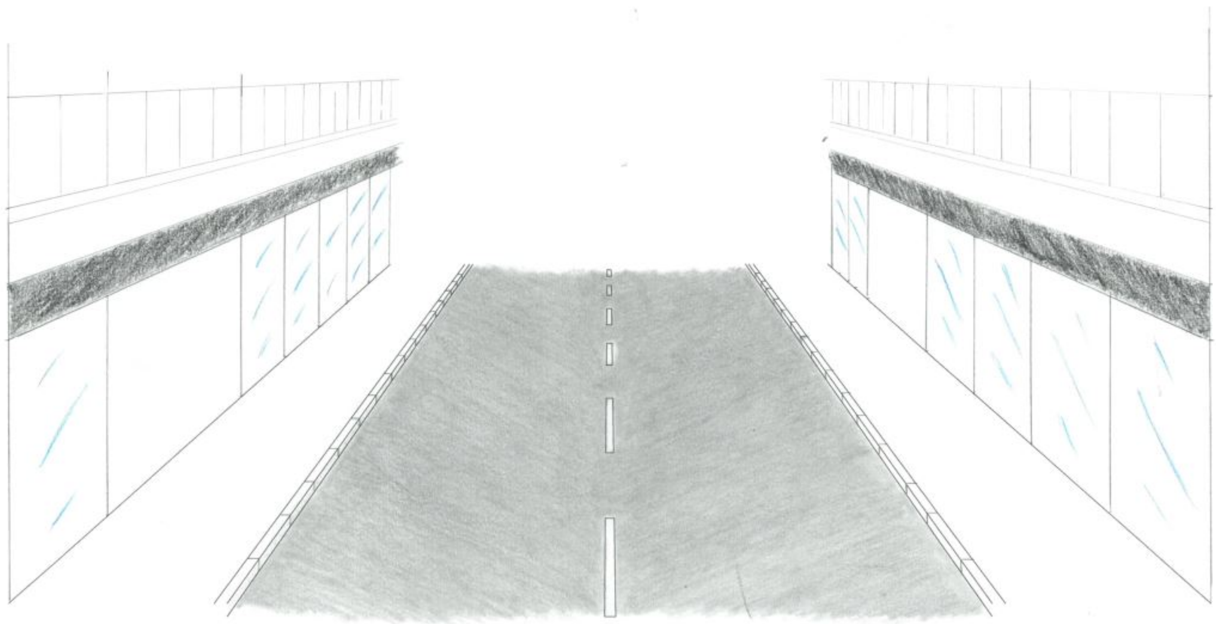
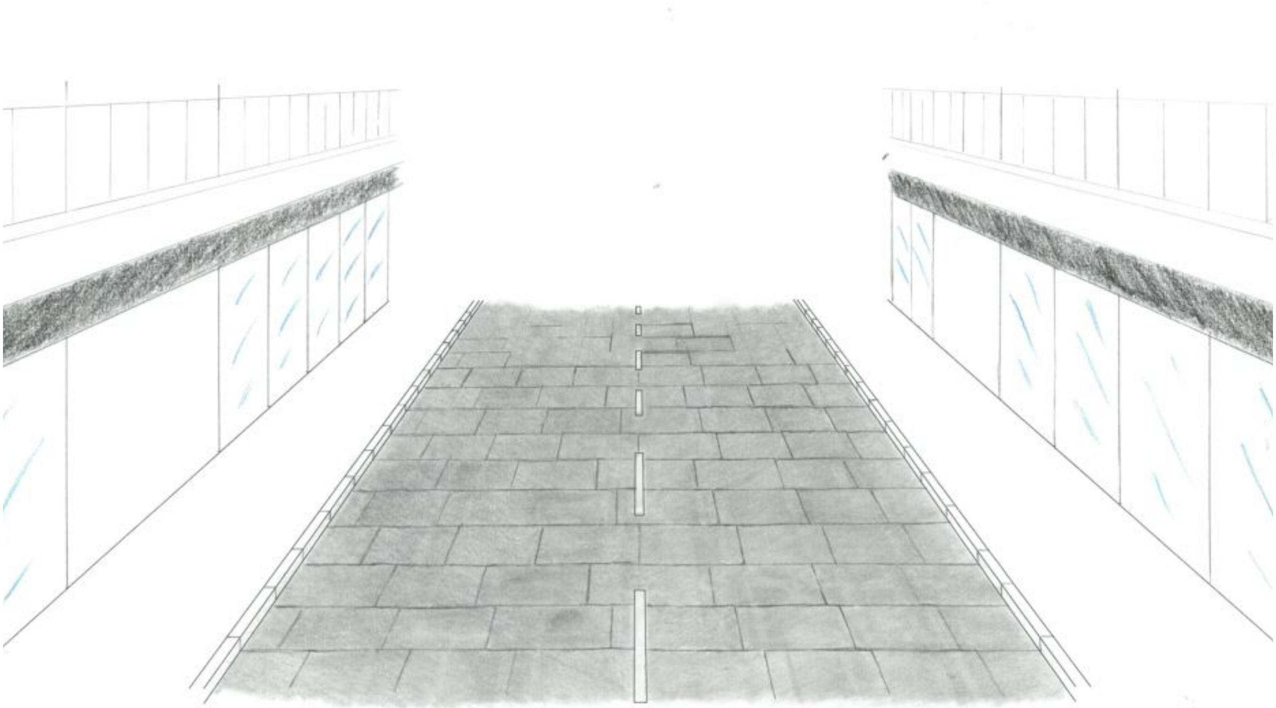


Figure 4.32: Diagram showing the distribution of Beta's response on question 12

Question 13

In streetscape B the pavement has changed. The lane width is unchanged.





You are driving. What speed would you drive in B compared to A?
Figure 4.33 shows that Alpha very likely would driver slower. 91 percent responded slower and 9 percent responded the same speed. Figure 4.35 shows that Beta responded by 73 percent slower driving and 27 percent responded they would drive with the same speed.

You are cycling. Which streetscape would you rather cycle in?
Figure 4.34 shows that Alpha would rather cycle on the more even surface. 22 percent did prefer the other pavement, for 13 percent it does not matter and 65 percent did prefer the normal pavement. Figure 4.36 shows that Beta strongly prefer the normal even surface which 86 percent responded. 5 percent would want the other pavement and for 9 percent it does not matter.

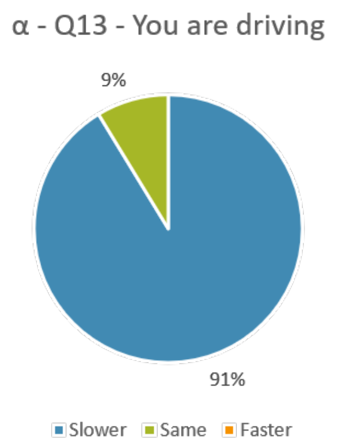


Figure 4.33: Diagram showing the distribution of Alpha's response on question 13

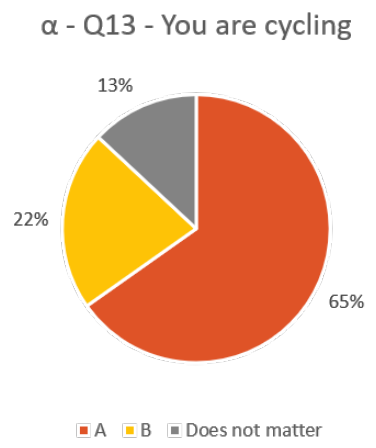


Figure 4.34: Diagram showing the distribution of Alpha's response on question 13

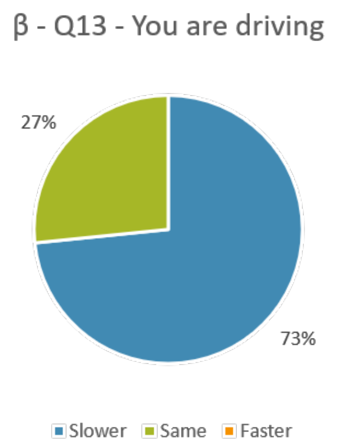


Figure 4.35: Diagram showing the distribution of Beta's response on question 13

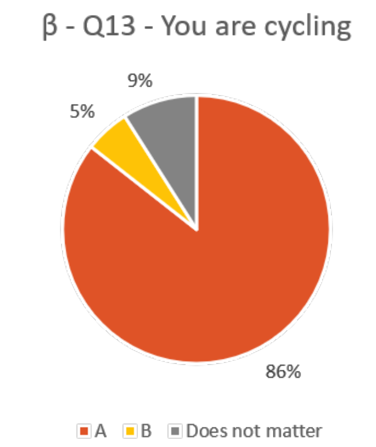
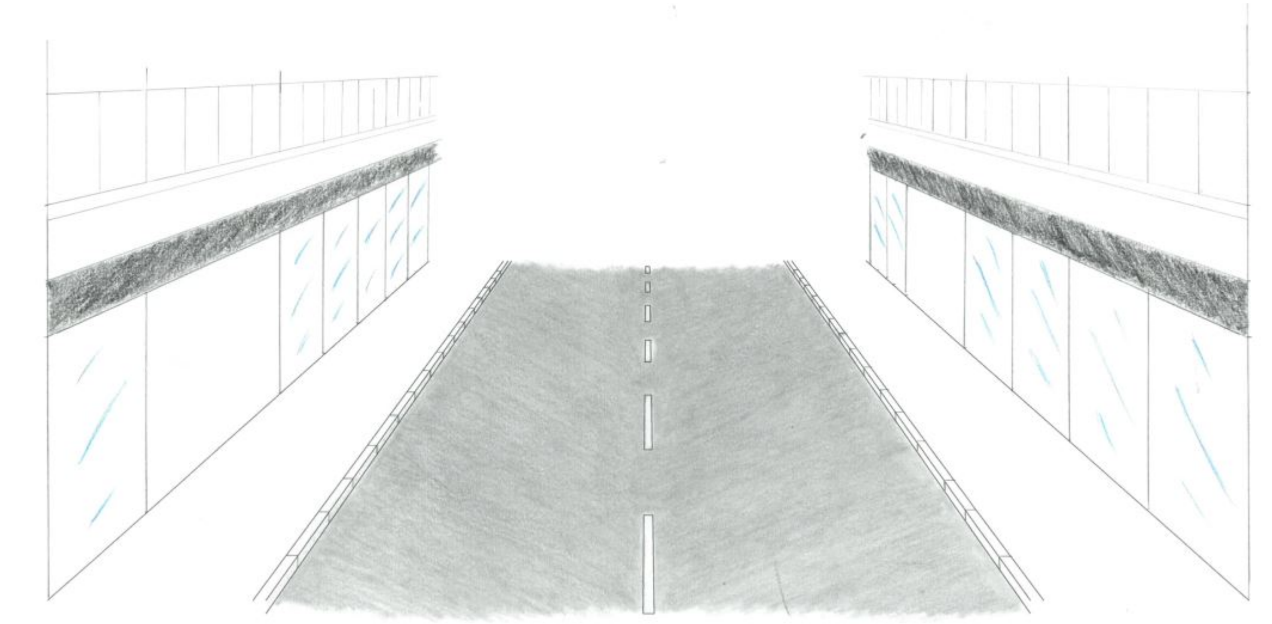
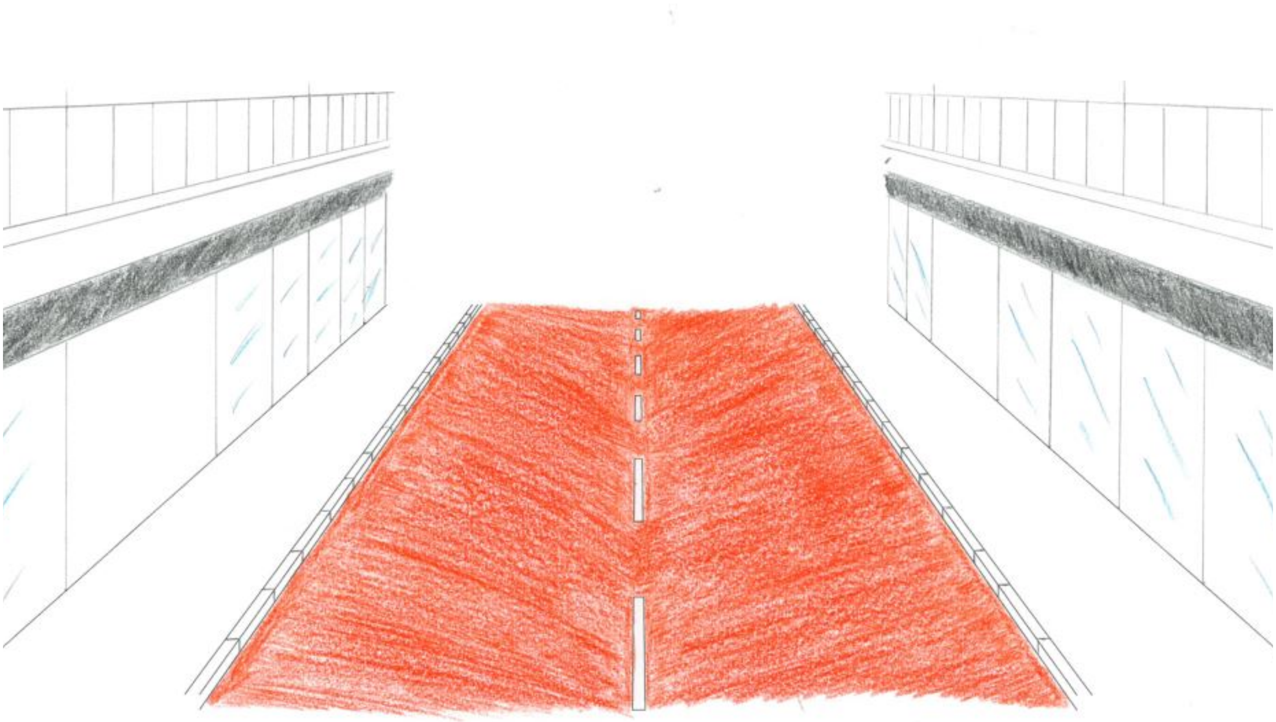


Figure 4.36: Diagram showing the distribution of Beta's response on question 13

Question 14

In streetscape B the pavement has received another color. The lane width is unchanged.





You are driving. What speed would you drive in B compared to A?
Figure 4.37 shows that another color of the pavement will not promote faster driving. Half of Alpha would drive with the same speed, 46 percent would drive slower and 4 percent would drive faster. Figure 4.39 shows that Beta would drive with the same speed or slower. 65 percent would drive with the same speed and 35 percent of the respondents would drive slower.

You are cycling. Which streetscape would you rather cycle in?
Figure 4.38 shows that another color does not matter for 63 percent of Alpha. 33 percent prefer it and 4 percent rather have no coloring. Figure 4.40 shows that the majority of Beta (56 percent) believe it does not matter while 27 percent prefer coloring and 17 percent do not prefer it.

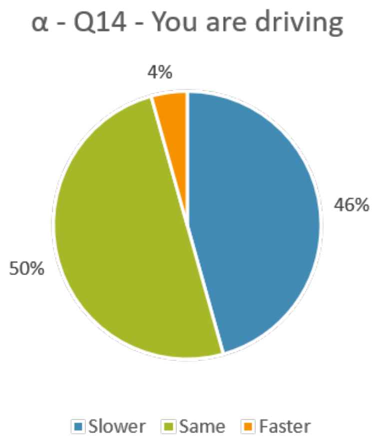


Figure 4.37: Diagram showing the distribution of Alpha's response on question 14

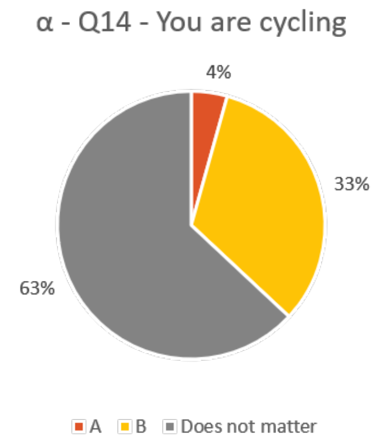


Figure 4.38: Diagram showing the distribution of Alpha's response on question 14

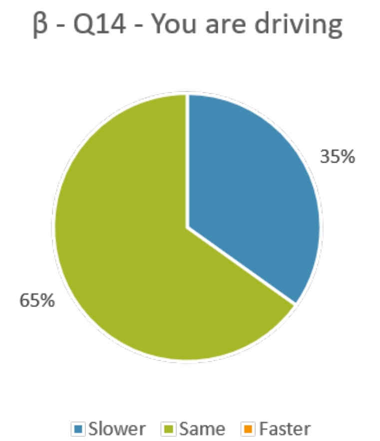


Figure 4.39: Diagram showing the distribution of Beta's response on question 14

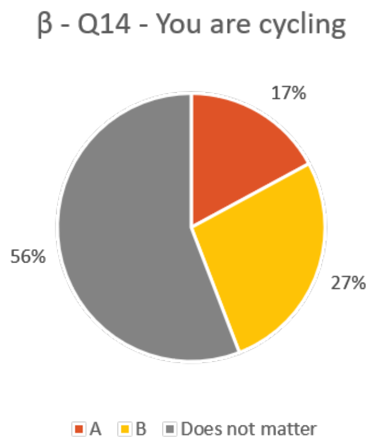
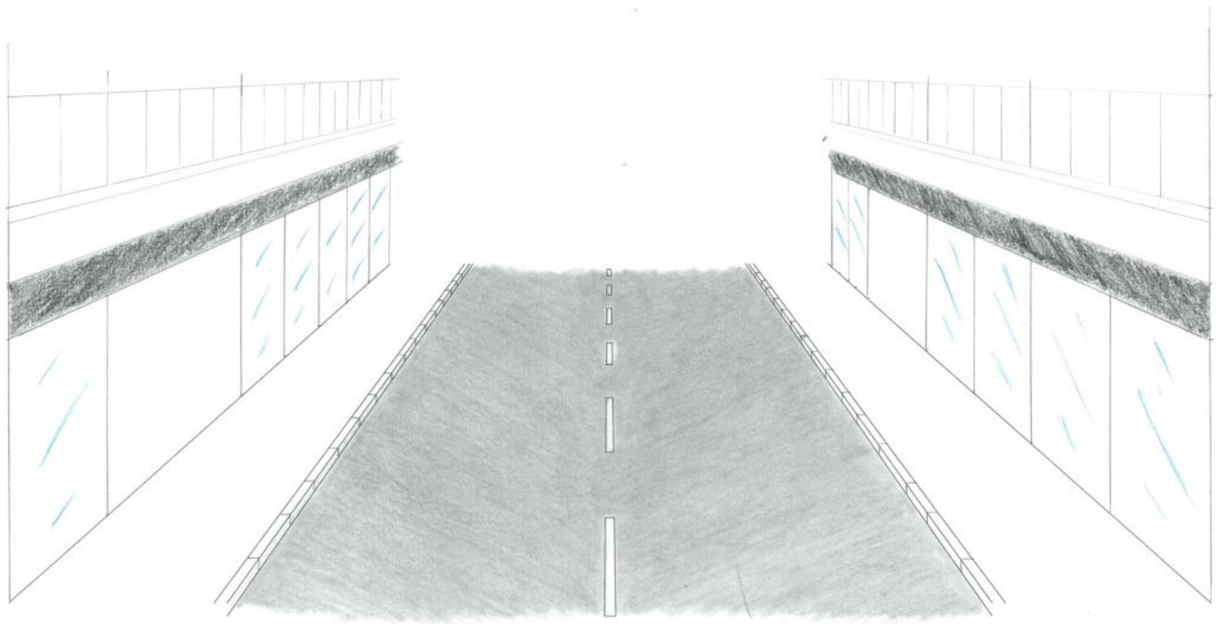


Figure 4.40: Diagram showing the distribution of Beta's response on question 14

Question 15

In streetscape B a bicycle symbol has been added in the driving lane. The lane width is unchanged.



You are driving. What speed would you drive in B compared to A?
Figure 4.41 shows that 67 percent of Alpha would drive slower with the bicycle symbol in the drive lane. 31 percent responded they would drive with the same speed and 2 percent would drive faster. Figure 4.43 shows that Beta responded the road marking bicycle symbol could have great impact on reducing driving speed. 61 percent of the respondents would drive slower and 39 percent with the same speed.

You are cycling. Which streetscape would you rather cycle in?
Figure 4.42 shows that Alpha very strongly prefer to the bicycle symbol. 91 percent would rather have it and for 9 percent it does not matter. Figure 4.44 shows that 78 percent of Beta would appreciate a bicycle symbol in the drive lane. Only 4 percent do not like it and for 18 percent it does not matter.

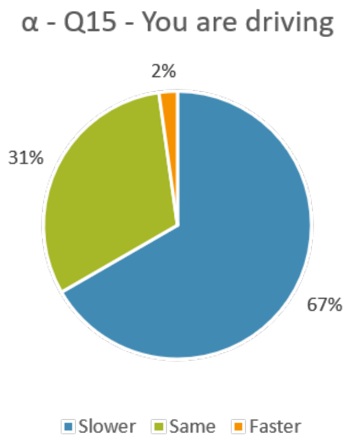


Figure 4.41: Diagram showing the distribution of Alpha's response on question 15

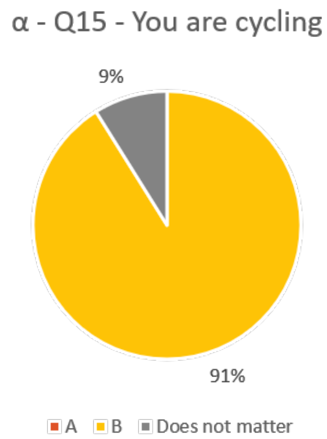


Figure 4.42: Diagram showing the distribution of Alpha's response on question 15

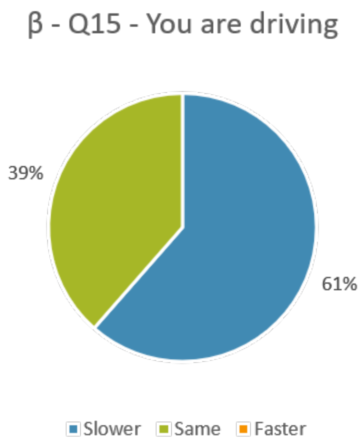


Figure 4.43: Diagram showing the distribution of Beta's response on question 15

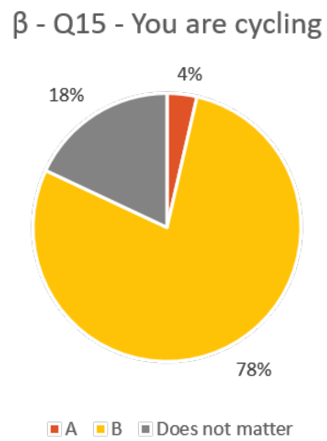
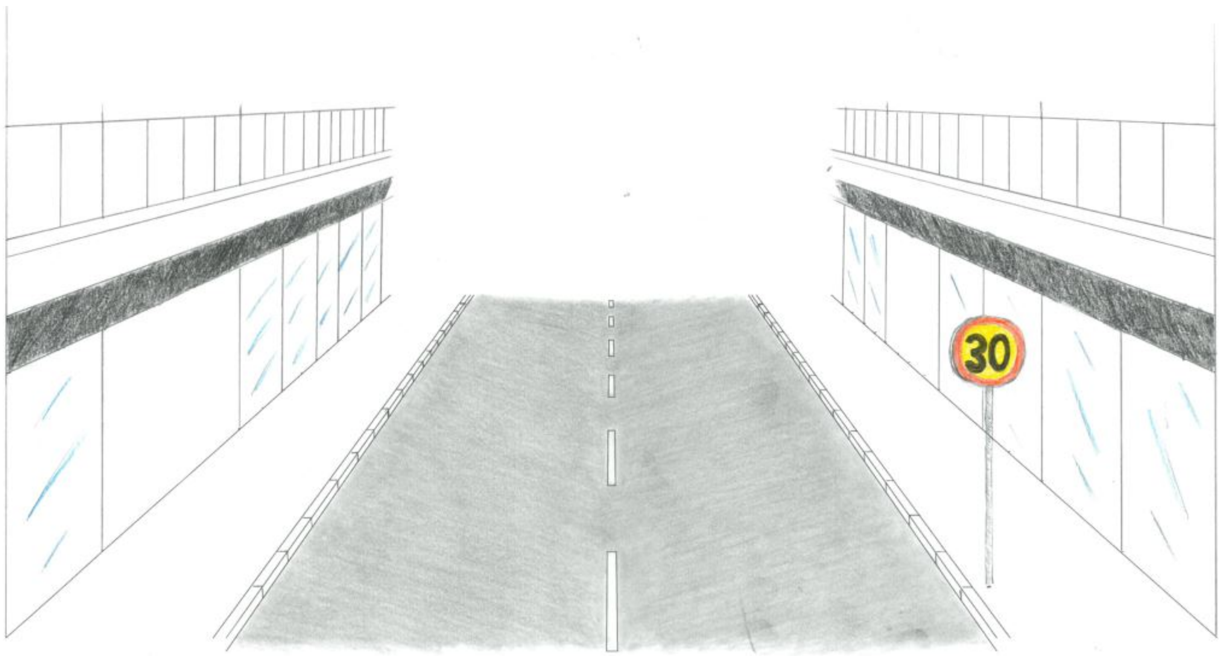


Figure 4.44: Diagram showing the distribution of Beta's response on question 15

Question 16

In streetscape B an extra panel road sign has been added with the text "Shared speed". The lane width is unchanged.



You are driving. What speed would you drive in B compared to A?
Figure 4.45 shows that Alpha an extra panel road sign with the text *Shared speed* compared to only the speed limit sign 30 km/h would not have significant effect, however, at least not increase driving speed. 65 percent responded they would drive with the same speed and 35 percent would drive slower. Figure 4.47 shows that 74 percent of Beta would drive with the same speed with the *Shared speed* sign and 26 percent would drive slower.

You are cycling. Which streetscape would you rather cycle in?
Figure 4.46 shows that the majority (52 percent) of Alpha rather have the *Shared speed* sign and for 48 percent it does not matter. Figure 4.48 shows that cyclists in Beta would not mind to include the *Shared speed* sign. Many more (42 percent) like it than dislike it (5 percent). Still, for the majority (53 percent) it does not matter.

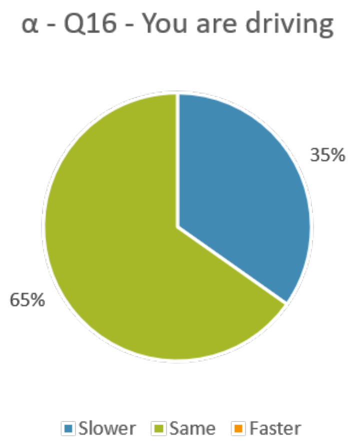


Figure 4.45: Diagram showing the distribution of Alpha's response on question 16

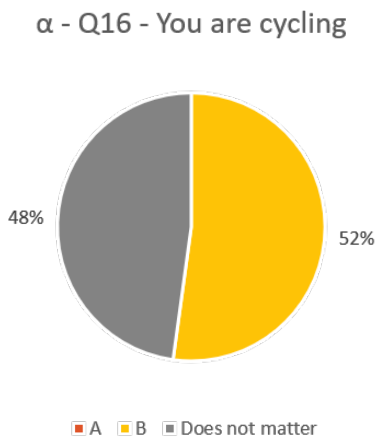


Figure 4.46: Diagram showing the distribution of Alpha's response on question 16

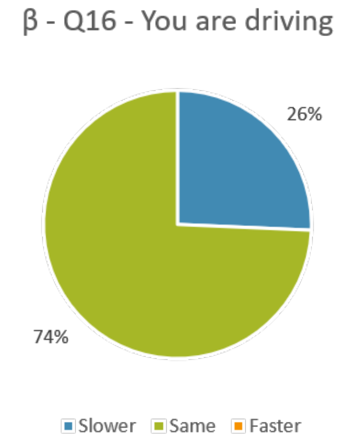


Figure 4.47: Diagram showing the distribution of Beta's response on question 16

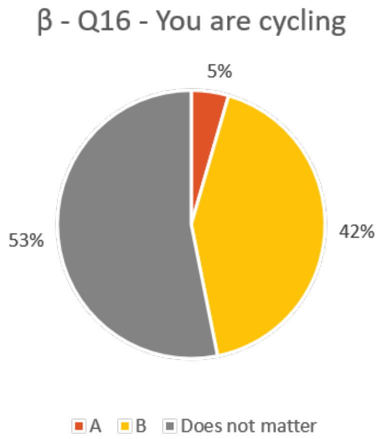
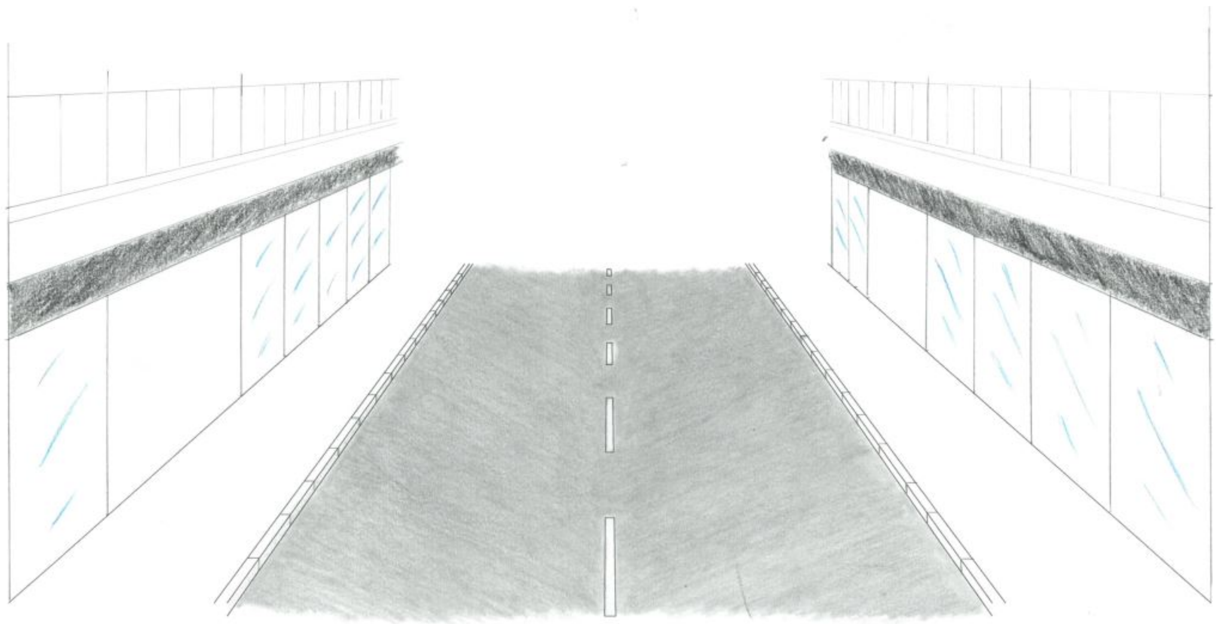


Figure 4.48: Diagram showing the distribution of Beta's response on question 16

Question 17

In streetscape B a road sign saying "Cars are guests" has been added. The lane width is unchanged.



You are driving. What speed would you drive in B compared to A?
Figure 4.49 shows that Alpha would very likely drive slower with the *Cars are guests* sign present. 74 percent responded slower and 26 percent responded the same speed. Figure 4.51 shows that in Beta would 61 percent reduce their speed, 37 percent would drive with the same speed and only 2 percent would drive faster.

You are cycling. Which streetscape would you rather cycle in?
Figure 4.50 shows that Alpha strongly prefer the *Cars are guests* sign. 85 percent would rather cycle with it present and for 15 percent it does not matter. Figure 4.52 shows that Beta would prefer a *Cars are guests* sign. 75 percent believe it is a good idea while only 5 percent do not like it. For 20 percent it does not matter.

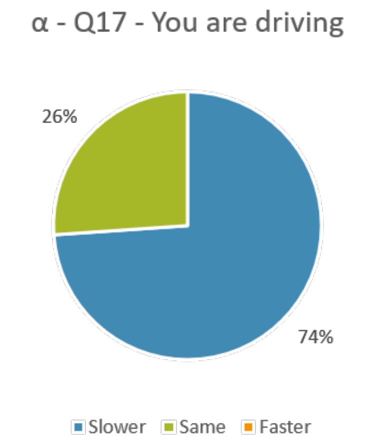


Figure 4.49: Diagram showing the distribution of Alpha's response on question 17

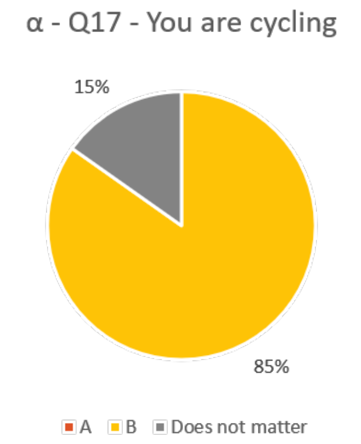


Figure 4.50: Diagram showing the distribution of Alpha's response on question 17

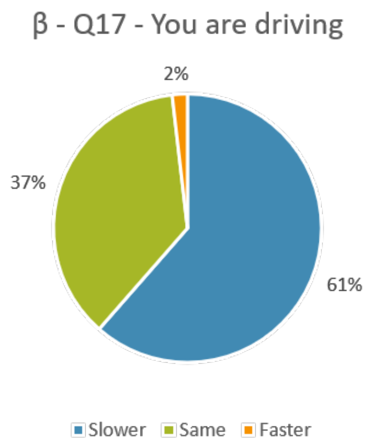


Figure 4.51: Diagram showing the distribution of Beta's response on question 17

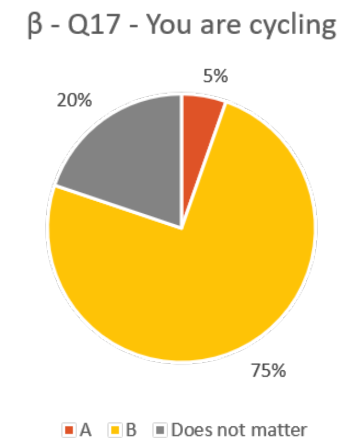
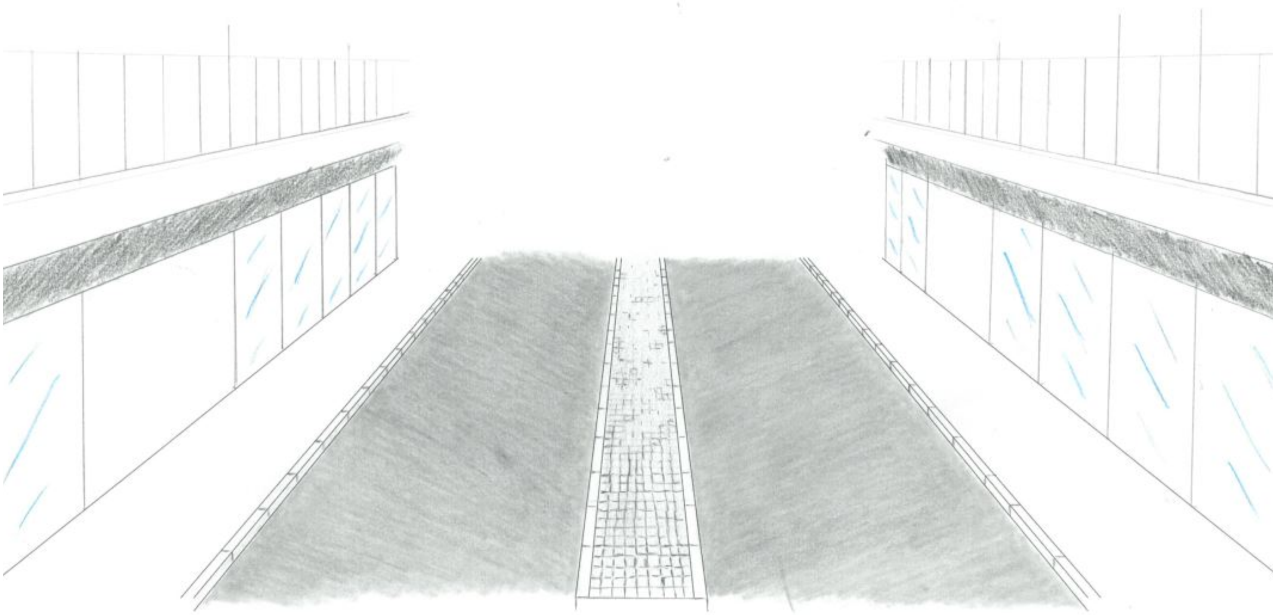
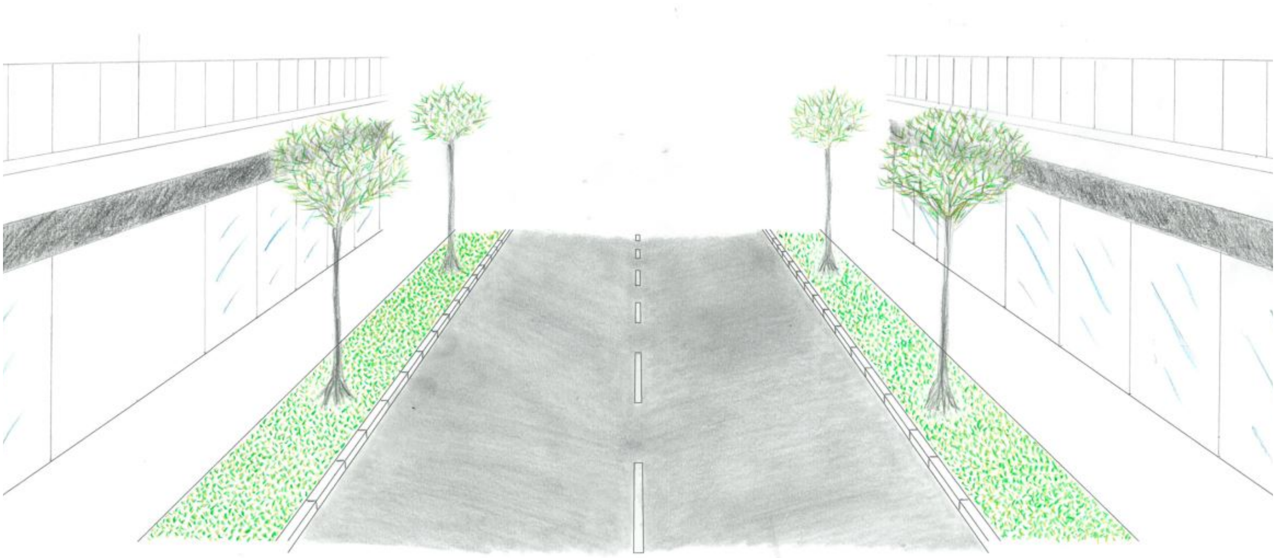


Figure 4.52: Diagram showing the distribution of Beta's response on question 17

Question 18

Compare the central divider in streetscape A with the trees in streetscape B. The lane width is unchanged.





You are driving. What speed would you drive in B compared to A?
Figure 4.53 shows that Alpha would drive faster with trees instead of a central divider. 43 percent responded faster, while 20 percent responded slower and 37 percent would drive with the same speed. Figure 4.55 shows that for Beta, a central divider and trees have nearly the same effect on driving speed. The majority (52 percent) would drive with the same speed. If the results indicate anything, the speed will not be reduced with only 19 percent responding slower driving and 28 percent faster driving.

You are cycling. Which streetscape would you rather cycle in?
Figure 4.54 shows that for Alpha, trees are more preferred than a central divider 52 percent of the responses. 35 percent prefer the central divider and for 13 percent it does not matter. Figure 4.56 shows that the majority of Beta (54 percent) prefer trees, while 33 percent prefer a central divider. 13 percent are neutral.

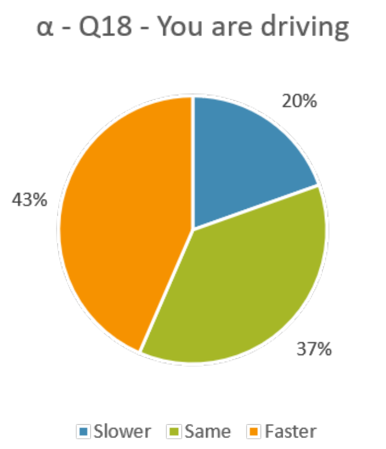


Figure 4.53: Diagram showing the distribution of Alpha's response on question 18

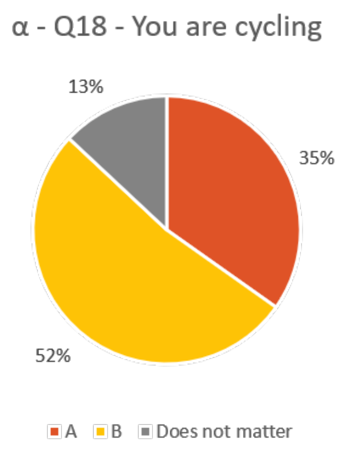


Figure 4.54: Diagram showing the distribution of Alpha's response on question 18

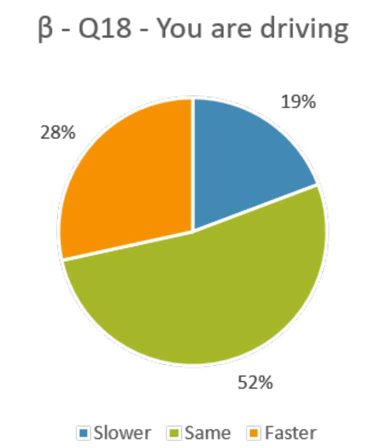


Figure 4.55: Diagram showing the distribution of Beta's response on question 18

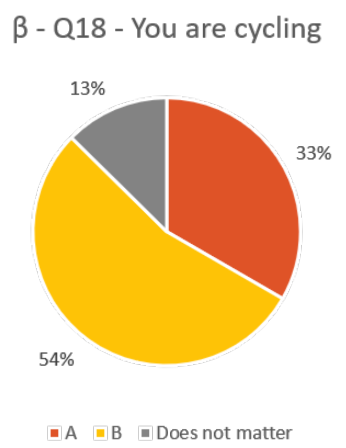


Figure 4.56: Diagram showing the distribution of Beta's response on question 18

Question 19

Compare the Shared speed sign in streetscape A with the Cars are guests sign in streetscape B. The lane width is unchanged.

You are driving. What speed would you drive in B compared to A?
Figure 4.57 shows that for Alpha, the *Cars are guests* sign would promote slower driving over the *Shared speed* sign. 59 percent would drive slower, 2 percent faster and 39 percent would drive with the same speed. Figure 4.59 shows that 45 percent in Beta would reduce their speed while 4 percent would increase their speed. The majority (51 percent) however, would drive with the same speed with either sign.

You are cycling. Which streetscape would you rather cycle in?
Figure 4.58 shows that Alpha strongly prefer the *Cars are guests* sign over the *Shared speed* sign. 80 percent compared to 4 percent and for 15 percent it does not matter. Figure 4.60 shows that Beta prefer the *Cars are guests* sign with 59 percent of the responses. For 26 percent it does not matter which sign and 14 percent prefer the *Shared speed* sign.

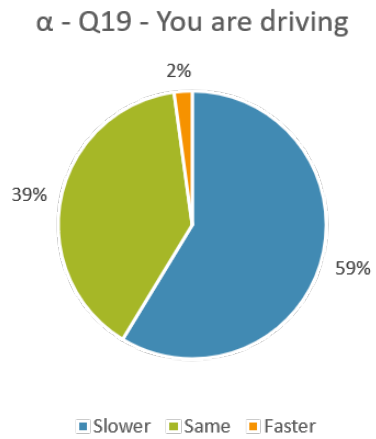


Figure 4.57: Diagram showing the distribution of Alpha's response on question 19

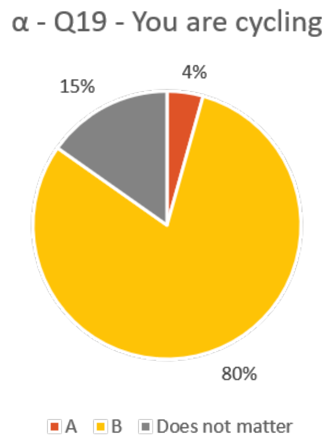


Figure 4.58: Diagram showing the distribution of Alpha's response on question 19

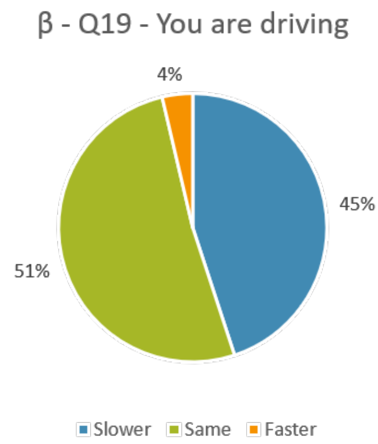


Figure 4.59: Diagram showing the distribution of Beta's response on question 19

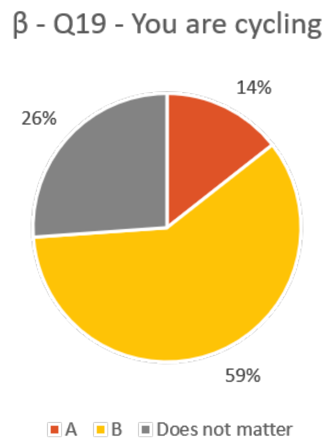
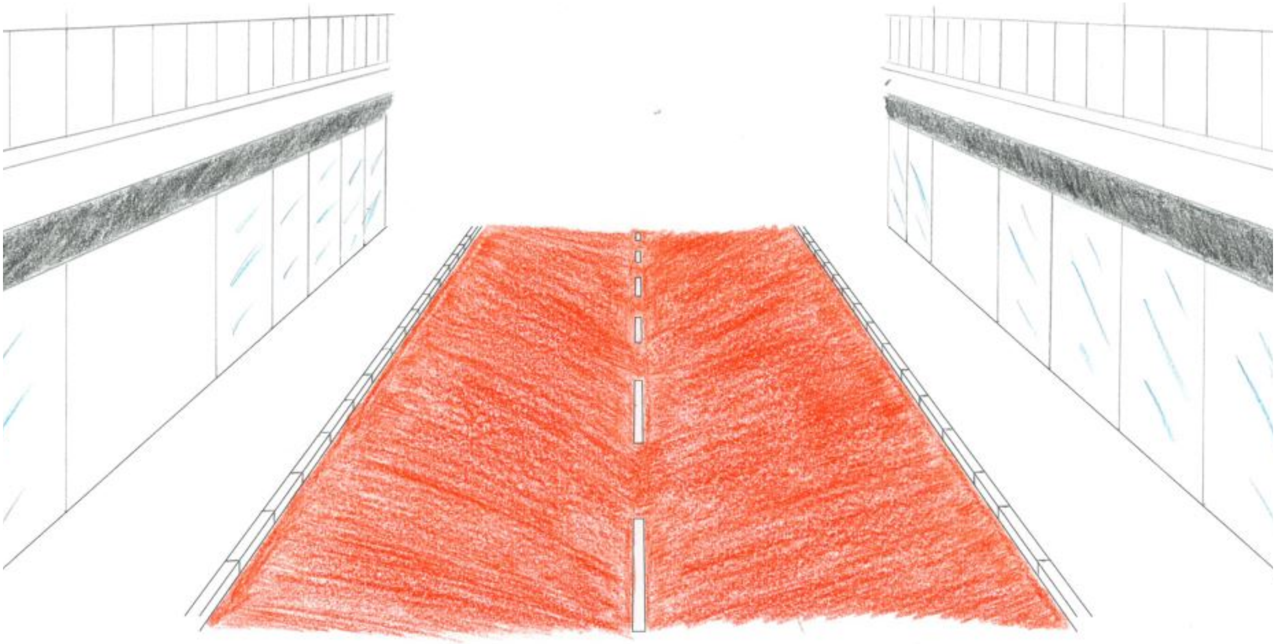
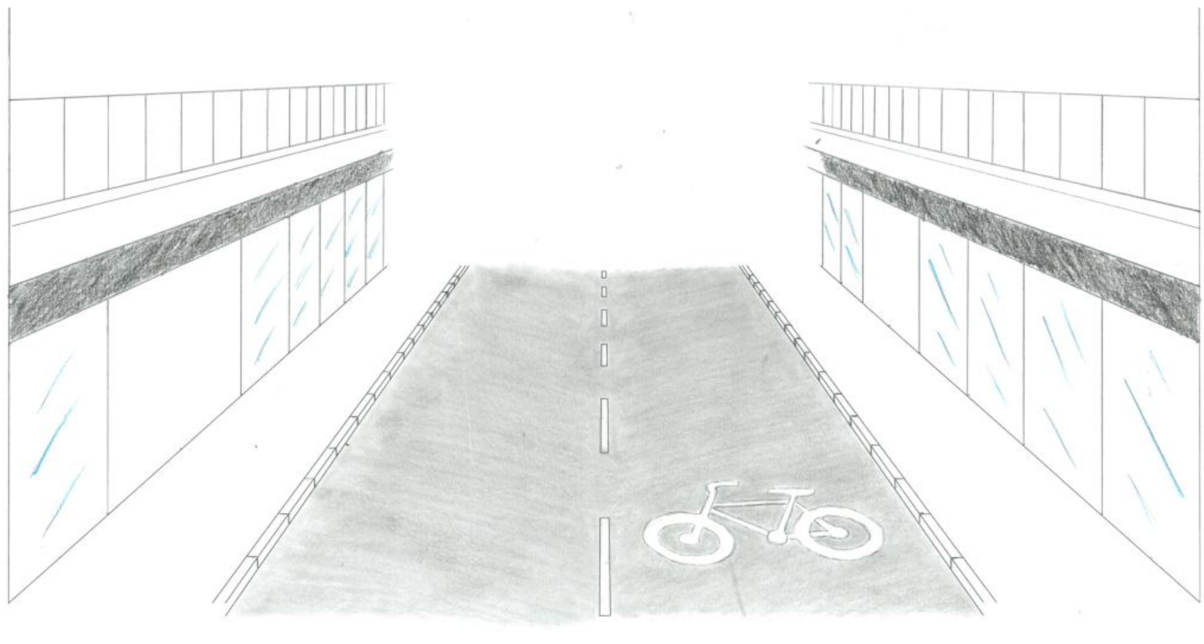


Figure 4.60: Diagram showing the distribution of Beta's response on question 19

Question 20

Compare the colored pavement in streetscape A with the bicycle symbol in streetscape B. The lane width is unchanged.





You are driving. What speed would you drive in B compared to A?
Figure 4.61 shows that for Alpha, the colored pavement and the road marking bicycle symbol would either reduce the speed (47 percent) or maintain the speed (44 percent). 9 percent responded they would driver faster. Figure 4.63 shows that Beta would drive with the same speed with 66 percent of the responses. 7 percent responded faster driving and 27 percent slower driving.

You are cycling. Which streetscape would you rather cycle in?
Figure 4.62 shows that 64 percent of Alpha prefer the bicycle symbol over the colored pavement. 13 percent prefer the colored pavement and for 22 percent it does not matter. Figure 4.64 shows that the majority of Beta (55 percent) prefer the bicycle symbol. For 27 percent of the respondents it does not matter and 18 percent prefer the coloring.

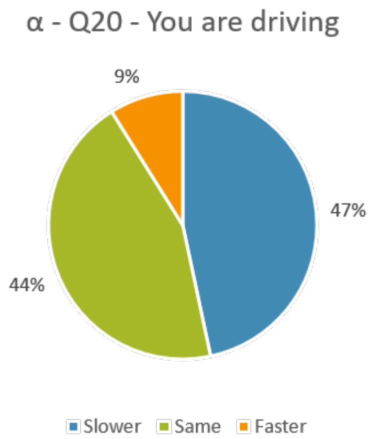


Figure 4.61: Diagram showing the distribution of Alpha's response on question 20

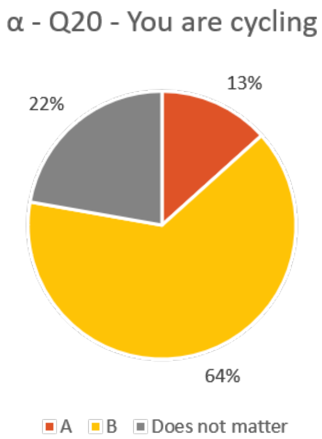


Figure 4.62: Diagram showing the distribution of Alpha's response on question 20

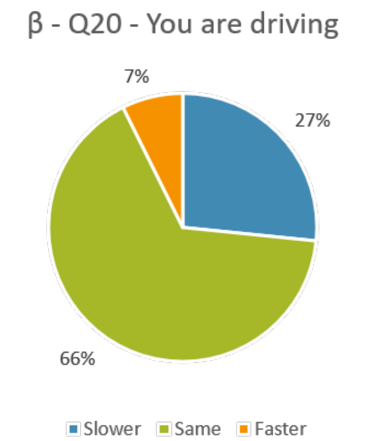


Figure 4.63: Diagram showing the distribution of Alpha's response on question 20

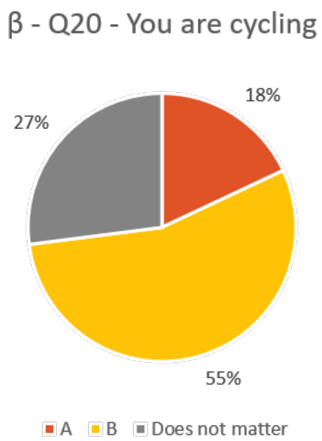


Figure 4.64: Diagram showing the distribution of Beta's response on question 20

Question 21

If you would combine 3 design elements, which ones according to you would give the best conditions for cars and bicycles to share the roadway?

Figure 4.65 shows that Alpha believe that the *Cars are guests* sign with 29 votes will give the best conditions for cars and bicycles to share the roadway. In second place lane width and bicycle symbol received 22 votes each. Central divider received 16 votes, pavement, 13, coloring 11, *Shared speed* sign 8 and on-street parking and greenery received 2 votes each. Figure 4.66 shows that Beta believe most in the bicycle symbol with 66 votes. In second place the *Cars are guests* sign received 59 votes. Lane width and central divider received 44 votes each on a tied third place. *Shared speed* sign and coloring tied in fourth place with 30 votes each. Pavement received 12 votes and on-street parking 3 votes.

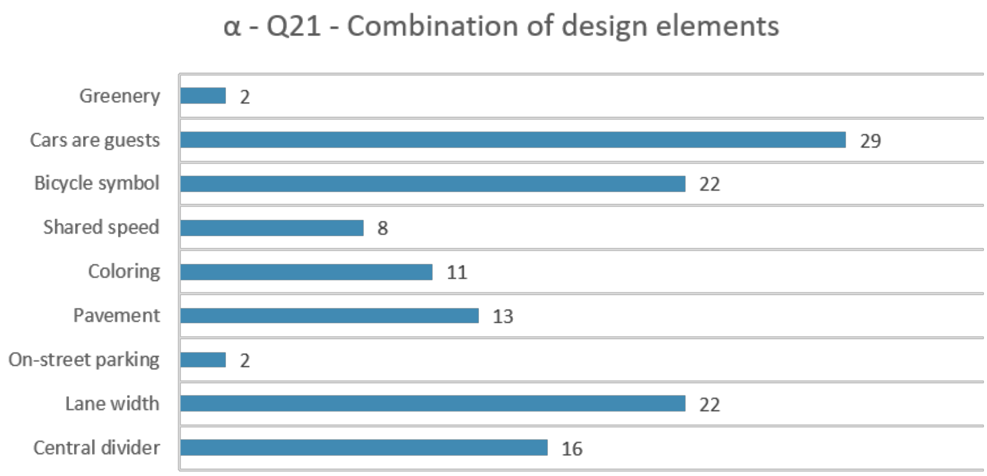


Figure 4.65: Diagram showing the distribution of Alpha's response on question 21

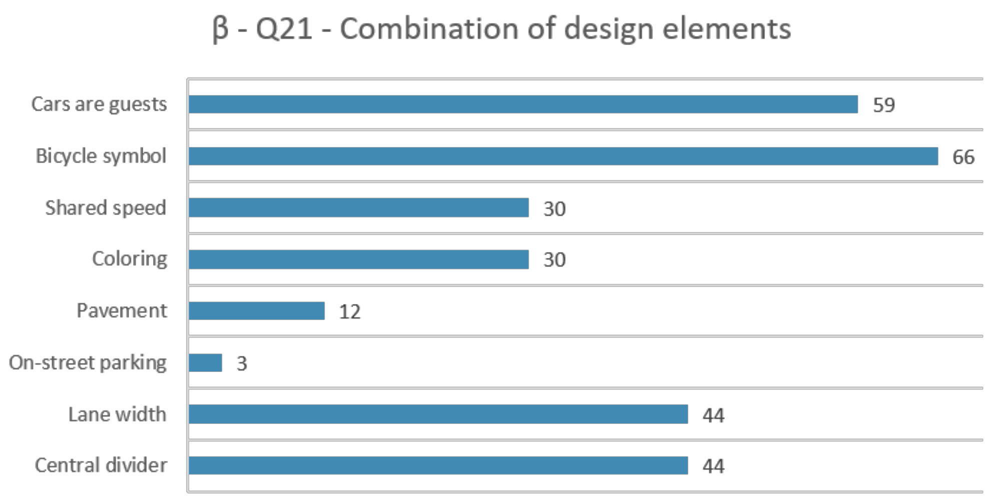


Figure 4.66: Diagram showing the distribution of Beta's response on question 21

5 | Analysis

Very few respondents in Alpha and 16 respondents in Beta do not hold a driver's license. Since, more people in Beta are cycling to work it is not a surprise. Not holding a driver's license can be a reason for cycling. It can both be since they are cycling they do not want or need a driver's license and also they cycle because they can not drive. No correlation to other questions were found.

Not surprisingly does almost everyone in Beta use bicycle on their work trips whereas in Alpha the dispersion is greater. Beta consist of faster cyclists than Alpha. The high use of bicycle and the higher speeds was expected since Beta can be assumed to consist of dedicated cyclists. Almost everyone in both groups together see themselves as comfort or fast cyclists which can be seen in figure 5.1. The only slow cyclist is found among the car drivers which might be connected to why they use the car on their work trip. The connection can be because slow cyclists prefer to take the car or it can be that when the car drivers use bicycle they are not in a hurry. It can also be in relation to the literature where experience was suggested to have influence on cycling speed. From this correlation those using bicycle on their work trip to higher extent see themselves as fast cyclists. The same was found between PT-users and bicycle users where those using bicycle on their work trip were faster. Therefore, the results from this study can support the suggestion that experience influence cycling speed and that the dedicated cyclists in Beta was assumed to have higher cycling speed than cyclists in Alpha.

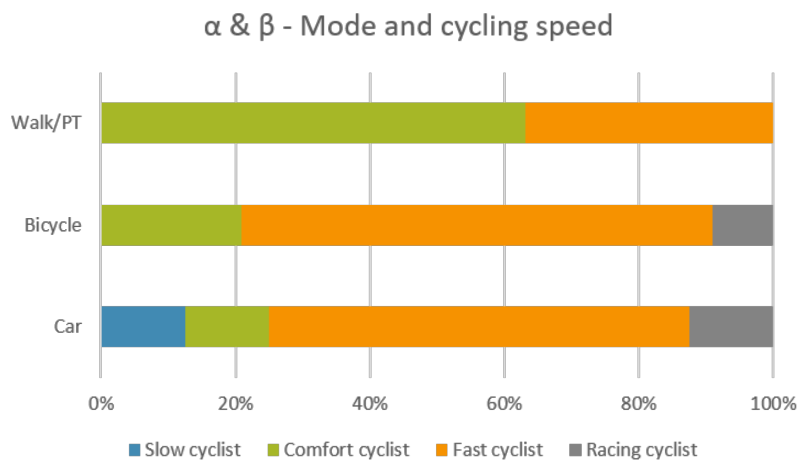


Figure 5.1: The diagram illustrate how the using of different transport modes correlate to how cyclists see themselves regarding speed.

Most respondents in Alpha responded they use public transport (PT) the longest distance. Therefore, it would have been interesting to know if the PT-users in both groups use bicycle to and from the stop. However, that was not included in this study. In Alpha 11 percent responded they use e-scooter or similar. These road users can be assumed to be driven mainly on bicycle lanes being part of the flow in that space.

The use of bicycle types is quite similar in Alpha and Beta. Most people use regular bicycles and electric bicycles are equally common. The biggest difference is the use of racers. However, if the bicycle types would to be subdivided into more types the distribution would look different. Some respondents specified that they use city bike, hybrid, single-speed, randonneur, cyclocross etc. The literature suggested that also bicycle type and cycling speed correlate. Figure 5.2 supports that suggestion. Those who see themselves as fast and racing cyclists use road races or similar to a higher extent. It seems that in order to be a racing cyclists one need to use a either an electric bicycle, mountainbike or road racer or similar. The slow cyclist was only one person and he/she uses a regular bike. Furthermore, it is difficult to analyze how cargo bikes correlate to speed.

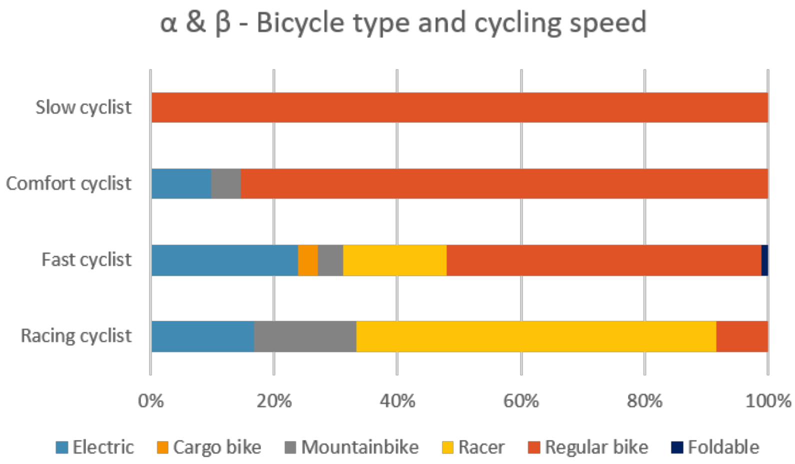


Figure 5.2: The diagram illustrate how the using of different bicycle types correlate to how cyclists see themselves regarding speed.

Beta is slightly more positive to sharing the roadway and most evidently fewer responded *No* than in Alpha. Then there is the group of *Maybe*, which is not a *No* and not a *Yes*. Yet, *Maybe* could be seen more towards a *Yes* than a *No*. Bicycles sharing space with vehicles is much less common in Sweden than sharing with pedestrians which might cause skepticism to not choosing *Yes*. In the same way Beta would rather share with car drivers to a higher extent than Alpha. An explanation could be the experience and higher speeds among these respondents.

Figure 5.3 show that those who use bicycle longest distance of their trip to work would rather share space with cars than pedestrians. Those who take the car to work would rather not share with cars when they bicycle themselves. PT-users have been grouped with pedestrians since PT-users often are pedestrians to and from the stop. The majority of pedestrians would rather share space with car drivers when cycling themselves.

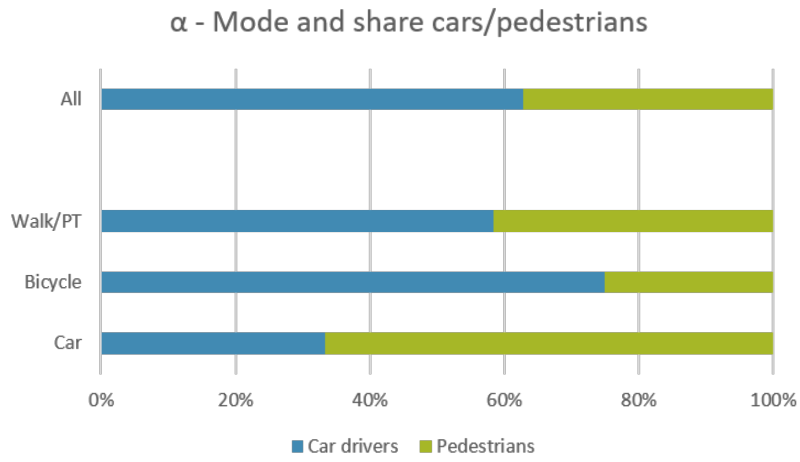


Figure 5.3: The diagram illustrates how the using of different transport modes correlate to how cyclists would like to share the space.

The majority of all respondents could envision cars and bicycles to share the roadway provided they share speed. In the same way as above the responses differ among the road users. Figure 5.4 shows that cyclists have a higher acceptance of mixed traffic cycling than the car drivers. A slight majority of the car drivers believe that mixed traffic cycling is not a good idea. Similarly to above the pedestrians are more positive than negative to the idea.

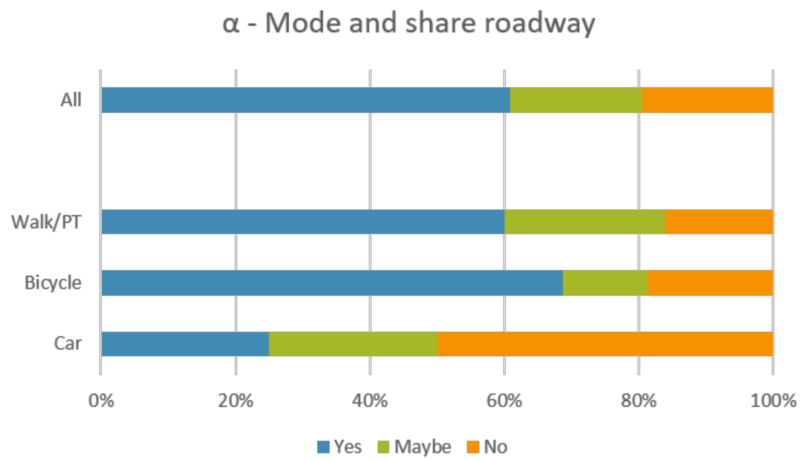


Figure 5.4: The diagram illustrates how the using of different transport modes correlate to the acceptance of cars and bicycles sharing the roadway.

Since both majorities in Alpha and Beta could envision cars and bicycles to share the roadway (question 6), it would be of interest to see how the response correlated with the cycling speed (question 5). Figure 5.5 reveal that for Alpha, fast cyclists could to a higher degree envision sharing the roadway and by comfort cyclists *Yes* did not have majority. Interestingly though, the one person responding slow cyclist, could envision sharing the roadway. More responses of slow cyclists would be needed to find any correlation. However, figure 5.6 shows that for

Beta the correlation is not as strong and the responses were more evenly distributed. Yet, a smaller share of racing cyclists responded *No* than comfort cyclists. The *Yes* response was evenly distributed over all cycling speeds within Beta.

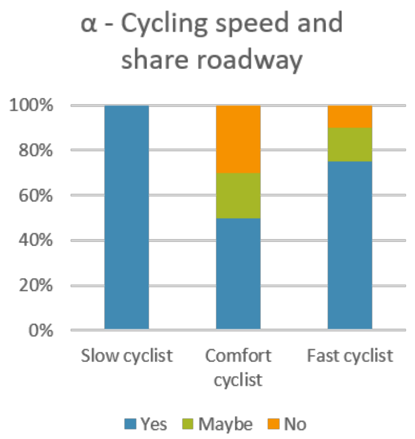


Figure 5.5: Diagram showing the distribution of Alpha's response on question 19

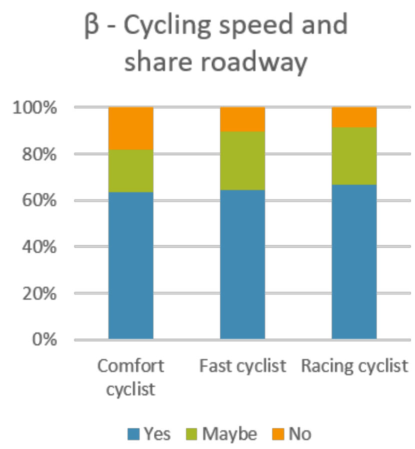


Figure 5.6: Diagram showing the distribution of Alpha's response on question 19

The same analysis was made between cycling speed and sharing space with cars or pedestrians (question 7). Figure 5.7 and figure 5.6 show that for both Alpha and Beta the fast cyclists are those that to the higher degree want to share with car drivers rather than pedestrians. The slow cyclist and the majority of comfort cyclists also want to share with car drivers. Racing cyclists in Beta however responded they wanted to share with pedestrians to a higher degree than the comfort and fast cyclists.

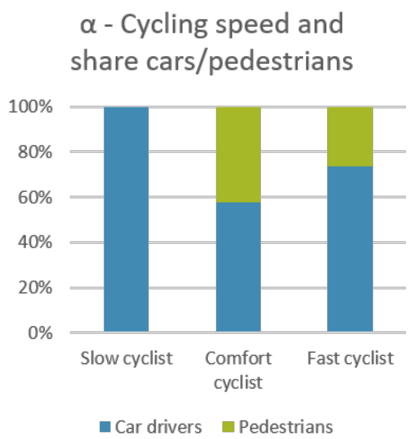


Figure 5.7: Diagram showing the distribution of Alpha's response on question 19

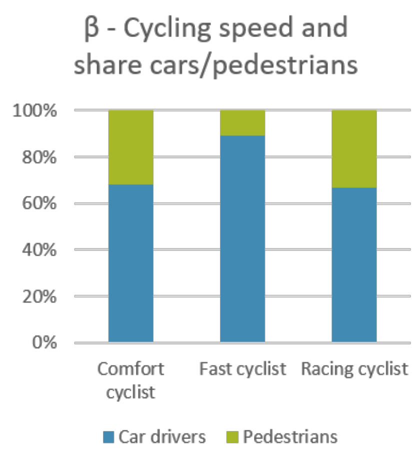


Figure 5.8: Diagram showing the distribution of Alpha's response on question 19

The responses are very similar over all the questions concerning the design elements. However, there is a bias to be find. All design elements expcept central divider would cause Alpha to reduce their speed more than Beta. Beta responded for all those questions that they would drive with the same speed to a higher degree than Alpha. Regarding the attractiveness for cycling, Alpha was more consistently united about the most preferred streetscapes.

The results show that the design elements that would have a traffic calming effect are central divider, narrow lane width, on-street parking, pavement, bicycle symbol and the *Cars are guests* sign. Looking at the distributions from each question, the design elements that would have the most considerable effect on driving speed were lane width with 93 percent and 88 percent of the responses from Alpha and Beta respectively. The second was pavement with 91 percent and 73 percent response for slower driving. Design elements that could have a calming effect, however, the results cannot fully support it are green barriers, trees, coloring, *Shared speed* sign. At least do these design elements not promote faster driving.

Design elements that would contribute to the attractiveness of cycling are green barriers, bicycle symbol and the *Cars are guests* sign. The design element most preferred when cycling is the bicycle symbol with 91 percent and 78 percent of the responses from Alpha and Beta respectively. The next element is the *Cars are guests* sign with 85 percent and 75 percent, respectively. Those design elements that need further investigation to establish if they are preferred or not, are trees, central divider, the *Shared speed* sign and colored pavement. Also, those that are not preferred when cycling are narrow lane width, on-street parking and uneven pavement.

When the design elements were dealt with individually, the respondents were asked to choose which three design elements they believe give the best conditions for cars and bicycles to share the roadway. Here the result differs slightly from the results of each element. Narrow lane width was not all preferred when cycling; however, it was one of the top three elements when choosing three important ones. Also, pavement was, at least by Alpha, one of the top five elements. The results indicate that not only the preference for cycling has been accounted for but also traffic calming measures.

There was no easy way to see the correlation between design elements and other question which is why it was not analyzed due to time constraints.

5.1 | Regarding chosen methodology and possible errors

First of all it should be remembered that the response of what the respondents claim they would do might not be equal to how they would actually act.

The questionnaire was shared to members on a Facebook group called Cykla i Göteborg [in English: Cycling in Gothenburg] which has to be assumed consists of devoted cyclists. This group of devoted cyclists most likely cycle on a regular basis and travel with a cycling speed above average. Therefore, this group cannot represent all cyclists of Gothenburg. The response from this group might be completely different from what the majority of cyclists think.

Possibly, the drawing of the central divider in the center of the picture has tricked a few people into seeing another type of design where the center of the road is only paved with cobblestones. The description indicates that it is an elevated central divider. The central divider makes overtaking more difficult which is why the design element was part of the questionnaire.

The narrowing of the drive lane was done drastically to only 2 meters width. That is a very small width when there is a central divider present. Cars just barely fit between the curbstones and that the results show a traffic calming effect is not surprising at all. When cycling the lane width is not totally rejected however not preferred. Another lane width between the standard 3.5 meters and 2 meters would maybe give a more positive response.

Trees did not have the effect that was assumed. Hypothetically drivers would drive slower to a higher degree with trees on both sides of the street. Potentially the trees were perceived as small and not having the same effect as large trees could have.

Comments from the respondents indicate that the colored pavement can have been interpreted as a layer of paint on top of the asphalt instead of asphalt with color pigments. The layer of paint does not have the same slip resistant surface and can therefore have compromised the response.

Eriksson et al. (2017) indicate that choice of bicycle type might be more connected to reason of travel and economy than interest of speed. Still, the authors mean that cyclists on racers and electric bicycles generally travel faster.

Public transport users in the questionnaire have been assumed to walk to and from the stop. They can of course also use bicycle, e-scooter etc. However, the question was expected to be complex in case those options were to be included.

After the collection of responses through the questionnaire was finished, it was realized that the option to not answer questions at all was possible. Therefore, some questions have fewer responses than others. The percentage was very small and the no-responses did not bias the results.

One thing that would have been beneficial to change in the questionnaire was the format of the last question where three design elements were combined. It would have been interesting to see if there was any correlation between cycling characteristics such as speed, bicycle type and willingness, and the design elements that the respondents wanted to combine. The format of the question would have to be different so that it would be easy to survey the correlation whereas with the current format it would all have to be done manually.

The questionnaire might have been confusing regarding the streetscape A and B can have been mixed up. You are driving. What speed would you drive in B compared to A? You are driving. What speed would you drive in B compared to A? The respondents could have responded the other way around A compared to B giving a complete opposite result of their response.

6 | Discussion

In this chapter the literature along with the results and analysis of the questionnaire are discussed.

One can wonder why the center of the street almost exclusively is dedicated to motor vehicles. Why are not cyclists and pedestrians allowed to be in the center of attention? They are often shoved to the sides and forced to share space with each other. Cyclists have equal rights to use the infrastructure and cyclists should be invited to the roadway. Planning after shared speed consequently supports mixed traffic cycling whereas cyclists on urban streets are closer to sharing speed with motor vehicles than pedestrians. Still, there is no doubt that cyclists is the group with the greatest dispersion of speed. The heterogeneous group have very different capabilities and needs. Cyclists as a whole group would be benefited the most by having their own lane separated from both motor vehicles and pedestrians, however that is seldom possible due to lack of space. Therefore, cyclists should share the roadway with motor vehicles. The speeds are for many cyclists similar to the motor vehicles and in other cases the slower cyclists would reduce the driving speed by acting as mobile traffic calming measures. However, it is not clear where to locate the slowest cyclists. Removing separated bicycle lanes would cause inaccessibility for those cyclists, interfering with the goal to provide accessibility for everyone. Besides, it seems that no one wants to share space with cyclists. The opinion is that cyclists behave recklessly and cycle excessively fast. Therefore, would it not be better if they shared space with motor vehicles?

The safety of cyclists is of great importance in the interplay with motor vehicles. Separation follows the safety work that Sweden has worked with for many years. However, when shared speed is acquired, cycling in mixed traffic might be as safe or even safer. Paper after paper suggest that mixed traffic cycling is less safe than separated bicycle facilities, yet no paper has been found to actually confirm this. The studies often compare cycling on multi-lane roads with higher speeds and low bicycle flows. Those studies cannot be fairly used for the intended streetscapes in this study. Certainly, cycling on streets with high speeds are to be avoided provided there is possibilities for separation. Also, cyclists in mixed traffic can cause obstruction to flow and cause dangerous situations not only for cyclists, but also drivers. The overtaking creates another element of safety hazard for both cyclists and drivers. Yet, cyclists can for traffic planners be recognized as mobile traffic calming measures. If drivers are not allowed or able to overtake cyclists, shared speed is further accomplished and vehicle speeds are forced to be low. What need to be taken into account is the speed affecting death and injuries. A reduction in speed thanks to mixed traffic, would result in fewer and less severe accidents.

Safety in numbers has shown to have positive effects and the travel surveys of the Gothenburg region reveal that there is huge potential to increase the number of active travelers. However, an increase in active travelers will probably have a negative effect on the interplay between cyclists, and pedestrians and cyclists. Studies show an increase of more rear-end conflicts with increased flows and it can be assumed that also more single-accidents will occur. Additionally, more cyclists will likely decrease efficiency per cyclist since it becomes more difficult to travel with desired speed. Consequently, hard work on making the bicycle infrastructure attractive is of great importance to supply the desired increase of cyclists. There is no consistent research that confirms increased mid-block safety with mixed traffic cycling. Still, speeds are reduced and cyclists become more visible, which entails improved safety. Furthermore, the safety in intersections would likely improve. Avoiding collisions between motor vehicles and cyclists in intersections should be reason enough for using mixed traffic solutions.

Furthermore, one-way cycling is stated to be one of the successful approaches to be a great cycling city. Mixed traffic is one-way solution and it would be more space-efficient than constructing separate one-way bicycle lanes. Also, using the already highly accessible and mobile street network would give also the cyclists direct routes.

It was found that red asphalt is more expensive than regular asphalt. However, since it was mostly due to lesser use, it implies that if used more regularly, it would not be as expensive. For example, streets intended for mixed traffic could be paved with red asphalt to increase awareness and provide a self-explanatory design. The red asphalt could express the use of bicycle speed. The same idea with color could work where walking is prioritized, however, not necessarily with asphalt.

$2-1$-roads are in conflict with the principle of not mixing bicycles and motor vehicles when speeds are over 30 km/h. Therefore, the concept is of interest for this study since it focuses on urban transport. $2-1$-roads could be functional on urban streets where the flows of bicycles and motor vehicles are low. The vehicle speeds are lower and the cyclists will be given more space, whereas the mobility for motor vehicles is reduced without compromising accessibility. In order for preventing motor vehicles of not driving with one wheel pair on the shoulder at all times it could be tested to use rumble strips. Likewise, bicycle streets have shown to have great beneficial effects on cyclists' opinions about that specific link in the bicycle network, without making it much worse for the other road users. The bicycle street can on flat stretches work to establish shared speed where motor vehicles and bicycles are reducing speed for each other.

It is somewhat unclear in the traffic regulations whether bicycles are vehicles or not. In some regulations they are included within the same regulations as motorized vehicles and in others they are specifically mentioned separately. Therefore, the speed limit on separated bicycle lanes is not clear. It can be interpreted that cyclists are allowed to travel with speeds up to 50 km/h on separated bicycle lanes, even though the parallel street has a speed limit of 30 km/h. Regulations generally need to be updated and accommodate cyclists better. For instance, slow cyclists older than eight years old maybe should be allowed to use dedicated walking spaces provided they operate on the premises of pedestrians.

6.1 | Results and analysis

The results from the questionnaire indicate that regulations promoting mixed traffic cycling are needed. A road sign designed for mixed traffic cycling is highly requested and should be introduced. The road sign exist in other countries and should therefore not be too difficult to bring to Swedish traffic regulations. The same goes for the road marking bicycle symbol which exist, however, is not allowed to be painted where motorized vehicles are allowed. Some changes in the regulations would be needed or creating a similar symbol intended for mixed traffic solutions. It is not only that these two design elements are highly requested by cyclists, they can also have great impact on securing shared speed. Shared speed as an expression, however seems to be obscure, and using it might not be applicable as a speed measure. *Cars are guests* seem to a better speed indicator even though it more express the function of the street. However, if that can work that should be used. In this case this means that the road sign must be introduced compared to *Shared speed* which could have been used as a extra panel to existing road signs. Figure 6.1 illustrates what the *Cars are guests* sign could look like if it were implemented in Swedish regulations.

Figure 6.1: Conceptual design of a Swedish version of the *Cars are guests* sign.

The difference in acceptance of mixed traffic cycling among the different road users can probably be connected to the experience factor as presented in the section 2.4. Those who cycle to work can be assumed to have higher experience level than those who take the car to work. It also correlates to the evaluation of the bicycle streets in Gothenburg (presented in section 2.4.3) where drivers are critical to mixed traffic cycling. In the same way the pedestrians would rather see cyclists sharing with car drivers because they do not want to share the space with cyclists.

Generally the both groups responded similarly on every question regarding the design elements. The design elements that showed least similarity were green barriers, tress and pavement. It might be that this is where traffic engineers and civilian cyclists think differently. Engineers might believe that greenery should be included in streetscapes whereas civilian cyclists do not think it is important since it does not provide them with any further accessibility och mobility. Regarding the pavement, Alpha tough of it as more important when combining three elements whereas Beta did not consider it important at all. The civilian cyclists probably see the pavement as a negative thing whereas they do not prefer it all when cycling, while the engineers see pavement as a excellent way to control speed.

6.1.1 | Actual results versus expected results

The assumption was that the results from the questionnaire would differ more between the two sample groups. Yet, the response revealed that traffic engineers and dedicated civilian cyclists more or less agree which design elements they think are most crucial. However, it could might as well depend on the questions asked. Furthermore, the results regarding the design elements were no surprise.

It seems that racing cyclists are not more interested in mixed traffic than fast cyclists. One could think that the faster the cycling speed the higher interest. One thought can be that when cycling close to or above 30 km/h racing cyclists believe that the cars will obstruct cycling more than pedestrians.

The colored pavement was expected to be more preferred than the actual results showed. Red asphalt on bicycle lanes are very common in e.g. the Netherlands and used to indicate bicycle infrastructure. One could therefore think that this feature was desired also in Sweden to strengthen the bicycle's position in the transport system. Likewise, including trees in the streetscape was expected to have larger effect on reducing the driving speed. However, apparently tress was not seen as particularly important.

6.2 | Shared speed as a concept

Accessibility and proximity are fundamental needs for people and their well-being. A city that is sized after walking and cycling speeds, as many of the old European cities are, gives great values. Urban planning must strive for this, securing sustainable development. Accessibility and safety go hand in hand and as we are safer, we feel safer and secure. Travel surveys report that many people live close to their workplace and many trips are very short trips. Still, people do not use sustainable transport modes. Of course, some people cannot choose to walk or cycle or even use public transport for several reasons. However, most people living within 5 kilometers should be able to walk or cycle.

Figure 6.2 illustrates a simplistic view of a city's spread. The city center is the greatest attraction of all places in a city and the majority of travelers travel to it or towards it and sometimes connecting for further traveling there. We all travel different lengths and with different transport modes. However, closest to the city center, the majority of people traveling are pedestrians. Still, pedestrians and cyclists all have individual abilities affecting the radius of action dependent on the speed one travel with and the distance one is willing to travel. Outside the pedestrian radius, the share of pedestrians decrease and the share of cyclists and motor vehicles increase. Here, the cyclists should be the majority but is seldom the case. Motor vehicles take up a great share of the trips that could have, by most people, been made by bicycle. Traveling by bicycle can make up great distances if one is willing to and today with the electric bicycles, more people are willing to cycle that distance or even longer. However, when the distance of cycling becomes untenable, public transport and cars are there to assist. The public transport provide us with another type of proximity bringing us to destinations over a greater area. Walking distance increase as we walk onto a train, bus or tram and leave by walking. Furthermore, the car has its own valuable attributes where flexibility is one of the most important ones. However, in a sustainable development the car needs to be more a compliment to walking, cycling and public transport than what it is today. Today, the car is the most comfortable transport mode even if it does not have to be.

With figure 6.2 in mind urban planning should prioritize road users within their radius of action. Those who live within bicycle distance should have a bicycle network where they are prioritized. The same goes for those who live within walking distance. Outside the bicycle radius, motorized transport can gradually obtain priority. Because, where motorized vehicles are allowed to dominate, large barriers will be the result. Problems with accessibility is created and cannot be the case where people are able and should travel by walk or bicycle.

It seems that it does not matter how fast we are letting our transport modes move. The travel time will stay the same and from the distance we are willing to travel is just pushed. Consequently, the radiuses of action can change over time. For instance, if the mobility is improved for cyclists and longer distance can be covered over shorter time, then people will cycle longer distances.

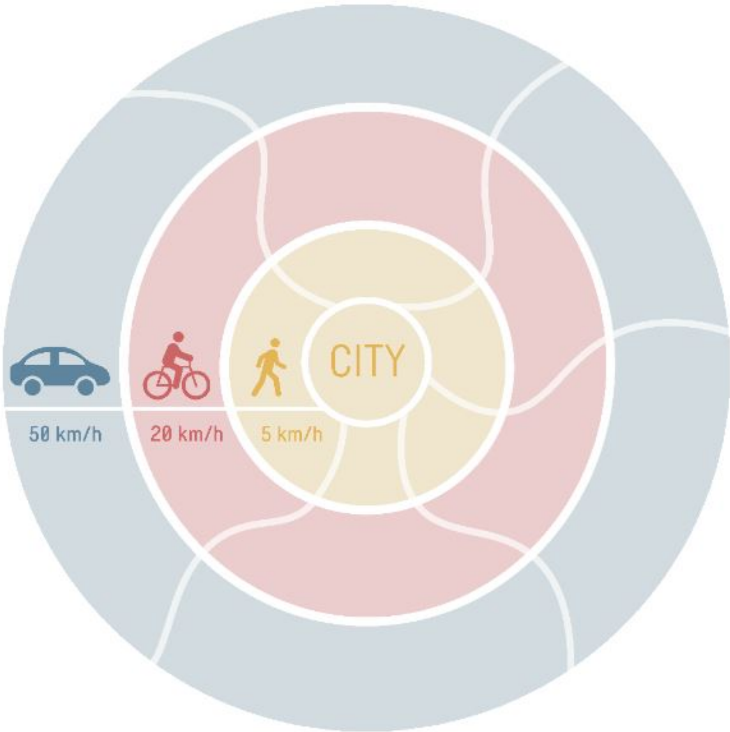


Figure 6.2: Principal illustration of the shared speed concept with the transport modes radius of action.

Geofencing can help with planning for shared speed. Speed can be controlled to which area the vehicle is in. The speeds can be pre-defined as the figure illustrate where the speed is set to walking pace from the city center to the edge of walking radius. Similarly, the speed limit is set to cycling pace from the edge of walking radius to the edge of bicycle radius. Of course, the urban design is not this simple, yet, the idea could still be applicable emerging from numerous centers within a city. Geofencing can be used on connected Geofencing on regular bicycles is not a possibility and can therefore not be used to prevent high cycling speeds where undesired such as pedestrian crossings and walking streets. Traffic calming measures for bicycles have been left out of this study yet need further investigations.

In practice cities are of course not as simple as the figure. The concept would likely be easier to implement in smaller cities where distances are shorter and only one city center exists. In Gothenburg there are several centers which would have to be designed for walking speeds. However, it is when the rings start to intersect one another it becomes complex. Also, it would not be practical for cyclists to have cyclists operating at walking speed or to travel around the walking radius and therefore the planning would of course need thoroughfares. However, for motor traffic the mobility should be highly limited. Consequently, the concept of shared speed can probably be functional in several places within Sweden and abroad.

7 | Conclusions and recommendations

Based on the objective and aim of the study, the main conclusions and recommendations are presented below.

There is already plenty of fruitful knowledge about creating a functional and attractive bicycle infrastructure. It has however, not yet been realized. The literature mentions tools to improve accessibility, mobility, and safety for cyclists. One-way bicycle network, separating cyclists from pedestrians, better maintenance, reduced vehicle speed, and design elements such as flat pavement, lane width and greenery are all essential features to create more attractive bicycle infrastructure.

To reclaim the lost human perspective, planning should strive for accessibility and mobility for pedestrians and cyclists. A prerequisite for increased accessibility is to improve safety, which can be improved by increasing the number of active travelers. The number of cyclists can be enlarged with direct routes for bicycles and limited accessibility for motor vehicles. A favorable approach is to use the efficient motor traffic infrastructure and invite cyclists into the roadway; thus will also state that cyclists have equal rights to the street. In urban areas, cyclists share speed with motor vehicles and not pedestrians. Consequently, the distribution of space in urban streetscapes should be reallocated based on speed.

The results from this study have shown that there is a willingness among both traffic engineers and dedicated civilian cyclists for mixed traffic cycling. The response from the questionnaire reveals that self-explanatory design and signals to the road users are seen as the most substantial aspects. The respondents consider road marking bicycle symbols, a *Cars are guests* sign, and lane width as the design elements that would give the best possible conditions for mixed traffic cycling. To establish shared speed, lane width and pavement was considered to have largest effect on reducing driving speed.

Cyclists are a very heterogeneous group. Speed, experience, and comfort level of cyclists vary, whereas mixed traffic does not suit all cyclists. Consequently, the bicycle infrastructure must provide solutions that are attractive for all types of users and, therefore, still must provide a separate space for cyclists. Cyclists that share speed with pedestrians could indeed use the sidewalks and shared walking and bicycle lanes.

Shared speed would not only improve safety and other conditions on each street individually. Planning for pedestrians and cyclists would affect the transport system and the city as a whole. An increased share of active travelers would profit the people and the city. By distributing more space to the active transport modes, cities would also benefit related to efficiency, air quality, noise, and public health, creating attractive and sustainable cities. Conclusively, shared speed can secure sustainable development.

8 | Future Research

In this chapter, topics for future research are suggested.

Further research should be made on the safety and health of cyclists if they were to cycle in mixed traffic. What would be the risk for rear-end collisions and the consequences of them? Also, what would the health effects be from cycling directly behind fossil fuel vehicles? Design changes would have to be studied and observed in real environments.

There should be some future research among cyclists in Gothenburg to better understand what they want. Also, it is necessary to weight in what the other road-users think of the planning and design. In order to attract drivers into choosing cycling those people's thoughts are of greatest interest.

A study of interest would be observing and measuring how well shared speed work. With what speed are bicycles and vehicles travel in mixed traffic? Are vehicle speeds affected by the presence of cyclists and also are bicycle speeds affected by vehicles? The observation should also include in what extent drivers overtake cyclists and placement cyclists choose to have in the drive lane.

It would be a great idea to do a study on traffic calming measures from the perspective of both drivers and cyclists. What type of measures do cyclists prefer? Is there a design that can work to slow down cyclists that do not jeopardize their safety? Also, it should be investigated what the possibilities are for introducing a speed limit on bicycle lanes.

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A | Shared Speed Questionnaire

When answering the questions, presume they derive from streets in an urban area with speed limit 30 km/h. Presume the streets are traffic-calmed with e.g. speed bumps.

2/21

1. Do you have a driver's license of any kind?

   Mark only one oval.

   - Yes
   - No

3/21

2. With what transport mode do you travel the longest distance of your trip to work?

   Mark only one oval.

   - Walk
   - Bicycle
   - E-scooter or similar
   - Public transport
   - Moped
   - Motorcycle
   - Car
   - Other: ______________________________

4/21

3. When you cycle, what type of bicycle do you use? (Are you using more than one type? Choose the one you use the most)

   Mark only one oval.

   - I never cycle *Skip to question 5*
   - Regular bicycle
   - Electric bicycle
   - Lay down bicycle
   - Cargo bike
   - Mountainbike
   - Road racer or similar
   - Other: ______________________________

5/21

4. Regarding speed, what type of cyclist are you?

   Mark only one oval.

   - Slow cyclist (cycle much slower than the majority, do not use electric bicycle)
   - Comfort cyclist (is more often passed by others, do not use electric bicycle)
   - Fast cyclist (more often passing other)
   - Racing cyklist (cycle much faster than the majority, over 30 km/h)

6/21

5. Could you envision cars and bicycles to share the roadway provided they share speed?

Mark only one oval.

- Yes
- No
- Maybe

7/21

6. On your bicycle trip, who would you rather share the space with?

Mark only one oval.

- Car drivers
- Pedestrians

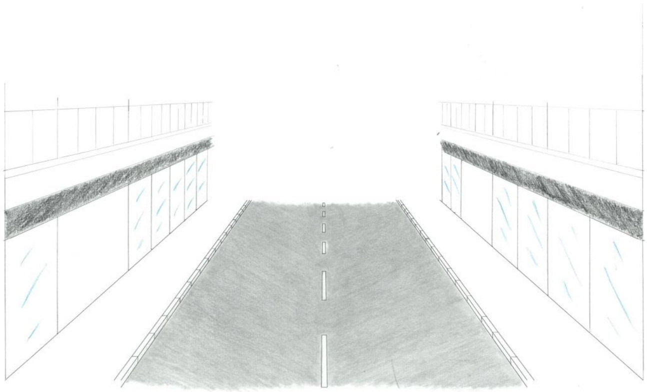
8/21

Now you will receive questions with drawings illustrating streets in an urban area with the speed limit 30km/h. Presume the streets are traffic-calmed with e.g speed bumps. Traffic is two-way.

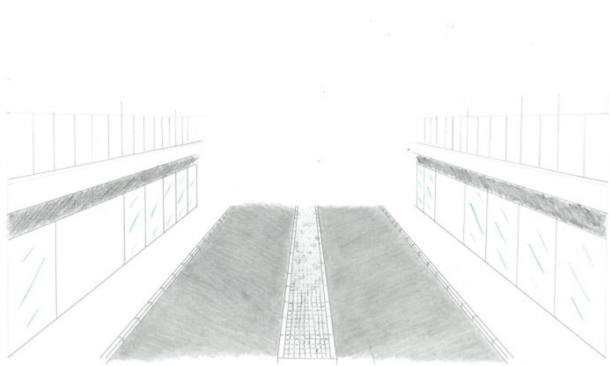
Imagine cars and bicycles sharing the roadway. Consider streetscape A and compare with streetscape B.

In streetscape B an elevated central divider has been added. The lane width is unchanged.

A



B



7. You are driving. What speed would you drive in B compared to A?

Mark only one oval.

- Slower
- Same
- Faster

8. You are cycling. Which streetscape would you rather cycle in?

Mark only one oval.

- A
- B
- Does not matter

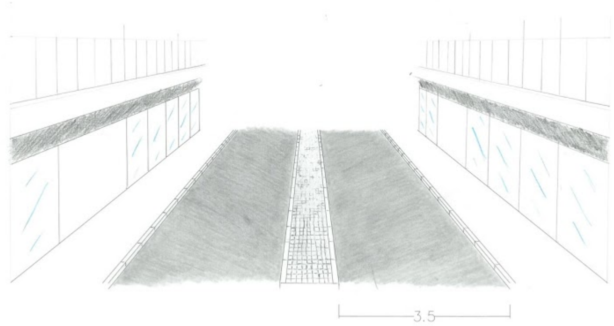
9/21

The drawings illustrate streets in an urban area with the speed limit 30km/h. Presume the streets are traffic-calmed with e.g speed bumps. Traffic is two-way.

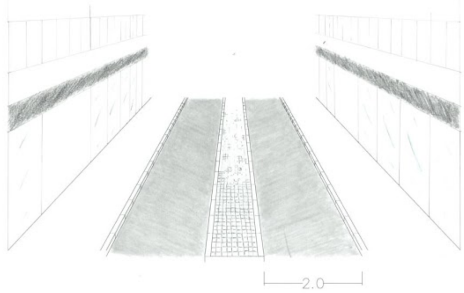
Imagine cars and bicycles sharing the roadway. Consider streetscape A and compare with streetscape B.

In streetscape B the lane width has been reduced to 2 meters.

A



B



9. You are driving. What speed would you drive in B compared to A?

Mark only one oval.

- Slower
- Same
- Faster

10. You are cycling. Which streetscape would you rather cycle in?

Mark only one oval.

- A
- B
- Does not matter

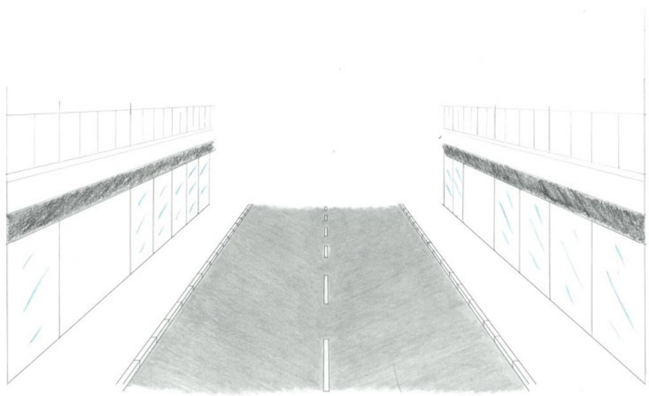
10/21

The drawings illustrate streets in an urban area with the speed limit 30km/h. Presume the streets are traffic-calmed with e.g speed bumps. Traffic is two-way.

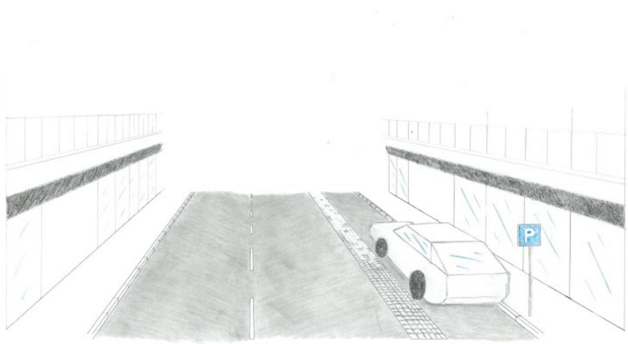
Imagine cars and bicycles sharing the roadway. Consider streetscape A and compare with streetscape B.

In streetscape B on street parking has been added on the right side in the driving direction. The lane width is unchanged.

A



B



11. You are driving. What speed would you drive in B compared to A?

Mark only one oval.

- Slower
- Same
- Faster

12. You are cycling. Which streetscape would you rather cycle in?

Mark only one oval.

- A
- B
- Does not matter

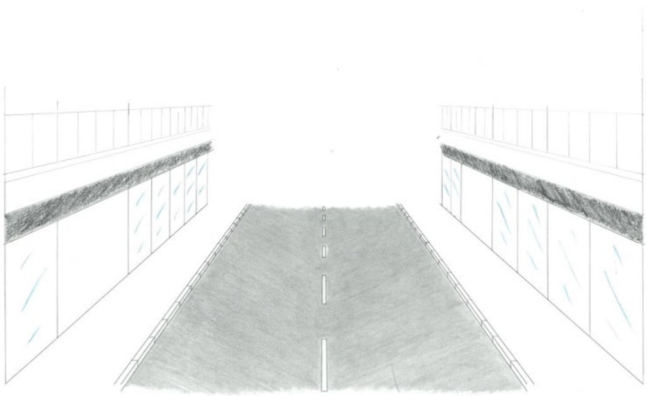
11/21

The drawings illustrate streets in an urban area with the speed limit 30km/h. Presume the streets are traffic-calmed with e.g speed bumps. Traffic is two-way.

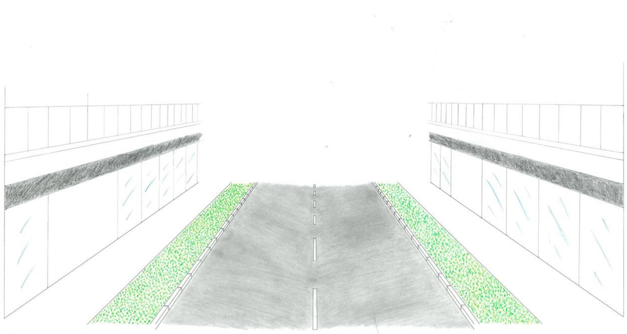
Imagine cars and bicycles sharing the roadway. Consider streetscape A and compare with streetscape B.

In streetscape B green barriers on both sides have been added. The lane width is unchanged.

A



B



13. You are driving. What speed would you drive in B compared to A?

Mark only one oval.

- Slower
- Same
- Faster

14. You are cycling. Which streetscape would you rather cycle in?

Mark only one oval.

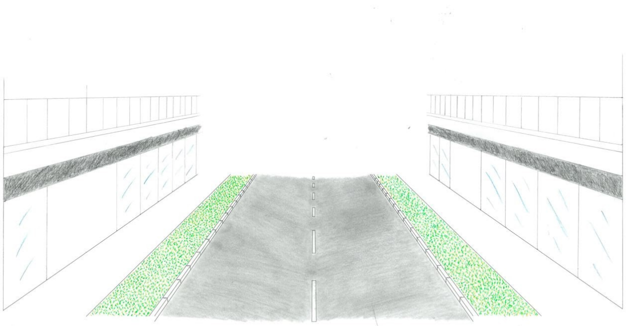
- A
- B
- Does not matter

The drawings illustrate streets in an urban area with the speed limit 30km/h. Presume the streets are traffic-calmed with e.g speed bumps. Traffic is two-way.

Imagine cars and bicycles sharing the roadway. Consider streetscape A and compare with streetscape B.

In streetscape B trees have been added on both sides. The lane width is unchanged.

A



B