Bicycle lane safety in the city of Barcelona

Using perception of safety and encouragement to analyse safety and the use of bicycle lanes

Bachelor Eind Project

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by

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Cover: Bicycle lane in the avenue Provença, Barcelona (Blanchar et al., 2021)

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Preface

The following research has been done as bachelor end project of civil engineering at the technical university of Delft. The topic of this research has been chosen because I have cycling experience in the Netherlands and was shocked by the lack of safety in the bicycle lanes of Barcelona. Many friends and relatives have spoken about the unsafe bicycle lanes, however no prior research has been done on this topic. Therefore, it is important to investigate and start the awareness on this matter.

This work would not have been possible without the support of others. I would like to thank my supervisors Dr.Ir. Yufei Yuan, Dr.Ir. Kuldeep Kavta and Dr. Shadi Sharif Azadeh for their weekly feedback and comments on my midterm presentation. I would like to thank my fellow peers D. Rijnders, T.Poelmans and T. van Hijum for giving me weekly feedback and helping me answer questions concerning the structure and contents of my research. Last but not least I would like to thank my family, friends and girlfriend who have helped the spreading of the survey in the city of Barcelona. Without their connections this research would have not been possible. Thank you.

Arend-Jan Timmermans Arribas
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Abstract

Urban areas are rapidly growing, with an increase in commuters and emissions of harmful gasses. To make cities more liveable and decrease the pressure on existing infrastructure, governments are considering more sustainable methods of transport. One of such methods is the bicycle. The bicycle, with its remarkable flexibility and minimal space requirements on the road and in storage, proves to be an ideal transportation option for older cities like Barcelona. The local government, aware of the benefits, has rapidly expanded the bicycle network to create a sustainable substitutional method of transport for its citizens.
The quick construction of bicycle lanes has created a 200 km network connecting most of the city. However, this has come at the cost of safety. Within five years, bicycles have accounted for 40% of the city's accidents, establishing themselves as the leading cause of accidents. Therefore, it is important to enhance the safety measures of the existing bicycle lanes and promote its use.

This research will focus on improving the use and safety of bicycle lanes in the city of Barcelona through the comprehension of perceived safety and encouragement of commuters. To understand the perceived safety and encouragement of commuters a survey will be used. The survey is broken up in two sections. In the first section details on socio-demographic, socio-economic and bike experience are asked and in the second section respondents are asked to grade different bike lane designs on their perceived safety and encouragement. The results are then compared through different methods of analysis to discover if there are any relationships between factors and outcomes.

The Kruskal-Wallis test affirmed the correlation between a more frequent use of bicycles and an increased perceived safety score. The same test, however, rejected a correlation between age and perceived safety score. Additionally, the test rejected another correlation between the diminished safety and encouragement score if the respondent has been in a bicycle accident before. The Mann Whitney U-test was applied to identify a significance between gender and perceived safety or encouragement score. The test was able to only identify a higher encouragement for male respondents. Another data analysis method applied, was the Wilcoxon signed-rank. The test concluded that there is a difference in score for both perceived safety and encouragement when respondents are shown different lane designs. Furthermore, the test revealed that respondents were more encouraged and felt safer in the presence of more physical barriers, while they only expressed a greater sense of encouragement with two-way bike lanes. The last test performed on the data was the Spearman-correlation. This test confirmed the positive correlation between perceived safety and encouragement scores and rejected a correlation between income and the use of bikes.

Derived from the analysis of data in this research it is clear that the safety and the use of bicycle lanes in the city of Barcelona must be improved. To do so, city planners should improve the safety of bicycle lanes, which as a result will automatically increase the use of bicycle lanes. To increase safety, lanes should be equipped with as much physical separation possible from other commuters and should consist of two-way lanes. If implemented, the survey reveals that 81% of the respondents would be more tempted to use the bike. Making the bicycle a method of transportation with a lot of potential in need of only an improvement in safety.

Contents

1 Introduction

In the following chapter the introduction of the research paper is presented. The introduction consists of the following structure. In section 1.1 the background is explained. In section 1.2 the research question is formulated and further enhanced with sub-questions. In section 1.3 the goal and scope of the research are elaborated. In section 1.4 the hypotheses are formulated. In section 1.5 the stakeholders are presented. And in section 1.6 the structure of the academic paper.

1.1. Background

Cities are changing rapidly to accommodate the rapidly growing populations. The European Union expected that around 80% of the European population would be living in urban environments in the year 2020 (Basse, 2010), in some countries even an astonishing 90%. Such expansions in urban environments creates strains and puts pressure on the existing infrastructure. Cities have to adapt their transportation methods to accommodate the increase in population. Within this expansion, governments are also trying to make the city more liveable. Due to the increase in commuters and citizens the emission of harmful gasses increases. Cities therefore want to create sustainable methods of transport to lower the emission of harmful gasses. A great example of such a rapidly changing city is the city of Barcelona. In an attempt to improve the living conditions in the city, the local government has reduced the circulation of cars by 17% between 2015 and 2022 (Vicente, 2022). This is a very good approach to reducing pollution, but is not a long term solution for commuters. Therefore, the city has put into practice the building of bicycle lanes. In 2020 the city put €4.4 million aside for the construction of 21km of bicycle lanes and the reformation of streets for public use (UCI, 2020). A sustainable and simple method of transport occupying little space in a city coping with capacity problems.

The slow but progressive construction over the years has resulted in the creation of a cycling network throughout the city spanning a total of 200km (B. Green, 2023). The network now provides citizens with the possibility to travel through the busiest areas of the city. This is of course great news, but is not exempt from problems. Barcelona is a very old city, resulting in many narrow streets with different stakeholders desiring to use the road. Due to the rapid expansion of the cycling network and inexperience in building such networks, many lanes have simply been placed in streets. This sudden placement of bicycle lanes without changing the lay-out of a street has caused the cyclist to be responsible for 40% of the accidents in Barcelona within 5 years (Gorman, 2022). The year 2021 counted 829 bicycle accidents, a 34% increase from the year before which had registered 618 accidents. The increasing number of accidents is not something the locals are surprised of. Citizens complain about the use of ”invented” signals and too many dashed lines by the government to demarcate the cycling lanes in the city, causing confusion and unrest (Losada, 2019). Therefore it is of the utmost importance to investigate the safety and use of the bicycle lanes in the city of Barcelona. Even more as the city is continuing to expand the bicycle networks. The longer bicycle lanes are unsafe or considered unsafe by users, the more accidents there will be and the less citizens are motivated to use this more sustainable method of transport.

This research has been done to map out dangers in the design of bicycle lanes and to understand how the perception of safety influences the use of bicycle lanes. Research done on the cycling network in Dublin concluded that cycling is not seen as an important mode of transport by planners and other traffic users (Lawson et al., 2013). As a result, safety measures were not considered as important in the design of the bicycle lanes. Through the use of a survey on the perception of safety, the researchers were able to pinpoint the safety problems in the network and advice on improvements. Due to the rapid increase of accidents in Barcelona, in which bikes are involved, it is important to detect the dangers, in the same way researchers have in Dublin, and remove them to reduce accidents. Furthermore, understanding the influence the perception of safety has on the use of bike lanes can give better guidelines to increase the use through changes in safety design. An enhanced use of the bicycle network in Barcelona will result in a decrease in the use of other methods of transport. In the case of motorised vehicles, this would result in less traffic jams and emissions of harmful gasses. For public transport, it would lead to smaller crowds and more space for users.

To collect data on the perception of safety the research will be conducted through the analysis of a survey. Through which, correlations can be found between different bike lane designs and socio-demographic factors influencing the perception of safety and the use of bicycle lanes. A frequent user of the bicycle lane may perceive dangers differently to an irregular user which is not familiar to the lay-out. On that account, it is important that the respondents of the survey are citizens of Barcelona. That way different opinions can be gathered concerning different groups. Analysing the survey data could result into safety and use improvements for bicycle lanes.

1.2. Research question

The research question of the following thesis is as followed:

How can the use and safety of bicycles lanes in the city of Barcelona be improved through the understanding of safety perception and encouragement of commuters?

To draw a conclusion to the research question above, sub-questions will be used. The goal is to answer the main research question through answering and combining the sub-questions. The sub-questions in this research are composed as followed:

1. *What are the safety measures applied in bicycle lanes?*

   In this sub-question the safety measures applied by the government of Barcelona in bicycle lanes will be analysed. An understanding of the safety measures is vital for later use in the survey to compare different safety measures. The comparison could prove to be of use as the different designs contain different factors, each altering the perception of safety and encouragement. This difference in perception and encouragement can be used to pinpoint factors deemed to be improved.

2. *What is the perceived safety?*

   It is important to be informed on the overall level of safety considered by the public.

3. *How does perceived safety influence the use of bicycle lanes?*
4. *Which safety design contributes the most to the perceived safety?*

   These two sub-questions provide the foundations for the answer to the research question. It is important to know whether it is an important factor for commuters when considering a mode of transport. If the city of Barcelona wants to persuade its citizens to displace through the use of a bike lane, it must reduce the reasons why a commuter would not use this mode of transport. Furthermore, it is important to identify how different safety designs influence the perceived safety of respondents.

1.3. Goal and scope

The goal of the research is to discover the safest bicycle lane design for commuters in the city of Barcelona. Moreover, determining whether the safety of current bike lanes or alternative designs influences commuters' choice of using this mode of transportation. Using this information city planners in the government of Barcelona could improve the current and future bike lanes to increase safety and use of the bike network.

The scope of the research is to analyse perceptions of safety and encouragement for different bike lane designs. The research will not focus on what bike lane design would be best for different individual streets, but instead on the overall best scoring safety design. This could further be enhanced or edited for its particular use in a street or avenue. In this investigation not all factors affecting the perception of safety will be included. The most important ones have been chosen and implemented in the research. The research does not include safety of intersections. Due to the complexity of intersections the research would be too extensive for the time available. The research is done from the point of view of a cyclist with other cyclists as users of the lanes. Other vehicles which make use of the lanes such as the electric scooters are not considered in the research. This has been chosen as it would add too many extra factors considering the short time available.

1.4. Hypotheses

A hypothesis is important as a beginning for further investigation based on limited data.
For the upcoming research the hypotheses formed are as followed:

1. Different demographic groups have different perceptions of safety and are encouraged differently.

   (a) Older respondents are more likely to give lower scores for perceived safety.
   Older individuals are more fragile and therefore more cautious for dangers. For this reason they are expected to give lower scores in the survey.

   (b) Males are more likely to give higher scores for perception of safety and encouragement.
   Males are bigger risk takers compared to females. Therefore males are more likely to give higher scores.

2. Perceived safety and use of bicycle lanes are correlated. If the perceived safety were to improve the use of bikes would augment.

   The safer a bike lane is considered, the more encouraged respondents are to use a lane. If full safety is guaranteed the drawbacks of using a bicycle are minimised.

3. Frequent bike users have higher perceptions of safety compared to non-frequent users.

   When a respondent is familiar to an environment it is more likely that they feel comfortable and give higher scores on the survey.

4. There is a difference in perceived safety score between designs.

   Different designs have different characteristics and result into different perceptions of safety.

5. There is a difference in encouragement of usage between designs.

   Different designs have different characteristics and result into different levels of encouragement.

6. Two-way bicycle lanes score less in perceived safety than one-way lanes.

   Two-way bicycle lanes result in traffic coming from the opposite direction. As it passes close by a user, it may be perceived as less safe.

7. The more physical barriers a design has the higher the perceived safety and encouragement score.

Perception of safety and encouragement are based on lane characteristics. The more physical objects there are separating a user from other users, the more probable a high safety and encouragement score is given.

8. The higher the income the less the bike is used.

Respondents with financial freedom are more likely to chose for luxurious and less physically intensive modes of transport.

9. If a respondent has had a bicycle accident, their perception of safety score will be lower than other respondents.

Experience with an accident may cause respondents to be more worrisome in traffic and perceive the space to be less safe.

1.5. Stakeholders

In this research there are many different stakeholders. Table 1.1 below depicts the different stakeholders with their amount influence and interest in the safety design of bicycle lanes. The influence and interest are marked with + and 0.

Stakeholder	influence	interest
City government	++	++
Regional government	+	+
Bicycle users	0	++
Car and motorbike users	0	++
Pedestrians	0	++

Table 1.1: Stakeholders with their influence and interest.

The city government and the regional government are the only parties which are able to influence the safety of bicycle lanes. The regional not as much as the local, but is still able to lay demands on the local government. A detail noteworthy to point out, is that commuters on either the bike, other modes of transport in the street and pedestrians have very high interests yet almost negligible influence on the change in safety design.

1.6. Structure of academic paper

The structure of the academic paper is as followed. Chapter 2 contains the literature review, in which other publications related to the research are presented, analysed and discussed. Chapter 3 explains the methodology used in the research. In this chapter the survey will be determined and the different statistical methods to analyse the data are presented. Chapter 4 will analyse the results of the survey through simple and complex methods. In chapter 5 the discussion is presented and in chapter 6 the conclusion and recommendations will be formed.

2
Literature review

In this chapter the background for the research will be presented. In section 2.1 the effects of bike lanes in cities is researched. In section 2.2 the different factors influencing perceived safety on bicycles is shown. In section 2.3 the factors influencing the choice in transport are discussed. In section 2.4 the safety measure designs of the government of Barcelona are examined. And in section 2.5 a summary of the chapter is presented.

2.1. Bicycle lanes in city centres

Sustainable mobility is a proposition on the agenda of modern day cities. Streets are being redesigned in which the car makes way for more green space, pedestrians and bicycle lanes. An accelerated method of testing whether this proposition works was performed in many European cities during the outbreak of the COVID-19 pandemic. An example of such city is Berlin. The local government placed temporal cycling-infrastructure and students of the technical university of Berlin assessed the air quality, behaviour and acceptance of such lanes before and during COVID-19 through the use of a survey. The results of the survey were very favourable for the bicycle lanes. According to the research respondents had a very high acceptance rate of bicycle lanes and were encouraged to use such infrastructure, also the researched concluded that cyclists were exposed to less harmful gasses (Becker et al., 2022). A factor which should be considered discovering the reduction of harmful gasses is the possibility of less motorised traffic due to the pandemic.
In Italy students of the university of Catania concluded already in 2013 that the Italian government should promote cycling. According to the students cycling helps the personal well-being of citizens, the environment and provides a substitutional method of transport (Schunemann et al., 2018).
The awareness on the importance of cycling lanes has also grasped the attention of the European commission. The importance of cycling has even been apprehended to the European Urban Mobility transport policy (Commission et al., 2017). Understanding that cycling in cities not only creates sustainable cities but also improves mobility and personal well-being.

Given the improvement in the environmental and personal well-being, the problem usually lays in the implementation of bicycle lanes in cities. Avenues are already very congested and have little space due to many different users. A group of researchers from the university of Melbourne has concluded that bicycle lanes should always be implemented to promote a greener mode of transport in urban areas (Bagloee et al., 2016). In streets where it is possible bicycle lanes should have separated lanes to provide safety and good flow of traffic. In the congested streets they also advice bicycle lanes to be placed, but through shared space. According to their research the advantages of placing a bicycle lane, even in shared spaces, outweigh the disadvantages (Bagloee et al., 2016). Governments have picked up this knowledge and installed bicycle lanes over the years in their cities. However, the bicycle networks of many large cities around the world consist of hundreds of disconnected patches (Natera Orozco et al., 2020). It is important for the mobility and the effectiveness of the network to be entirely connected. To truly provide a sustainable substitutional method of transport for citizens.

2.2. Perceived safety on bicycles and its factors

According to the Canterbury well being index (“Perceptions of safety”, n.d.) ”The wellbeing of individuals may be affected not only as a result of direct experience of harm but also as a result of a fear of harm”. This results into a broad number of factors which could be considered as influential to the perceived safety. There are countless factors which could affect the perceived safety, therefore the ones that will be used in this research are shown in Table 2.1 below, divided into three different columns. The first column depicts the socio-economic factors, the second contains the lane characteristics factors and the third contains the demographic factors.

Socio-economic	**Lane characteristics**	**Demographic**
Occupation	Bike lane space	Age
Ownership of a bike	Physical separation	Gender
Frequent user of bicycle	Sharing space	
Income	Bicycle accident	
Education		

Table 2.1: Influence factors considered in the research

2.2.1. Socio-economic

Socio-economic factors are social and economic factors which give an understanding to how well we live (“Social & economic factors”, n.d.). For this research these factors are interesting as they may hint to possible reasons for the use of bicycle lanes.

Occupation

Occupation is important to consider as it occupies a significant part of the week and dictates the financial capabilities of a respondent. A student may for example be less flexible financially and therefore be more tempted to use the bike compared to a labourer, who may have a car provided by their work.

Education

Higher educated respondents may have a better understanding on safety and can assess dangers better on the road. A better education may also result in improved socio-economic circumstances. This could lead to the use of finer equipment and therefore better preparedness for unsafe situations.

Income

This socio-economic factor is important as it indicates the financial capabilities of a respondent. A respondent with more financial capabilities is more likely to use more luxurious modes of transport. This could effect the view on the use of the bike. The opposite could be said about respondents with little financial freedom. As they are more likely to use cheap modes of transport, like the bike, and could have a different perception of safety.

Ownership of bike

The probability of a respondent to use the bike given that he/she owns a bike is much greater.

Frequent use of bike

Frequent use of a bike may result into the familiarisation of bicycle lanes. This could lead to a perception of higher safety compared to a respondent that has little experience on a bike. Repetition of a process could result into the user feeling more at ease and perceiving safety differently.

2.2.2. Lane characteristics

Surroundings and the perception of the surroundings have large effects on the behaviour of cyclists and their perception of safety (Blitz, 2021). In the presence of a marked road with clear objects separating from other users, an enhanced perception of safety and encouragement can be expected. However, if the road is littered with trash and the separation objects are vandalised, the perception of safety is more likely to be diminished. Therefore, the lane characteristics play an important role.

Bike lane space
Lane space is important as lack of space gives the perception of reduced manoeuvrability. Giving the user the impression that if a dangerous situation would occur they would not have enough space to react.

Physical separation
The presence of a physical separation creates the impression of safety. If something were to happen, the cyclist assumes that the physical barrier would stop the other object.

Sharing space
Shared space is ideal for the optimisation of space but could however create the feeling of unsafety. Due to different users in one space one is always more vulnerable than the other user. In the case of the pedestrian and the cyclist, it would be the pedestrian. While in the case of a cyclist and the car, the cyclist would be the most vulnerable.

Bicycle accident
If a respondent has been in a bicycle accident, their perception of safety and encouragement of use might have diminished. This unpleasant experience could have effect on an individuals opinion.

2.2.3. Demographic
Demographics are important in research as they may show different decisions taken by certain groups in a population.

Age
Different ages could affect the perception of safety and use of the cycling network. The older a person gets the more fragile they are in cases of accidents.

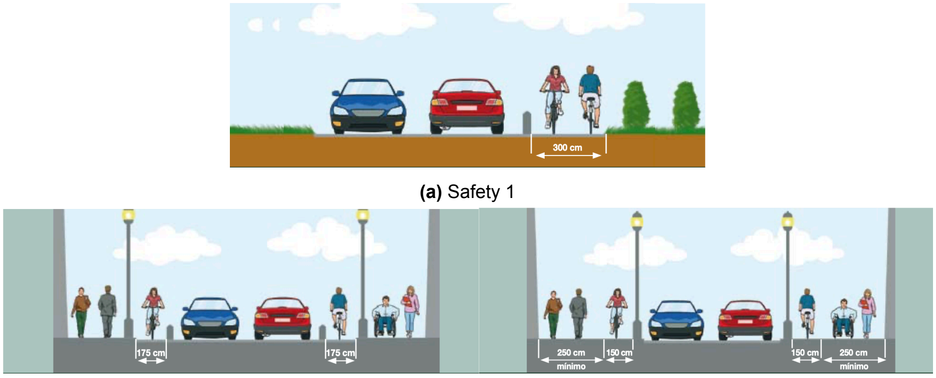
Gender
Male and females may react differently to different situations.

2.3. Effects of perception of safety on the use
The mode of transport is chosen depending on the perception of safety, distance, availability of other transport, age, gender, density of urban environment and the motive (Ashrafi and Neumann, 2017). Perception of safety is an important factor which must be taken into consideration as it is a variable dependent on many different factors. A great example of perceived safety is the car. As a car user is surrounded by the chassis and has full control over the vehicle, a feeling of safety is created. Resulting in the most displacements done by car. This could also be because the car is an all-round useful commodity or just because it is available. Apparently a great majority of car users lack information on other modes of transport (Horeni et al., 2007). Furthermore, car users that have knowledge about other modes of transport usually have negative perceptions of those (Beirão and Sarsfield Cabral, 2007). This shows that the perception of safety plays an important role in the choice of transport.
As there are many factors influencing the use of transport the following have been chosen for further use.

1. Age
2. Gender
3. Perception of safety
4. Use of the bicycle

2.4. Safety measures designs in Barcelona

The government of Barcelona has been constructing bicycle lanes following two different manuals of safety. One set-up by the provincial government of Catalonia and the other being their own. The provincial safety manual is a guideline defining the general safety measures which should be applied, such as the minimal width of bike lanes. The safety measures in the provincial document, which are of interest to this research, are shown in figure 2.1 below.



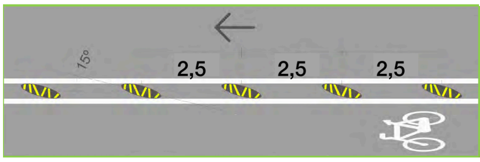
(a) Safety 1

(b) Safety 2

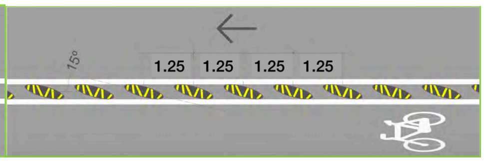
(c) Safety 3

Figure 2.1: Provincial safety standards (M. Nadal i Farreras, 2008)

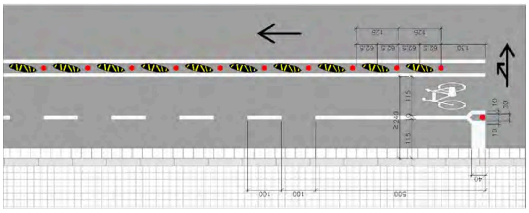
The government, using the guidelines of the province, has designed the bike lanes to their liking in the city of Barcelona. The government of Barcelona implements 4 different bike lane designs in the city. The most common one is a two-way bike lane, with small low blocks separating the lane from the motorised traffic. This common bike lane has three different designs in which the blocks are far apart, densely placed and densely placed with a pole in between. After that the most common bike lane designs are ones that have a physical separation using a ”New Jersey” block of concrete and one with a line demarcating the separation. The latter of the two is usually used on the sidewalk. The fourth design is one which has been implemented as of late, consisting of a two-way bike lane in the middle of a street separated by trees from other traffic. This fourth design is so new that it has not been registered in the bike lane design manual of the city. The four different designs, in which one has three different variations, are shown in Figures 2.2 and 2.3 below.



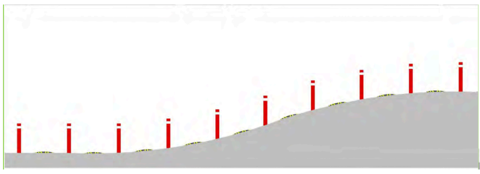
(a) Low blocks non dense



(b) Low blocks dense



(c) Low dense blocks with pole



(d) Low blocks side view

(e) New Jersey blocks

Figure 2.2: Low block and ”New Jersey” safety designs (E. Barquets Alfonso, 2016)

(a) Line demarcation (deandar.com, n.d.)

(b) Separate lane (Molina, 2022)

Figure 2.3: Line demarcation and separate cycling path

A characteristic to point out is that the width of the bicycle lane used in the city of Barcelona is less than the one given in the guidelines of the province. It was not stated in the government document, but the most probable cause would be the lack of space. Both sub-figures in Figure 2.2 were not shown in the bike lane manual of the government. This is most-likely because Figure 2.3 a) was the old bike lane design and Figure 2.3 b) is the latest design. It should be noted that bike lane design b) cannot be implemented as a permanent solution for all streets due to the large space it occupies. One of the main setbacks of the construction of bicycle lanes is the placement in streets which already have a lack of space, therefore creating dangerous situations (BenvenutyBarcelona, 2017).

In the survey the seven different designs and variations shown in Figures 2.3 and 2.2 will be assessed by the respondent. The three different variations of the non-dense low block design are shown to discover whether users have a different opinion on the variations. A change in the density of low-laying blocks or the placement of a pole could change the perception of safety and the level of encouragement. The incorporation of the ”New Jersey” block is also very important. The ”New Jersey” style blocks are a phenomenal barrier, providing separation and safety due to the size and rigidness of the structure. This size and rigidness however also comes with a negative point. If a user were to swerve into the blocks, the injuries would be much greater compared to a sidewalk or a demarcation line. Perception of safety could be high, but the level of encouragement low. If one of these two factors is low the bike lane is not deemed effective. The last two designs in Figure 2.3 must be included as well. The line demarcated lane has been in the city since the beginning of the bike lane network, making it important to evaluate its effectiveness. If deemed insufficient changes must be made immediately to make it safer and encourage commuters. Design b in Figure 2.3, is the newest bike lane design. As mentioned before, it has not yet been included in the design manual of the city. For that reason, it is important to assess the bike lane on its effectiveness compared to other bike lanes already in use.

2.5. Summary

In chapter 2 the literature study has been presented. In section 2.1 the bicycle lanes in the city centres around Europe have been discussed. The bicycle can become a key element to sustainable methods of transport and improved living conditions in cities. Section 2.2 was focused on the perception of safety on the bicycle. The three influence factors consisting of socio-economic, lane characteristics and -demographic factors have been divided in subcategories, vital as foundations for the questions in the survey. Section 2.3 dove into the effects of perception of safety on the use and looked at how different aspects like age, gender and transportation influence the choice in use of the bicycle. In section 2.4 the safety measure designs applied in Barcelona are analysed. The local government uses the provincial guidelines to make different bike lanes to their own liking. There are four different bike lane designs applied in Barcelona, of which one consists of three variants. All different designs will be embodied in the survey to retrieve data on the perception of safety and the level of encouragement for each design.

3
Methodology

The following chapter depicts the techniques used to answer the research question. The structure of the chapter consists of section 3.1, outlining the questions in the survey and the different bicycle lane designs questioned. Section 3.2 is focused on the data interpretation of the survey.

3.1. Survey

3.1.1. Survey structure

The solemn reason for the use of a survey is to extract the public opinion. The bike lane designs have been developed by a transport planner, but have not been used in practice before. Therefore, it is important to evaluate the network after citizens have made use of it. The structure of the survey is made in such a way that the hypotheses can be answered. In the first part of the survey the questions asked are concerning socio-demographic and -economic structures. The middle part is related to the method of transportation and the frequency with which the bike is used. And the end of the survey is focused on the retrieval of information concerning the perception of safety and the use of bicycle lanes. The survey has been written in Spanish to maximize the amount of respondents. For a better understanding of the survey, the survey is shown in Appendix A.

Questions 1 to 5

These questions inquire the age, gender, education, income and occupation of respondents. The socio-demographic data is important to understand the group of respondents answering the survey. The group can be split into different categories that may have a different perception of safety and use of bicycle lanes. The questions give the research insight in the independent variables. The ages are categorised in the groups: <18, 18-24, 25-34, 35-44, 45-54, 55-64, 64<. Gender is categorised in three different groups: male, female, other. Education is classified in: high school, module, bachelor, master, doctorate or more and other. The income is separated with steps of 400 euros starting from 1,260, the minimum salary per month in Spain. Occupation is divided into different options: scholar, student, employed, unemployed, retired. With these questions hypotheses 1 and 2 can be answered.

Questions 6 and 7

The following questions regarding the respondents' typical mode of transportation and bicycle usage help establish a comprehensive background for each respondent. This information enables to explore correlations between the use of different modes of transport and its effects on perceptions of safety and bicycle lane usage. With these two questions hypotheses 3 and 8 can be answered.

Questions 8 to 10

The respondent is presented a design with an explanation of its characteristics. The respondent then grades the perceived safety and encouragement of the bike lane, imagining that they are using the bike lane as a cyclist. With these questions the research question of the paper and hypotheses 4,5,6,7 and 9 can be answered.

3.1.2. Bicycle lane designs

The different bicycle lane designs will be depicted in the section below. Every different design will be described, and its important characteristics will be depicted. Below each design, respondents are inquired to score their perceived safety and level of encouragement to use the bike lane.

Lane design 1:

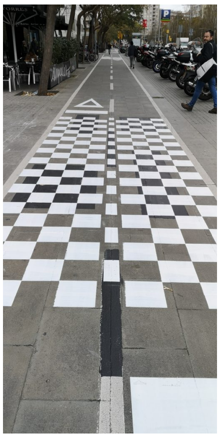


Figure 3.1: Bike lane on sidewalk without physical barriers to separate from other traffic ("Nous passos de vianants al carril bici de Tarragona", n.d.)

The bike lane design above is the simplest of the designs. The construction of such bike lane is done through the painting of lines on a sidewalk. The placement of such bike lane is very cheap, however could result in confusion. As can be observed in Figure 3.1, the lane has a sudden demarcation of squared blocks, signals which are non-existent in the international rules of traffic. Furthermore, if pedestrians or cyclists are not conscious of their surroundings, there exists a great chance of them crossing into space used by other commuters, increasing the probability of an accident.

Lane design 2:

Figure 3.2: One-directional bike lane implemented in the road with low blocks as physical barrier (Pacheco, 2022)

Bike lane design shown in Figure 3.2 is the simplest variant of the bike lanes implemented in the street. The bike lane has been placed on the street with use of a shared space, separated by two white demarcation lines and low blocks from other traffic. As can be depicted in the Figure, the bike lane has a pole at the beginning of the street. This is to avoid vehicles from crossing the boundary of the bike lane when turning into the street. A design detail to point out is the placement of the bike lane on the left side of traffic. In other countries, such as the Netherlands, bike lanes are placed on the right side of traffic.

Lane design 3:

Figure 3.3: Two-directional bike lane implemented in the road with low dense blocks as physical barrier (Campos and Campos, 2023)

Bike lane design in Figure 3.3 is a reformed version of the bike lane in Figure 3.2. The bike lane is two-directional and has more densely placed blocks. The placement of a two-directional bike lane has probably been done due to the availability of space. The placement of more dense blocks is most-likely linked to increased safety measures. The lane is, as mentioned before in lane design 2, on the left side of traffic.

Lane design 4:

Figure 3.4: Two-way bike lane implemented in the road, separated with cones from other traffic (Puertas, 2022)

In Figure 3.4 above, there is a two-directional bike lane implemented in the road. The bike lane is on the left side of traffic and is equipped with green plastic cones as a barrier and demarcation. The choice for cones as a demarcation line is unknown. A reason for this could be that car users can see the cones, even when they are close to the car. This was not the case with the low blocks.

Lane design 5:

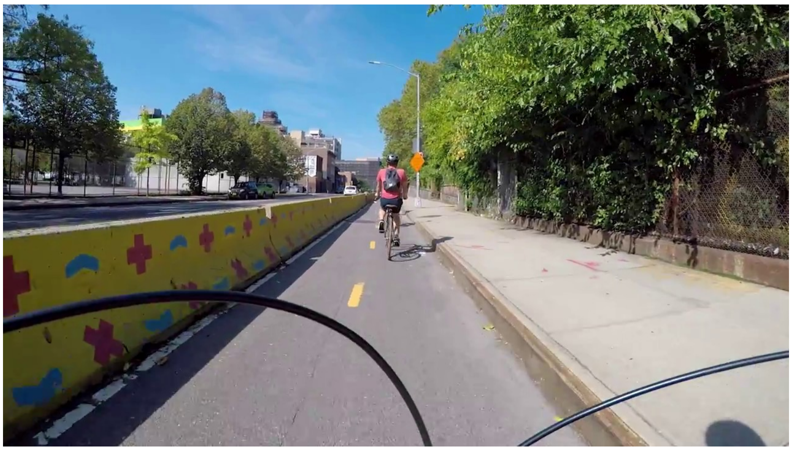


Figure 3.5: Two-directional bike lane implemented in the road, separated with "New Jersey" style blocks (Rozier, 2017)

Bike lane design five, shown in Figure 3.5, is a two-directional bike lane placed on the right side of the road. The bike lane is separated from other traffic with "New Jersey" style concrete blocks. The blocks create a phenomenal barrier for safety. They are strong, high and will probably not displace easily in the case of a collision. A noteworthy possible feeling with such concrete blocks is unsafety as well. If a user were to collide with the barrier the damage will be worse. This is true for both vehicles and cyclists.

Lane design 6:

Figure 3.6: Two-directional bike lane in the middle of the avenue, separated by plants and trees from other traffic (Tower, 2019)

Lane design 6, shown in Figure 3.6, is a two-directional bike lane placed in the middle of the avenue. With such lay-out it could be interpreted as a highway for bikes. The lane is separated with grass and trees from other traffic surrounding the bike lane. The bike lane is very wide and provides enough space for green and cyclists. This has however, come at the cost of many car lanes in the avenue.

Lane design 7:

Figure 3.7: One-directional bike lane on sidewalk without any physical separations from other users (“Carril - Bici Av Meridiana (Aragó - pl de les Glòries) | Sant Martí”, n.d.)

The last design, shown in Figure 3.7 above, is bike lane design 7. This bike lane is a one-directional lane implemented in the sidewalk. The lane has been painted with a different colour than the sidewalk and is marked with white lines.

3.2. Data interpretation

In this section the different methods of data analysis will be shown. The methods used have been extracted from Data Analysis and Statistics with R. (Warren and H., 2021). The tests applied on the data will be the Kruskal-Wallis test, the Mann-Whitney U-test, the Wilcoxon signed-rank test and the Spearman's rank correlation. These tests make use of categorising dependent and independent variables. Independent variables are variables that stand alone and are not changed by others. Examples of such used in the investigation are age, gender and occupation. Dependent variables are ones which are influenced by other variables. In this research the dependent variable would be the perception of safety and the encouragement.

All tests are done using the SPSS system, which rejects or retains the null hypothesis. By rejecting or retaining the null hypothesis, a significance or no significance can be concluded between two variables. Each subsection below, discussing the four different methods of data analysis, entails the corresponding null hypotheses.

The tests mentioned above are non-parametric tests. These are used instead of parametric tests as they can be applied on much wider scales of data due to weaker assumptions(Warren and H., 2021). The tests work by dividing the data into nominal, ordinal, interval or ratio categories. These categories in this research are the variables extracted from the survey. Nominal data are variables that can be placed in mutually exclusive groups, without any rank between them. Ordinal data consists of variables which are placed in groups and ranked in an order, but without a clear difference between the ranks. The interval category variables are placed in mutually exclusive groups, ranks and can infer equal intervals between data points, but without a zero point. The ratio category variables are also placed in mutually exclusive groups, ranks, can infer in equal intervals and have a zero point (Bhandari, 2023).

3.2.1. Kruskal-Wallis test

The Kruskal Wallis test is a method which permits to test differences among more than two samples (Warren and H., 2021). To test this the following is necessary:

1. The dependent variables must be either ordinal, interval or ratio.
2. Group observations must be independent from each other.
3. Variable distribution must be similar in each group.

If by any means there is too much of a difference after analysing the data, the Mann Whitney U-test should be applied to asses the differences in groups.

In this method hypotheses 1a, 3 and 9 are applied from section 1.4.

- H1.1.0 - Perception of safety score is not influenced by age categories.
- H1.1.1 - Younger participants are prone to give higher perception safety scores.

- H3.0 - Perception of safety score is not influenced by use of bike.
- H3.1 - Frequent bike users give a higher perception safety score.

- H9.0 - There is no difference in perception of safety score when a respondent has been in a bicycle accident.
- H9.1 - There is a difference in perception of safety score when a respondent has been in a bicycle accident.

3.2.2. Mann Whitney U-test

The Mann Whitney U-test is used to compare the median of two different samples. It is also an alternative for the independent two-sample t-test. To make this method possible the following assumptions have to be made:

1. Dependent variables are ordinal, interval or ratio scales
2. Observations of the two distinct groups are independent of each other
3. The distribution of the dependent variable is similar in each group.

What the last assumption implies is that the distributions of the two samples are not important as long as they look alike (Warren and H., 2021). When the assumptions above have been put to practice, the Mann Whitney U-test serves to analyse the differences in central tendency.

The following method is applied on hypothesis 1b from section 1.4.

- H1.2.0 - Perception of safety and encouragement score is not influenced by gender.
- H1.2.1 - Male bike users give a higher perception safety and encouragement score.

3.2.3. Wilcoxon signed-rank test

The following test is a versatile method to compare the median of a sample to a single value (Warren and H., 2021). It is able to conclude whether there is a difference in score given by the respondents to two distinct situations. The following assumptions are made using this method:

1. The dependent variable is ordinal, interval or ratio.
2. The distribution between the two groups is more or less symmetric.

Using the Wilcoxon signed-rank test a p-value must be chosen. In the case of this report $p = 0.05$. This means that there is a 95% that the hypotheses is right.

For this method hypotheses 4, 5, 6 and 7 are applied from section 1.4.

- H4.0 - There is no difference in perceived safety score between designs.
- H4.1 - There is a difference in perceived safety score between designs.

- H5.0 - There is no difference in encouragement of usage between designs.
- H5.1 - There is a difference in encouragement of usage between designs.

- H6.0 - There is no difference in score between one- and two-way bicycle lanes.
- H6.1 - There is a difference in score between one- and two-way bicycle lanes.

- H7.0 - There is no difference in perceived safety and encouragement score with more physical barriers.
- H7.1 - There is a difference in perceived safety and encouragement score with more physical barriers.

3.2.4. Spearman-correlation

The Spearman correlation is the nonparametric version of the Pearson correlation ("Spearman's Rank-Order Correlation - A guide to when to use it, what it does and what the assumptions are." n.d.). It is able asses whether there is a positive or negative correlation between two variables. The variables used are either ordinal, interval or ratio and must have some linear correlation. The correlation gives a 1 in case of a positive correlation and a -1 in case of a negative correlation.

Hypotheses 2 and 8 are applied for this method from section 1.4.

- H2.0 - There is no correlation between perceived safety and use of bicycle lanes.
- H2.1 - There is a positive correlation between perceived safety and use of bicycle lanes.

- H8.0 - There is no correlation between income and the use of a bike.
- H8.1 - There is a negative correlation between income and the use of a bike.

3.3. Summary

In chapter 3 the survey and the methods of data interpretation have been discussed. In section 3.1.1, the structure of the survey has been designed to answer the hypotheses formulated in section 1.4. Every question in the survey has an outcome which can be used for further research. In section 3.1.2, the different designs questioned in the survey have been shown with their different characteristics. In section 3.2, the different data analysis methods have been presented and linked to the hypotheses they would give an answer to. The data analysis methods chosen are non-parametric tests and consist of the Kruskal-Wallis test, the Mann Whitney U-test, the Wilcoxon signed-rank test and the Spearman correlation. With use of these four different data analysis methods the hypotheses in section 1.4 can be evaluated and retained or rejected.

4
Data analysis

In the following chapter the data analysis is done on the results from the survey. Section 4.1 will discuss the obtained data from the survey. Section 4.2 will present the independent variable results in pie charts and bar graphs. Section 4.3 will analyse the results, using the data analysis methods mentioned in chapter 3.2. At the end of the chapter a short summary is written in section 4.4.

4.1. Obtaining data

For the processing of data it is vital that the survey is filled in as much as possible. The more respondents there are the smaller the margin of error becomes. Anomalies will then not outweigh the data and create unrealistic results. In this research a minimum of 100 respondents was deemed enough for the data analysis. With this minimum, the chances were greater that the data would be more spread over the different independent variables. It is not only important to have a certain amount of respondents, but also enough respondents from different socio-demographic and -economical groups. Fortunately, the amount of respondents was above the 100 respondents threshold, with a total of 116 responses. Also the spread of data was deemed enough, with a 48.3% of respondents being 18-24, considering most means used to spread the survey are frequented by this age category.
To achieve a greater number of respondents, the survey was written in Spanish. This was done because in Spain only a 27% of the population is able to express themselves in English, this number is even lower for fluent speakers (Бекишев, 2022). To reach out to the respondents, the survey has been spread through the means of social media. This is a phenomenal method to reach out to large groups. A simple post on a platform like Instagram can be viewed over 500 times within a day. This is most likely the reason why the group between the ages 18 and 24 is the largest group of respondents. For the older groups of respondents, the main method of securing responses was through the promotion of the survey in WhatsApp groups or private chats. Contacts were asked to spread the survey to other group-chats of work, family and friends to reach out to the maximum amount of people possible. The promotion of the survey in Facebook pages focused on cycling in Barcelona was attempted, but was sadly not permitted by the page owners. All in all the promotion of the survey was a success, considering that the minimum desired amount of responses was surpassed.

4.2. Independent variable results

In the following section the results for the independent variables will be presented. The section is divided into two subsections consisting of the socio-demographic and -economic data (subsection 4.2.1) and the transport data (subsection 4.2.2). The socio-demographic and -economic results will be compared with population data of the city of Barcelona. To see whether the group of respondents represents the population.

4.2.1. Socio-demographic and -economic

In the following section, the results of the respondents are presented and then compared to population data of Barcelona. Below in Figure 4.1, the socio-demographic and -economic pie charts are shown with the results.

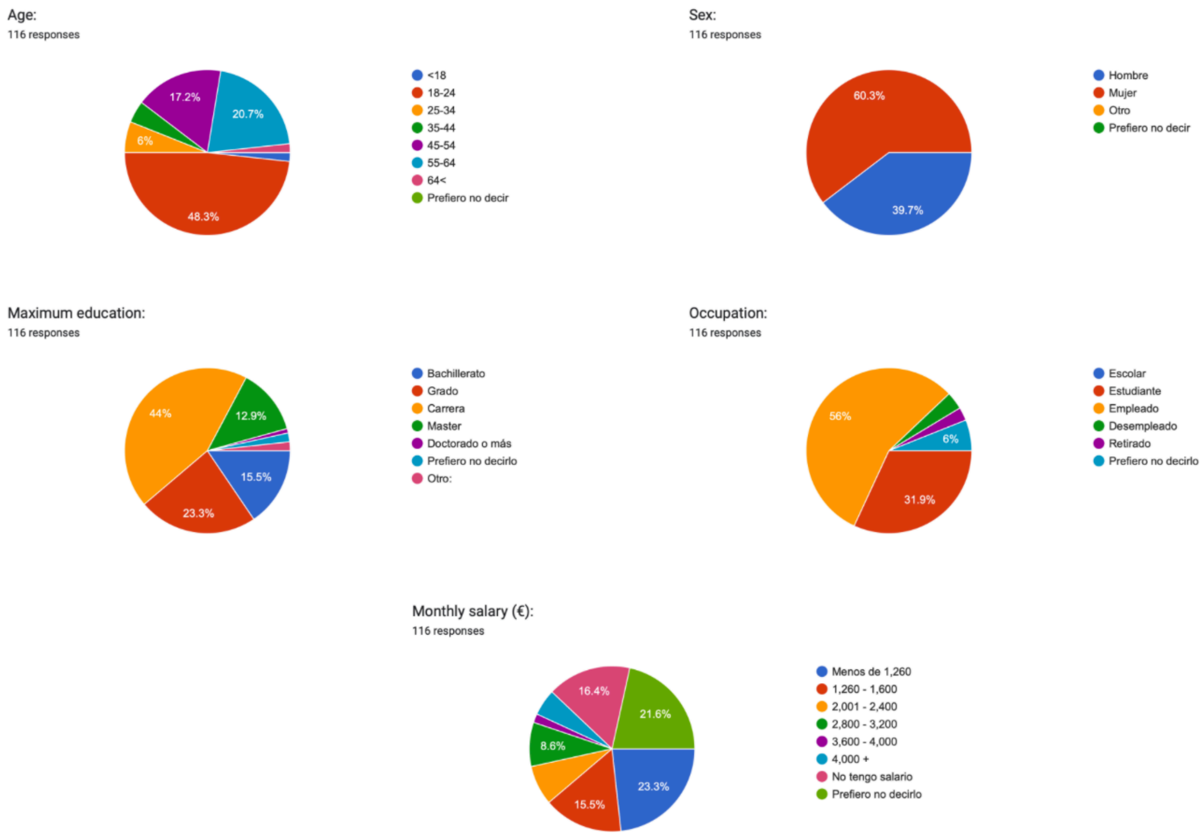


Figure 4.1: Socio-demographic and -economic survey results

As mentioned in section 4.1 and depicted in Figure 4.1, it can be observed that the group of 18-24 year old's make up a 48.3% of the respondents. The next largest group is between the ages of 55-64, making up a 20.7% of the respondents. Followed by the third largest group of 45-54 year old's, representing a 17.2% of respondents. Groups which have not been that well represented are above the age of 64 and below the age of 18, with both only two respondents.
In terms of gender there is a greater amount of female respondents, but fortunately not too large to make the data insignificant.
The distribution in education levels shows that a 44% of the respondents has a bachelors degree. Followed by a 23.3% of the respondents having done a degree in a profession. The finishing of the high school diploma comes in third and fourth comes the finishing of a masters degree. The other educational options are represented by 1 or 2 respondents, making them almost negligible.
Occupation was a category consisting of mainly employed respondents (56%) and students (31.9%). The next largest represented group, was of respondents that would rather not state their occupation (6%). The monthly salary chart is one with the most distributed responses. Due to the high amount

of students responding, with probably part-time jobs, it is not odd to see that a 23.3% of respondents earns under the minimum wage. Followed by the second largest group, of 21.6% of the respondents, rather not sharing their salary. The third largest group, representing 16.4%, does not have a salary.

The city of Barcelona has a population of 1.6 million inhabitants, consisting of 47.3% males and 52.7% females ("Barcelona", n.d.). The distribution of males and females in the survey is not the same, as 60% of the respondents were female. This could have to do with the platforms on which the survey has been spread or that female friends have spread the survey more compared to male friends.

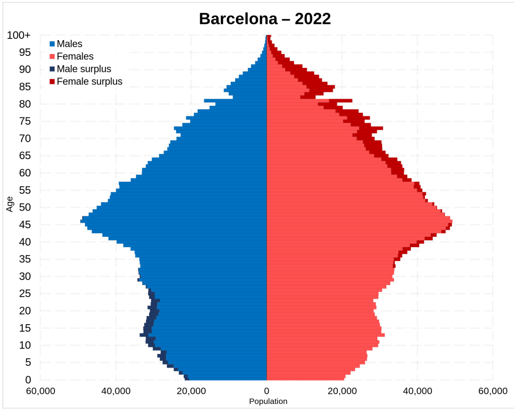


Figure 4.2: City of Barcelona demographics (Wikipedia contributors, 2023).

In Figure 4.3 above, the demographics of the city of Barcelona are shown. As can be seen the largest group of citizens belongs to the age groups of 40 to 47. This is something not fully accounted for in the survey. The group of young citizens is much larger and so is the group of seniors above the age of 47. This is because the survey has been spread largely within these two groups due to student friends and parents. In terms of education, it is noticeable that most respondents are students. Populations in contrary tend to have a negative correlation, the more difficult an education becomes the less people do it.

4.2.2. Transport data

The results of respondents on their usual use of transport, bike use and bike experience will be shown in the following subsection. In Figure 4.3 below the results are shown for the usual mode of transportation and use of the bicycle.

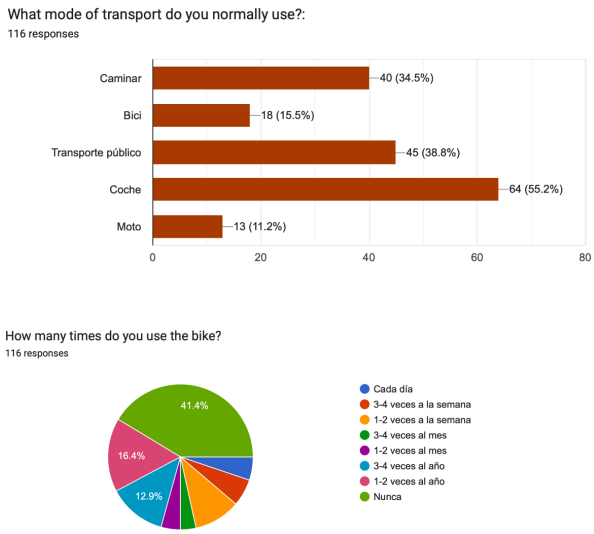
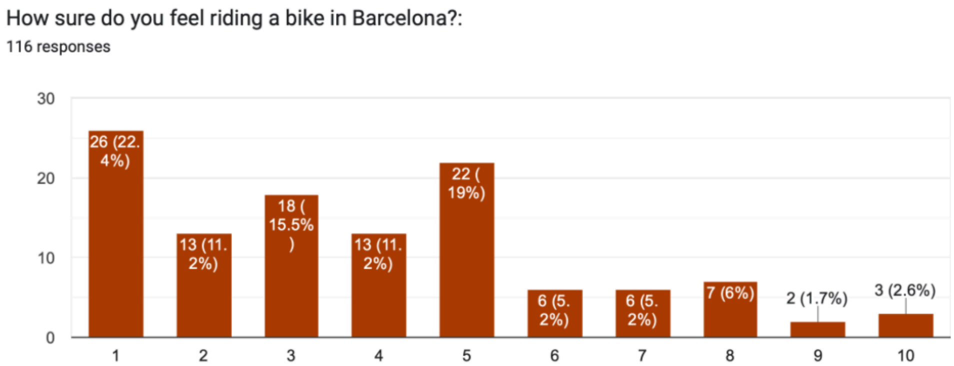


Figure 4.3: Usual mode of transport and bicycle use

From Figure 4.3 interesting observations can be made. The most noticeable in the bar chart is that the bike is the second least used mode of transport by the respondents, with only 15.5%. The car however, is by far the most used with 55.2%, followed up by public transport with 38.8% and walking at 34.5%. The only mode of transport used less than the bike is the motorbike, used by 11.2% of the respondents. This could be very interesting for the research in discovering whether this low use of the bike has something to do with the perception of safety and encouragement. In the bar chart the amount of times the bicycle is used per respondent is shown. The most voted is no use of the bicycle at all, at an astonishing 41.4%. The second most voted is 1 to 2 times per year at 16.4% and on third 3 to 4 times per year with 12.9%. After that the most voted options are daily, 3 to 4 and 1 to 2 times per week. This shows that there are extremes in the use of bicycles. Either respondents use it on a weekly/daily basis or (almost) not at all. This means that within the enormous group of young respondents a very small percentage uses the bike to travel. A group which is usually considered as one to use cheap and accessible modes of transport.

In Figure 4.4 below, the results are shown for the current perceived safety on the bicycle and if a respondent has had an accident.



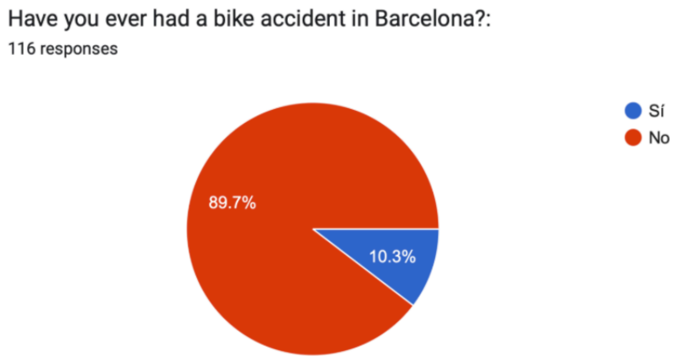


Figure 4.4: Perception of safety and having had a bicycle accident in Barcelona

The bar chart in Figure 4.4 shows the answers of respondents on how safe they feel going by bike through Barcelona. There are some respondents very happy with the safety in the bike lanes, however the large majority finds the perceived safety below average. These results are crucial, confirming the necessity for safety improvements in Barcelona's bicycle lanes. Later in this chapter the analysis will be made to see if there is a relationship between the amount of times a respondent uses a bike and its perception of safety. Observing the small amount of respondents giving high perceived safety scores and the small amount of cyclists, there could be a correlation. Another correlation that could be seen is one mentioned in section 2.3, concerning the use of transport depending on perceived safety. It is clear by looking at Figures 4.3 and 4.4 that a feeling of unsafety by the majority of respondents has lead to a very low use of the bicycle. Furthermore, Figure 4.4 also shows if respondents have been in a bicycle accident. In total 12 respondents have been in a bicycle accident, representing 10.3% of the respondents. Another respondent has stated that they have been almost in a bicycle accident multiple times. This shows that the bicycle lanes could be considered unsafe and must be evaluated.

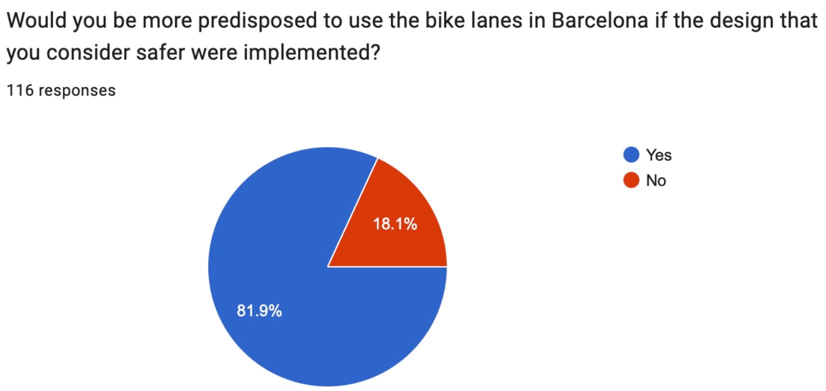


Figure 4.5: Would consider using the bike if the bike lane they consider safest were to be applied

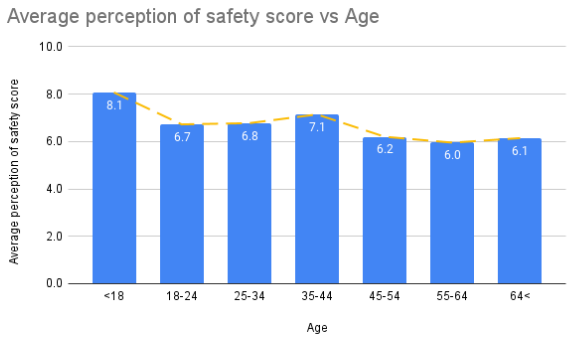
Figure 4.5 above shows that if the lane that respondents consider the safest in the survey were to be applied, a staggering 81.9% would be tempted to use the bicycle lanes. This hints that the low amount of bike users in the current network is related to the low safety perceived by its citizens.

4.3. Analysing results

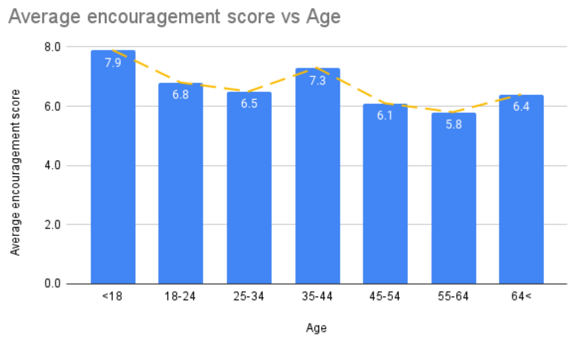
In this section the data will be analysed to reject or retain the hypotheses formulated in section 1.4. In subsection 4.3.1, the data will be analysed through simple methods of comparing means and variables. In subsection 4.3.2, the data interpretation methods of chapter 3.2 will be performed.

4.3.1. General data analysis

In this subsection Figures 4.6, 4.7 and 4.8 will be presented. The three figures are a simple analysis of the data retrieved from the survey. The three graphs give a simple answer to three hypotheses formulated in section 1.4.



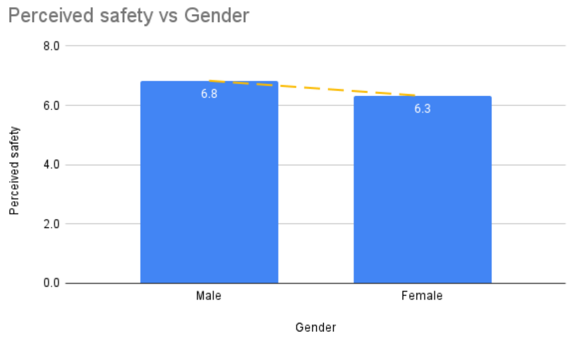
(a) Perceived safety



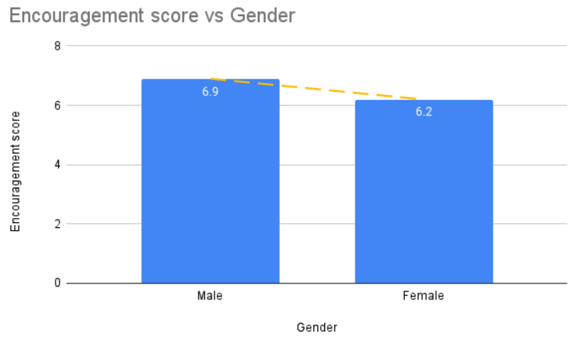
(b) Encouragement

Figure 4.6: Perceived safety and encouragement vs age

Figure 4.6 gives a general view on the average score on the perception of safety and encouragement given by the different age categories of all the designs in the survey. A noticeable trend in the data is a higher perception of safety in the younger age categories compared to the older ones. The younger ages are close to the 7 while the older groups are moving closer to the 6. An anomaly in the data trend is the age category 35-44. The overall perceived safety score decreases until it reaches this category, resulting in an increase in perceived safety of 0.3. After this increase, the overall score keeps decreasing. A point which should be noted is the age category of above 64. There were only two respondents



(a) Perceived safety



(b) Encouragement

Figure 4.7: Average safety and encouragement score per gender

in this category, which could explain the very small increase of 0.1. In the case of encouragement the same trends can be seen as in perceived safety, including the increase of encouragement in the age category 35 to 44.

Comparing the results to hypotheses 1a, stating "Older respondents are more likely to give lower scores for perceived safety", it is interesting to see that the trend is followed on a large scale with the exception of one age category.

Figure 4.7 shows the average safety and encouragement scores given by males and females of all designs in the survey. The data set follows the hypotheses 1b, stating "Males are more likely to give higher scores of perception of safety and encouragement". It is interesting to see that there is, with simple analysis of the data, a clear distinction in the safety and encouragement score between males and females.

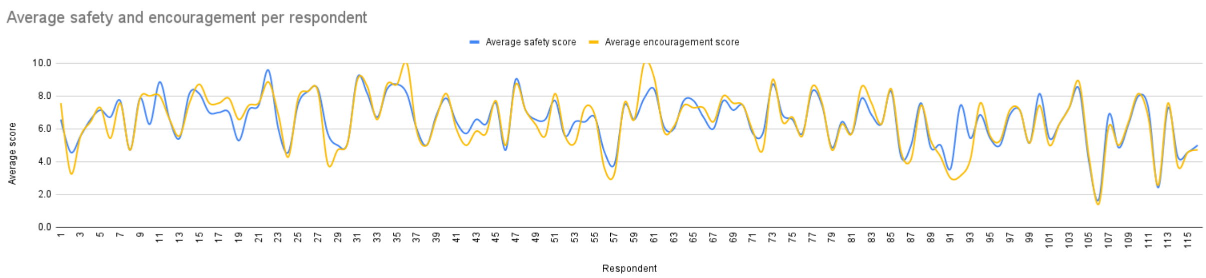


Figure 4.8: Average safety and encouragement per respondent

Figure 4.8 above shows the average score given by respondent on perceived safety and encouragement. In the graphs there is a noticeable trend in the perceived safety and the encouragement. There are very clear signs that the two different variables are very much correlated. There are some anomalies, but generally speaking the average encouragement follows or is just below the average perceived safety score. There are two cases in the data however which show a very strong average in encouragement, yet a lower score for perceived safety. It is unclear why the two respondents gave such answers, as no comments were provided and both had very different responses for the socio-demographic, -economic and bike use inquiries.

4.3.2. Methodological data analysis

In the following subsection, the data from the survey is interpreted using four different methods mentioned in section 3.2. The interpretation is done using the Kruskal-Wallis test, the Mann Whitney U-test, the Wilcoxon signed-rank test and the Spearman-correlation. Using these methods, the null hypotheses shown in section 1.4 will be rejected or retained and a significance is concluded. The lower the degree of significance, the greater the possibility that there is a relationship between groups being compared.

Kruskal-Wallis test

The Kruskal-Wallis test is applied on 3 hypotheses, consisting of hypotheses 1.1, 3 and 9. To test hypothesis 1.1, the average perceived safety score given by each respondent is classified into 5 age groups and compared. Due to the age groups under 18 and above 64 consisting of only 2 respondents each, the groups are merged with the neighbouring group. Creating a total of 5 groups, instead of 7. The result is that the null hypothesis is retained with a significance p = 0.290, shown in Figure B.1. A null hypothesis is rejected when $p < 0.05$. To assess whether this result is due to the low number of respondents of certain age categories, the age categories have now been separated into 3 groups. The young group, with respondents under the age of 25. The middle group, with respondents aged between 25 and 54. And the elder group, consisting of respondents above the age of 54. The results of this test, shown in Figure B.2, gave a lower significance of p = 0.165, yet still with the result of a retained null hypothesis. This means that the predicted correlation in section 2.2.3 between age and perceived safety is rejected.

To test hypothesis 3, the Kruskal-Wallis test was run on the 8 different bike use groups asked in the survey. The result of the test, seen in Figure B.3, was a retained null hypothesis. Due to many different groups and few respondents representing some, the test was run again on three different groups. The groups consisted of frequent users, which were respondents using the bike on a weekly basis. Non-frequent users, representing monthly and yearly users. And the third group, representing the non-users. This test, shown in Figure B.4, gave a rejection of the null hypothesis with a significance p = 0.043. This means that there is a relation between more frequent use of the bicycle and a higher score for the perception of safety. This correlation is mentioned in section 2.2.1 concerning the socio-economic aspects of respondents.

Hypothesis 9 examines whether respondents with previous accidents perceive safety differently and receive varying levels of encouragement. The respondents are placed in two different groups of which the scores are compared for perceived safety and encouragement. After the test, the significance for perceived safety equalled p = 0.97 and for encouragement p = 0.414, depicted in Figure B.5 and Figure B.6. This implies no significant difference in scores between respondents who have experienced a bicycle accident, rejecting the predicted correlation in section 2.2.2.

Mann Whitney U-test

The Mann Whitney U-test is performed on hypothesis 1.2. The null hypothesis states ”Male bike users give a higher perception of safety and encouragement score”. The result of the Mann Whitney U-test, depicted in Figure B.7, is a retained null hypotheses for the perceived safety score, with a significance of p = 0.113, and a rejected null hypotheses for the encouragement score, with a significance of p = 0.040. This means that in terms of perception of safety there is no significant difference between genders, however in encouragement there is. Showing a higher encouragement for males to use the bicycle lanes. Predictions made in section 2.3 on encouragement are therefore in line with the results shown, yet predictions in section 2.2.3 on perceived safety are rejected.

Wilcoxon signed-rank test

The Wilcoxon-signed-rank test is a test in which the median scores of two different designs are compared, indicating whether there is a difference between the two designs. The test is used to reject or retain hypotheses 4, 5, 6 and 7.

In Table 4.1 the test results are shown for hypothesis 4 and in Table 4.2 the results are shown for hypothesis 5. The Wilcoxon signed-rank test can only be done between two designs. For that reason all designs have been compared to design 1. Design 1 is the simplest design and was the first one to be implemented in the city of Barcelona. As it is the simplest design it is easier to analyse the differences between design characteristics and their scores. The test results from SPSS are shown in Figure B.8 and Figure B.9

Null hypothesis	Decision
There is no difference in perceived safety score between design 1 and 2	Rejected
There is no difference in perceived safety score between design 1 and 3	Rejected
There is no difference in perceived safety score between design 1 and 4	Rejected
There is no difference in perceived safety score between design 1 and 5	Rejected
There is no difference in perceived safety score between design 1 and 6	Rejected
There is no difference in perceived safety score between design 1 and 7	Rejected

Table 4.1: Results hypotheses 4 test

Null hypothesis	Decision
There is no difference in encouragement score between design 1 and 2	Rejected
There is no difference in encouragement score between design 1 and 3	Rejected
There is no difference in encouragement score between design 1 and 4	Rejected
There is no difference in encouragement score between design 1 and 5	Rejected
There is no difference in encouragement score between design 1 and 6	Rejected
There is no difference in encouragement score between design 1 and 7	Rejected

Table 4.2: Results hypotheses 5 test

As can be concluded from the Tables 4.1 and 4.2, there is a difference in safety and encouragement between designs. This conclusion goes in line with the predictions made in section 2.2.2 and section 2.3, predicting different perceived safety and encouragement scores due to alterations in lane characteristics.

Null hypothesis 6 states ”There is no difference in score between one- and two-way bicycle lanes”. To test this hypothesis there were two different bike lane designs in the survey containing a one-way and a two-way lane. The two different lanes compared to each other are design 1 with 7 and design 2 with 3. As stated in the Wilcoxon signed-rank test of hypothesis 4 and 5, the null hypothesis was rejected. So in terms of safety and encouragement there was a difference between design 1 and 7. For the test done between design 2 and 3 the null hypothesis was retained for safety and rejected for encouragement, shown in Figure B.10. This means that respondents are more encouraged to use the two-way bicycle lane compared to the one-way bicycle lane. This also means that respondents see no difference in safety between dense and non-dense low blocks as a physical barrier.

Null hypothesis 7 states ”There is no difference in perceived safety and encouragement score with more physical barriers”. The test was done by step-wise comparing lanes with more physical barriers to each other. The lanes compared to each other were 1 to 3, 3 to 4, 4 to 5 and 5 to 6. The results are shown in Table 4.3 below, in Figure B.11 and Figure B.12.

Additional physical barrier	Safety	Encouragement
Small low blocks	Rejected	Rejected
Tall round cones	Rejected	Rejected
”New jersey blocks”	Rejected	Rejected
Trees and grass	Rejected	Rejected

Table 4.3: Results hypotheses 7 test

As can be concluded from Table 4.3. The more physical barriers there are, the higher the encouragement and perceived safety score is.

Spearman-correlation
The following test will be performed on hypotheses 2 and 8. Through this test it is possible to assess whether there is a positive, a negative or no correlation between two variables.

The null hypothesis 2 states that there is no correlation between the perceived safety and the use of bicycle lanes. After having run the test, the result was that there is a significant correlation between the perceived safety score and the score for encouragement, shown in Figure B.13. This is logical and mentioned in section 2.3, as the safer something is considered, the more encouraged a respondent is to make use of such commodity. This is important for the government, as an increase in perception of safety of the bike lanes results in an increase in the use of the lanes, this unfortunately also works the other way. One of the results of the survey, shown in Figure 4.4, indicates that the great majority of respondents grades their current perceived safety a 5 or lower. This results in less encouragement and therefore a limited amount of bicycle lane users. This could indicate why there is such a large group of respondents that never uses the bike.

The null hypothesis 8 states that ”There is no correlation between income and the use of a bike”. To test this hypothesis the different income groups were numbered from 1 to 7 and the frequency of bike use from 1 to 8. The data set consisted of 91 respondents, as some respondents preferred not to specify their income. From the test the result was that there was no correlation between income and the use of a bike, shown in Figure B.14. Rejecting the correlation between income and use of bike, mentioned in section 2.2.1. The government therefore by improving bicycle lanes encourages citizens of different salaries to make use of the bicycle lanes. Making cycling a mode of transport for all citizens and not just for a specific group.

4.4. Summary

In this chapter the data has been analysed using simple methods of analysis and the non-parametric tests mentioned in section 3.2. From the analysis relationships can be seen between different factors and perceived safety and encouragement.

Age played no significant role in the perception of safety. Younger respondents were prone to give higher scores, but that was not significant enough. Gender and use of bike however did play an important role in the encouragement of bicycle lanes. Males gave higher scores of encouragement than females and frequent bike users had higher perceptions of safety compared to non-frequent users. In terms of safety, the scores remained the same between genders. Also respondents that have been in a bicycle accident before gave no significant different scores on perceived safety and encouragement.

Furthermore, it was very clear that different bike lane designs had different perceived safety and encouragement scores and that the more physical barriers a bike lane had the higher the encouragement and perceived safety scores were. Two-way bicycle lanes also gave higher scores of encouragement but no difference in perceived safety. On top of that there was a clear correlation between the perceived safety and the encouragement to use a bike lane, but no correlation between income and the use of the bike. This is important, as the safer a bike lane is perceived the more encouraged citizens are to use the lane. Also, from a governmental perspective, allocating resources to bicycle lanes constitutes an investment that benefits the entire population.

5 Discussion

In the following chapter, a discussion is written on the research that has been done in this paper. The structure consists of three sections which are the extraction and analysis of data in section 5.1, limitations in section 5.2 and ensuing research in section 5.3.

5.1. Extraction and analysis of data

The focus of this research was to discover the possibilities of improvement in safety and use of bicycle lanes in the city of Barcelona by understanding the perception of safety and encouragement of commuters. To do so, the investigation was done with the use of a survey, answering hypotheses to achieve a response to the research question. The hypotheses were important elements to see if variables had influence on each other. Three of the dependent variables were the socio-demographic, socio-economic and bike experience. To improve the use and safety of bicycle lanes it is important to analyse correlations between groups and observe behaviours. This way the ideal recommendations can be made for improvements.

Other important observations were how changes in design characteristics of bicycle lanes affected the scores of perceived safety and encouragement. Through analysis of responses made, correlations were able to be analysed to answer the research question. The most important correlation found was that design changes of bicycle lanes resulted in different scores for both perceived safety as for encouragement. Another important correlation was that an increase in physical barriers resulted in higher perceived safety and encouragement scores. Hypotheses that gave different results than the predictions were the perception of safety scores related to age and to having had experience in a bicycle accident. This could be because there were not many respondents that have been in a bicycle accident before and because the older groups were more limited. However, the significance was still very low.

The ideal situation would be a larger group of older respondents and more respondents with experience in accidents. Through having more respondents data is more trustworthy as anomalies have less effect on the result of the data analysis. A larger group of respondents would have been better for the research in all aspects. The amount of respondents was enough to draw conclusions on some hypotheses, but would have been more helpful in the case of others.

5.2. Limitations

Due to the time limitations there are also limitations in the research. The research was solemnly focused on the perceived safety and encouragement from the point of view of a cyclist. Considering all the other stakeholders using public roads it is only a small group. To gain overall safety for everyone using space around bicycle networks, it is also important to consider the perception of safety from the point of view of pedestrians, car users, scooter users and motorcyclists. An important stakeholder mentioned is the scooter, also called electric steps. These vehicles are powered by an electric motor and are very new to using cycling lanes. Cities like Barcelona have permitted use of such vehicles on cycling lanes, however, countries like The Netherlands have forbidden the use of such modes of

transport due to the dangers ("Elektrische step - hoe zit dat? | ANWB", n.d.). The perception of safety and encouragement scores will most-likely change due to the use of other modes of transport and also their point of view on the bicycle lane.
Another important factor, which has not been discussed in the research with a significant impact on safety, is education. Users in Barcelona make use of bicycle lanes without knowing the rules of traffic. If citizens were to be educated at school, from a young age, the coming generations would have experience using bicycle lanes and therefore would probably decrease the amount of accidents occurring. The same accounts for commuting time, a respondent is still not prone to use the bicycle if the commuting time is too long, even if the perceived safety is very high.

5.3. Ensuing research

For future research it would be interesting to have a larger group of respondents for the survey. As mentioned above, more respondents result in a better analysis of data. Furthermore, it would be interesting to make a logistical regression model. Having such a model would prove very helpful in predicting correlations in the future using data from the survey. This way of scores can be estimated for different designs, creating the opportunity for city planners to predict their effectiveness of a bicycle lane design.
Another noteworthy subject for future research is the implementation of the most effective bicycle lane in different avenues. The safest bike lane designs and characteristics have been depicted, however not every street can have the safest design implemented. It is therefore important to research the most effective lane design for each street.

6 Conclusion and recommendations

The aim of this research was to obtain a better understanding on the perceived safety and encouragement of bicycle lanes in the city of Barcelona and to answer the following question:

How can the use and safety of bicycles lanes in the city of Barcelona be improved through the understanding of safety perception and encouragement of commuters?

To formulate an answer to this question the data was collected through the use of a survey. The goal of the survey was to quantify the score of perceived safety and encouragement of each respondent for different bike lane designs. The bike lane designs varied from sizes to physical barriers between the lanes and other traffic around it. Furthermore, independent variables like socio-economic, socio-demographic and bike experience were questioned to examine whether there are correlations in responses and groups of independent variables. Results from the survey show that the great majority of the respondents give a score of lower than 5 for the current safety of the bicycle network in Barcelona. To add to that a staggering 41.4% of the respondents never use a bike, however 81.9% is tempted to use the bicycle lanes if the design they considered safest in the survey is applied. This indicates that bicycle lanes are considered unsafe by citizens and that they are not using them due to safety. Adjustments to the current network will give fruit to more use of bicycle lanes, creating a sustainable method of transport in the city. Reducing the emission of harmful gasses and therefore creating a more liveable urban environment.

Non-parametric analysis of the survey data has shown correlations between variables. One of the most important of all is the positive correlation between perceived safety and encouragement, justified with the use of the Spearman-correlation. This implies that when the perceived safety score rises, so does the encouragement. This also works vice-versa. On that account, if the local government were to revamp the bicycle lanes the encouragement would automatically be higher resulting in more users of the bicycle network. The Spearman-correlation test was also applied to the relationship between income and the use of bikes, but resulted in no correlation. This implies that income and the use of the bike do not influence each other. With the use of the Mann Whitney U-test a difference was found in encouragement between males and females on the bicycle network. Males were more encouraged to use the bicycle lanes compared to females. Applying the Kruskal-Wallis test to the same results of the respondents resulted in a higher perception score given by respondents that frequently use a bike, no difference in perception of safety score in relation to age and no difference in perception of safety score related to having already been in an accident. This means that once a citizen uses the bike they will get used to the circumstances and give higher scores for perception of safety. This is a positive remark for the government, but to increase the use of bicycle lanes citizens will first have to consider it safe enough to start using it.

The other important correlation found was that there is a different score for the perception of safety and encouragement between bike lane designs. There were certain key characteristics that gave rise to the different scores. The test was done using the Wilcoxon signed-rank test and the two key characteristics were the lane width and the physical objects as barriers. Respondents were more encouraged to use two-way bicycle lanes compared to one-way, yet perceived no difference in safety between the two. In terms of physical barriers, respondents were more encouraged and perceived more safety the more a physical barrier was present between the bike lane and other users.

Based on the research in this investigation it is clear that to improve the use and safety of bicycle lanes it is vital to improve the safety perceived by bike users. The higher the perceived safety, the more the bike lanes will be used. To improve the perceived safety two-way bicycle lanes should be used with as much of a physical separation as possible from other users. Designs 5 and 6 show such barriers and the implementation of such designs would result into 81% of the respondents being more tempted to use the bike. While the placement of a barrier like in design 5 is much easier compared to design 6, which would limit the other road users on the street. Furthermore, exploring implementations of various bike lane designs across the city should also be a subject of research. Such an approach ensures the development of the most effective and safest bike lanes for each street, taking into consideration the interests of all relevant stakeholders.

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A

Survey questions

A.0.1. English Survey

The link to the survey is the following:
https://docs.google.com/forms/d/e/1FAIpQLSdQmR1paIVzw8hk_Ma-FlW6xEznI0ZFTPAA9sryGLC6RZ1NrQ/viewform?usp=sf_link

Part 1:

In this part the socio-demographic, use of transport and cycling experience questions are asked. The figures are in the order that the respondent answers the survey.

This part is shown in the next page.

Bicycle lane safety in the city of Barcelona

In a time span of 5 years the bike has become responsible for 40% of the accidents in Barcelona. Rapid placement of bicycle lanes in the city has come at cost of safety. Designs of lanes should be evaluated and accidents should be reduced.
The survey has been made to investigate how the safety and use of bicycle lanes can be improved in the city of Barcelona. This way we can recommend different bike lane designs and improve safety for users.

The following survey will be used for research purposes only and is filled in anonymously. The survey will take less than 4 minutes to answer.

If there are any questions concerning the survey you can send an email to the following address:
A.J.Timmermans-1@tudelft.nl

(a) Intro

Age: *
- <18
- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 64<
- Rather not say

(b) Q1

Gender *
- Female
- Male
- Other
- Rather not say

(c) Q2

Education *
- High school
- Bachelor
- Master
- PhD or higher
- Rather not say
- Other...

(d) Q3

Occupation *
- Scholar
- Student
- Employed
- Unemployed
- Retired
- Rather not say

(e) Q4

Monthy salary (€)
- 1,260 - 1,600
- 2,001 - 2,400
- 2,800 - 3,200
- 3,600 - 4,000
- 4,000 +
- No salary
- Rather not say

(f) Q5

What mode of transport do you usually use? *
- Walking
- Cycling
- Public transport
- Car
- Motorbike

(g) Q6

How often do you use the bike? *
- Every day
- 3-4 times per week
- 1-2 times per week
- 3-4 times per month
- 1-2 times per month
- 3-4 times per year
- 1-2 times per year
- Never

(h) Q7

How safe do you feel whilst cycling in Barcelona? *

	1	2	3	4	5	6	7	8	9	10	
Very unsafe	○	○	○	○	○	○	○	○	○	○	Very safe

(i) Q8

Have you ever been in a bicycle accident in Barcelona? *
- Yes
- No

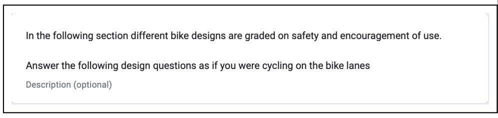
(j) Q9

Figure A.1: Part 1

Part 2:

In this part the perception of safety is asked and the encouragement of use of each design. Under each design the same two questions are asked, shown after the first design. To avoid pointless repetition the two questions are shown only under design 1.

This part is shown in the next page.

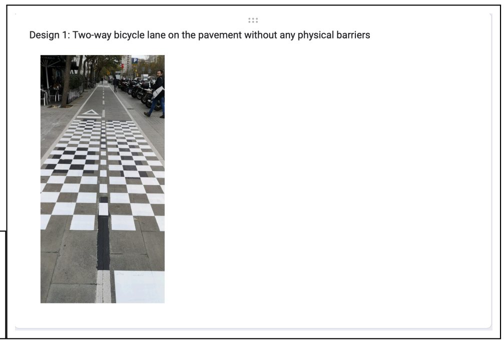


In the following section different bike designs are graded on safety and encouragement of use.

Answer the following design questions as if you were cycling on the bike lanes

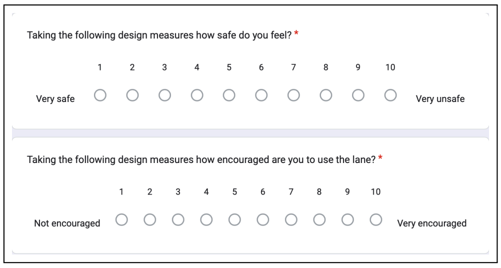
Description (optional)

(a) Intro



Design 1: Two-way bicycle lane on the pavement without any physical barriers

(b) Design 1



Taking the following design measures how safe do you feel? *

	1	2	3	4	5	6	7	8	9	10	
Very safe	○	○	○	○	○	○	○	○	○	○	Very unsafe

Taking the following design measures how encouraged are you to use the lane? *

	1	2	3	4	5	6	7	8	9	10	
Not encouraged	○	○	○	○	○	○	○	○	○	○	Very encouraged

(c) Two questions under each design

Design 2: One-way bicycle lane implemented in the road and separated by low blocks

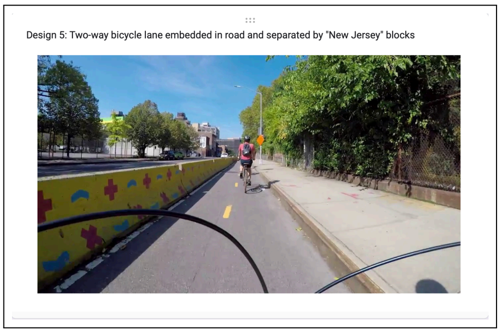
(d) Design 2

Design 3: Two-way bicycle lane embedded in road and separated by densely placed low blocks

(e) Design 3

Design 4: Two-way bicycle lane embedded in road and separated by poles from other traffic

(f) Design 4



Design 5: Two-way bicycle lane embedded in road and separated by "New Jersey" blocks

(g) Design 5

Design 6: Two-way bicycle lane in the middle of the road with trees and plants as physical barrier from other traffic

(h) Design 6

Design 7: One-way bicycle lane placed on the pavement with no physical barriers

(i) Design 7

Figure A.2: Part 2

Part3:

Would you be more tempted to use the bike if the design you consider safest were to be implemented everywhere? *

- Yes
- No

(a) Final question on safety

Any comments or questions about the survey can be written below

Long-answer text

(b) Comments on survey

Figure A.3: Las questions on survey

A.0.2. Original survey in Spanish

The link to the survey is the following:
https://docs.google.com/forms/d/e/1FAIpQLSdRiNfLGRzKaDQKmTn9hh62LBOno8NXDwgM0PadkqG9kuAs7Q/viewform?usp=sf_link

Just like in appendix A the appendix has the same structure with part 1 and 2.
Part 1:

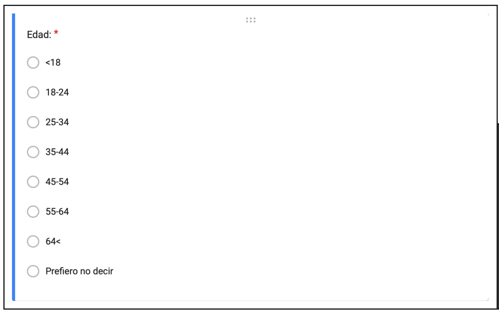
Seguridad de los carriles bici en Barcelona

En menos de 5 años la bicicleta ha sido responsable del 40% de los accidentes en el área metropolitana de Barcelona. La rápida expansión del carril bici ha sido a costa de la seguridad. Los diseños de los carriles bici deben ser evaluados y mejorados para reducir el número de accidentes.

La siguiente encuesta será exclusivamente utilizada para investigación y las respuestas son anónimas. Rellenar la encuesta dura unos 4 minutos aproximadamente.

Para preguntas o comentarios sobre la encuesta pueden enviar un email al siguiente correo: A.J.Timmermans-1@tudelft.nl

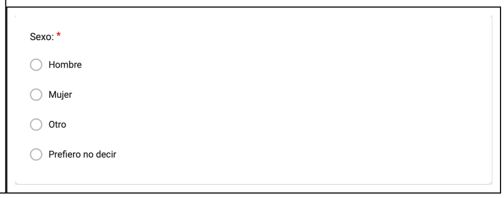
(a) Intro



Edad: *

- <18
- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 64<
- Prefiero no decir

(b) Q1



Sexo: *

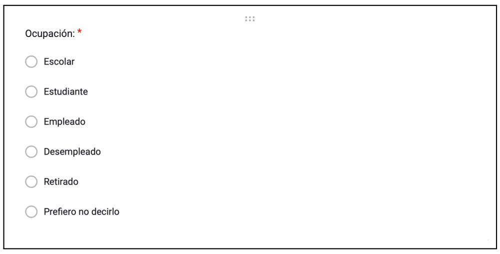
- Hombre
- Mujer
- Otro
- Prefiero no decir

(c) Q2

Máxima educación: *

- Bachillerato
- Grado
- Carrera
- Master
- Doctorado o más
- Prefiero no decirlo
- Otro:

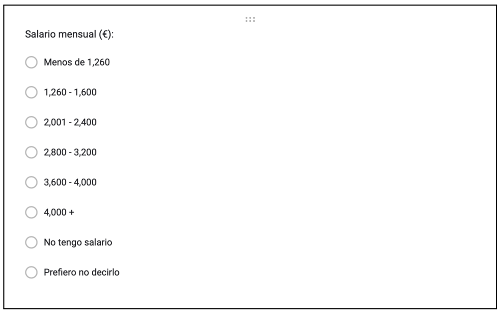
(d) Q3



Ocupación: *

- Escolar
- Estudiante
- Empleado
- Desempleado
- Retirado
- Prefiero no decirlo

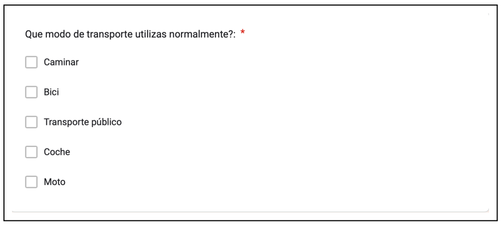
(e) Q4



Salario mensual (€):

- Menos de 1,260
- 1,260 - 1,600
- 2,001 - 2,400
- 2,800 - 3,200
- 3,600 - 4,000
- 4,000 +
- No tengo salario
- Prefiero no decirlo

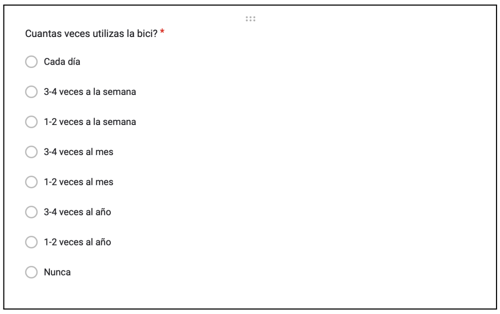
(f) Q5



Que modo de transporte utilizas normalmente?: *

- Caminar
- Bici
- Transporte público
- Coche
- Moto

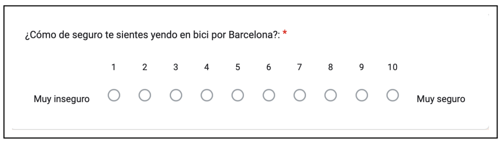
(g) Q6



Cuantas veces utilizas la bici? *

- Cada día
- 3-4 veces a la semana
- 1-2 veces a la semana
- 3-4 veces al mes
- 1-2 veces al mes
- 3-4 veces al año
- 1-2 veces al año
- Nunca

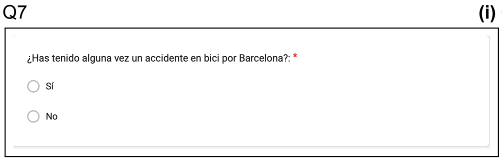
(h) Q7



¿Cómo de seguro te sientes yendo en bici por Barcelona?: *

Muy inseguro 1 2 3 4 5 6 7 8 9 10 Muy seguro

(i) Q8



¿Has tenido alguna vez un accidente en bici por Barcelona?: *

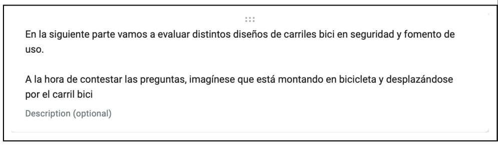
- Sí
- No

(j) Q9

Figure A.4: Part 1

Part 2:

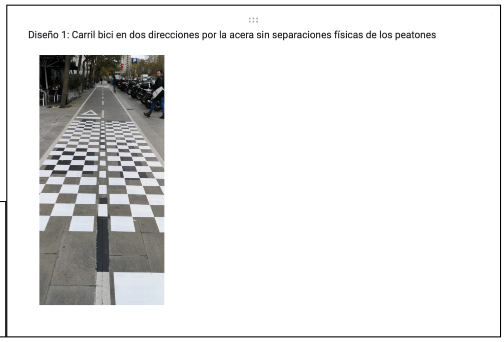
This part is shown in the next page.


En la siguiente parte vamos a evaluar distintos diseños de carriles bici en seguridad y fomento de uso.

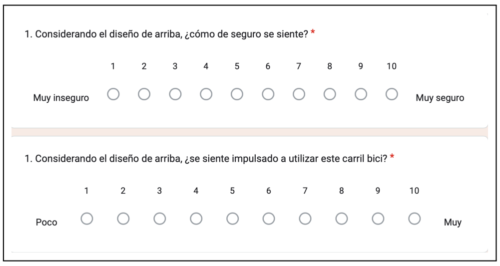
A la hora de contestar las preguntas, imagínese que está montando en bicicleta y desplazándose por el carril bici

Description (optional)

(a) Intro


Diseño 1: Carril bici en dos direcciones por la acera sin separaciones físicas de los peatones

(b) Design 1


1. Considerando el diseño de arriba, ¿cómo de seguro se siente? *

	1	2	3	4	5	6	7	8	9	10	
Muy inseguro	○	○	○	○	○	○	○	○	○	○	Muy seguro

1. Considerando el diseño de arriba, ¿se siente impulsado a utilizar este carril bici? *

	1	2	3	4	5	6	7	8	9	10	
Poco	○	○	○	○	○	○	○	○	○	○	Muy

(c) Two questions under each design


Diseño 2: Carril bici de una dirección sobre la calzada y separado de otros vehículos por bloques bajos

(d) Design 2


Diseño 3: Carril de dos direcciones sobre la calzada y separado de otros vehículos por bloques bajos consecutivos

(e) Design 3


Diseño 4: Carril bici de dos direcciones sobre la calzada y separado de otros vehículos por postes verdes

(f) Design 4


Diseño 5: Carril bici en dos direcciones sobre la calzada y separado de otros vehículos con bloques de hormigón tipo "New Jersey"

(g) Design 5


Diseño 6: Carril de dos direcciones en medio de la calzada separado de otros vehículos por árboles y plantas

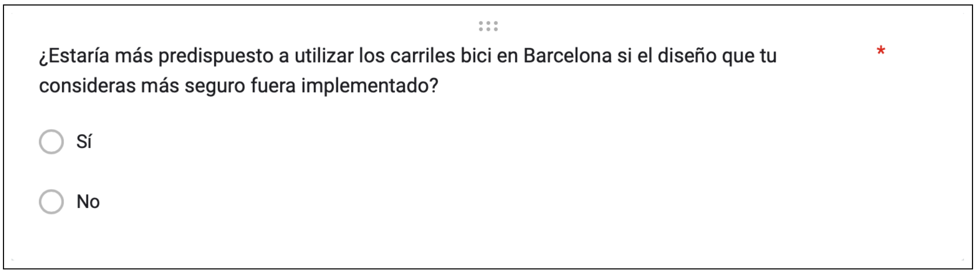
(h) Design 6


Diseño 7: Carril de una dirección, con suelo marcado como carril de bicicleta, implementado en la acera sin objetos físicos para separarlo de los peatones

(i) Design 7

Figure A.5: Part 2

Part3:

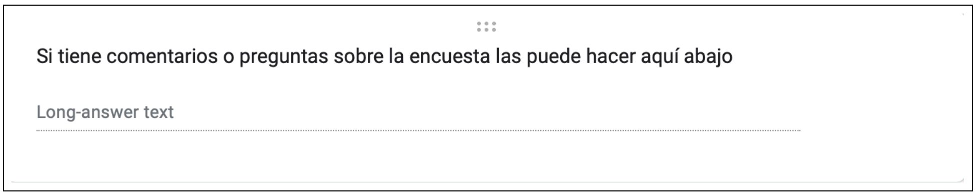


¿Estaría más predispuesto a utilizar los carriles bici en Barcelona si el diseño que tu consideras más seguro fuera implementado? *

Sí

No

(a) Final question on safety



Si tiene comentarios o preguntas sobre la encuesta las puede hacer aquí abajo

Long-answer text

(b) Comments on survey

Figure A.6: Las questions on survey

B

SPSS results

Kruskal-Wallis test

Hypothesis 1.1

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of Average safety is the same across categories of Group.	Independent-Samples Kruskal-Wallis Test	.290	Retain the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Figure B.1: Age vs perceived safety in 5 different age groups

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of Average safety is the same across categories of Group.	Independent-Samples Kruskal-Wallis Test	.165	Retain the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Independent-Samples Kruskal-Wallis Test

Average safety across Group

Independent-Samples Kruskal-Wallis Test Summary

Total N	116
Test Statistic	3.602[a]
Degree Of Freedom	2
Asymptotic Sig.(2-sided test)	.165

a. The test statistic is adjusted for ties.

Figure B.2: Age vs perceived safety in 3 different age groups

Hypothesis 3

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of Average safety is the same across categories of Group.	Independent-Samples Kruskal-Wallis Test	.069	Retain the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Independent-Samples Kruskal-Wallis Test

Average safety across Group

Independent-Samples Kruskal-Wallis Test Summary

Total N	116
Test Statistic	13.138[a]
Degree Of Freedom	7
Asymptotic Sig.(2-sided test)	.069

a. The test statistic is adjusted for ties.

Figure B.3: Bike use vs perceived safety in 8 different bike use groups

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of Average safety is the same across categories of Group.	Independent-Samples Kruskal-Wallis Test	.043	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

Independent-Samples Kruskal-Wallis Test

Average safety across Group

Independent-Samples Kruskal-Wallis Test Summary

Total N	116
Test Statistic	6.286[a]
Degree Of Freedom	2
Asymptotic Sig.(2-sided test)	.043

a. The test statistic is adjusted for ties.

Figure B.4: Bike use vs perceived safety in 3 different bike use groups

Hypothesis 9

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of Safety score is the same across categories of Group.	Independent-Samples Kruskal-Wallis Test	.970	Retain the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

Independent-Samples Kruskal-Wallis Test

Safety score across Group

Independent-Samples Kruskal-Wallis Test Summary

Total N	116
Test Statistic	.062[a]
Degree Of Freedom	2
Asymptotic Sig.(2-sided test)	.970

a. The test statistic is adjusted for ties.

Figure B.5: Perceived safety vs bike accident

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of Encouragement score is the same across categories of Group.	Independent-Samples Kruskal-Wallis Test	.414	Retain the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

Independent-Samples Kruskal-Wallis Test

Encouragement score across Group

Independent-Samples Kruskal-Wallis Test Summary

Total N	116
Test Statistic	1.765[a]
Degree Of Freedom	2
Asymptotic Sig.(2-sided test)	.414

a. The test statistic is adjusted for ties.

Figure B.6: Encouragement vs bike accident

Mann Whitney U-test

Hypothesis 1.2

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of Safety score is the same across categories of Group.	Independent-Samples Mann-Whitney U Test	.113	Retain the null hypothesis.
2	The distribution of Encouragement score is the same across categories of Group.	Independent-Samples Mann-Whitney U Test	.040	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

Figure B.7: Gender vs encouragement and perception of safety

Wilcoxon signed-rank test

Hypothesis 4

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 1 and Design 2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

(a) 1 vs 2

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 1 and Design 3 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

(b) 1 vs 3

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 1 and Design 4 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

(c) 1 vs 4

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 1 and Design 5 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

(d) 1 vs 5

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 1 and Design 6 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

(e) 1 vs 6

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 1 and Design 7 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hypo

a. The significance level is .050.
b. Asymptotic significance is displayed.

(f) 1 vs 7

Figure B.8: There is no difference in perceived safety score between designs

Hypothesis 5

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 1 and Design 2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

(a) 1 vs 2

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 1 and Design 3 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

(b) 1 vs 3

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 1 and Design 4 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

(c) 1 vs 4

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 1 and Design 5 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

(d) 1 vs 5

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 1 and Design 6 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

(e) 1 vs 6

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 1 and Design 7 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hyp

a. The significance level is .050.
b. Asymptotic significance is displayed.

(f) 1 vs 7

Figure B.9: There is no difference in encouragement score between designs

Hypothesis 6

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 2 and Design 3 equals 0.	Related-Samples Wilcoxon Signed Rank Test	.076	Retain the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

Related-Samples Wilcoxon Signed Rank Test

Design 2, Design 3

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	116
Test Statistic	2278.500
Standard Error	230.044
Standardized Test Statistic	1.774
Asymptotic Sig.(2-sided test)	.076

(a) Safety

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 2 and Design 3 equals 0.	Related-Samples Wilcoxon Signed Rank Test	.043	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

Related-Samples Wilcoxon Signed Rank Test

Design 2, Design 3

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	116
Test Statistic	2439.000
Standard Error	237.488
Standardized Test Statistic	2.025
Asymptotic Sig.(2-sided test)	.043

(b) Encouragement

Figure B.10: There is no difference in score between one- or two-way bike lanes

Hypothesis 7

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 3 and Design 4 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

Related-Samples Wilcoxon Signed Rank Test

Design 3, Design 4

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	116
Test Statistic	2513.000
Standard Error	217.307
Standardized Test Statistic	3.543
Asymptotic Sig.(2-sided test)	<.001

(a) 3 to 4

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 4 and Design 5 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

Related-Samples Wilcoxon Signed Rank Test

Design 4, Design 5

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	116
Test Statistic	3753.500
Standard Error	252.952
Standardized Test Statistic	6.383
Asymptotic Sig.(2-sided test)	<.001

(b) 4 to 5

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 5 and Design 6 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hyp

a. The significance level is .050.
b. Asymptotic significance is displayed.

Related-Samples Wilcoxon Signed Rank Test

Design 5, Design 6

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	116
Test Statistic	2238.000
Standard Error	196.827
Standardized Test Statistic	3.544
Asymptotic Sig.(2-sided test)	<.001

(c) 5 to 6

Figure B.11: Safety

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 3 and Design 4 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

Related-Samples Wilcoxon Signed Rank Test

Design 3, Design 4

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	116
Test Statistic	2670.000
Standard Error	213.001
Standardized Test Statistic	4.547
Asymptotic Sig.(2-sided test)	<.001

(a) 3 to 4

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 4 and Design 5 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

Related-Samples Wilcoxon Signed Rank Test

Design 4, Design 5

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	116
Test Statistic	3071.000
Standard Error	232.745
Standardized Test Statistic	4.971
Asymptotic Sig.(2-sided test)	<.001

(b) 4 to 5

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The median of differences between Design 5 and Design 6 equals 0.	Related-Samples Wilcoxon Signed Rank Test	<.001	Reject the null hypothesis.

a. The significance level is .050.
b. Asymptotic significance is displayed.

Related-Samples Wilcoxon Signed Rank Test

Design 5, Design 6

Related-Samples Wilcoxon Signed Rank Test Summary

Total N	116
Test Statistic	2166.000
Standard Error	186.612
Standardized Test Statistic	3.971
Asymptotic Sig.(2-sided test)	<.001

(c) 5 to 6

Figure B.12: Encouragement

Spearman correlation

Hypothesis 2

Correlations

			Perceived safety score	Encouragement score
Spearman's rho	Perceived safety score	Correlation Coefficient	1.000	.913**
		Sig. (2-tailed)	.	<.001
		N	116	116
	Encouragement score	Correlation Coefficient	.913**	1.000
		Sig. (2-tailed)	<.001	.
		N	116	116

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

Figure B.13: Correlation between safety and encouragement

Hypothesis 8

Correlations

			Use of bike	Income
Spearman's rho	Use of bike	Correlation Coefficient	1.000	.036
		Sig. (2-tailed)	.	.735
		N	91	91
	Income	Correlation Coefficient	.036	1.000
		Sig. (2-tailed)	.735	.
		N	91	91

Figure B.14: Correlation between income and bike use

C
Timetable

Timetable BEP Q1 2023

Week 1: Workplan is made and research question is brainstormed.

Week 2: Gathering of information
Online information on the perception of safety, safety designs of bicycle and the use of lanes is gathered. Contact will be made with a relative in the government of Barcelona to receive information on the criteria implemented on bicycle lanes in the city. Different types of safety measures are researched Why is it important to have safety in bicycle lanes and who benefits from it

Week 3:
A survey is made to ask users in Barcelona on their experience in the lanes. An important part of this survey is the questioning of different safety measures applied in Barcelona. Further research is done on the methodology. Survey is shown to colleagues and supervisors at the end of the week.

Week4:
Data analysis methods are chosen. The survey receives the finishing touches and is translated to Spanish to be published on Thursday. Literature study and the methodology are further improved with feedback from peers. Midterm presentation is given on the work that has been completed.

Week 5:
All filled in data of the survey is analysed with the statistical analysis methods that have been chosen through SPSS.

Week 6:
Preliminary, summary, conclusions and recommendations

Week 7:
Presentation of results with short pitch