Curitiba bikeways quality mapping index

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Spatial analysis on the quality of the bicycle infrastructure that Curitiba offers

Bachelor thesis report

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1. Preface

The research was performed in Curitiba, a fast growing city in the state of Paraná (PR) in southern Brazil. In the 1960s Curitiba was inhabited by 300.000 inhabitants. In 2015 Curitiba had 1.879.355 residents and a population density of 4.062/km². The metropolitan area has circa 3.4 million inhabitants with a population density of 211/km² (Marques, 2013). In about 50 years the population has quadrupled and this has had significant consequences. At the time of the huge growth of the population, the individual motorized transport became affordable for the middle class. This was the reason why a lot of inhabitants bought a car. Curitiba has the highest vehicle ownership rate per capita of any Brazilian capital city (0.63). The national average of Brazil is more than two times smaller (0.27) (Scruggs, 2013). The growth of the city and the crowded led to an innovation. In 1974, the first BRT system was founded in Curitiba (Reed, 2015). At the moment the BRT system is used in 204 worldwide and serves over 33 million passengers per day (BRT data, 2016) . Curitiba has 84 kilometres of BRT lanes and these are used by 561.000 passengers daily (BRT data, 2016). Nowadays the roads are overcrowded, the BRT lanes are saturated and there is little space to add new roadways. It has already been proven that adding more roadways is not the solution to reduce the traffic jams, because it will only lead to more people buying private motorized transport (Gertten, 2015). So there is need for another solution, to get more people to use non-motorized transports, like bicycles, or public transport, like busses. (Gertten, 2015)

As mentioned in the paragraph above, there is need for a change from cars and motorcycles to other types of vehicles. In this thesis the focus will lie on increasing the bicycle use in Curitiba. There is already a project to get more people on bicycles in Curitiba.

In September 2013 the municipality of Curitiba with the major, Gustavo Fruet as the key person, started with a plan to increase the bicycle mobility of the city. A new department called CMOB (Coodenadoria de Mobilidade Urbana no Trânsito) was born. Some Technicians from SETRAN and URBS were chosen to work for CMOB at that time. The first priority was to improve the sidewalks and add ramps at the crossings, since disabled people had a lot of problem while traveling through the city. Next the bicycle facilities had to be increased. In 23 nights the first Via Calma of Sete de Setembro avenue was built and plans were made to make it possible to take your bicycle on the bus as well. The information signs above the road show messages to make other road users more aware of the cyclists and stimulate to leave the car at home and take the bicycle to work. The results of these messages was an 8% reduction of traffic flow on the roads (Coordenadoria de Mobilidade Urbana no Trânsito, 2014).

As mentioned before the municipality is the founder of this project, and as a result the media was easy to use as a platform to spread information about the new plans and the improvements that are already made and the ones that are planned. Events to promote cycling were organized and there was space for discussion. In the meantime and especially since September 2015, new bicycle paths have been build and some old ones have been improved (Coordenadoria de Mobilidade Urbana no Trânsito, 2014). In conclusion, is that in less than three years Curitiba grew from an insufficient place to cycle to a rather acceptable place. The number of achievements in the last three is high and the work that the people here put into increasing the quality of bicycle facilities is impressive, but there are some aspects that could have been done better, in a different way and more efficient.

Therefore the existing bicycles roads and parking facilities for bicycles should be validated. The set objectives are reached by answering the following three research questions:

1. How bicycle friendly are the bicycle paths in Curitiba?
2. How much inhabitants of Curitiba have access to the bicycle network and what is their position in the society?
3. What kinds of places have facilities to store bicycles and how are these facilities distributed throughout the city?

2. Summary

The name of the research is 'Curitiba bike quality mapping index'. The research took place in Curitiba, a city of circa 2 million inhabitants and located in Southern Brazil. The city wants to improve the bicycle use among the residents. This research is a part of this project and focuses mainly on the quality of the existing bicycle infrastructure. The following research questions are answered in the report

1. How bicycle friendly are the bicycle paths in Curitiba?
2. How much inhabitants of Curitiba have access to the bicycle network and what is their position in the society?
3. What kinds of places have facilities to store bicycles and how are these facilities distributed throughout the city?

To answer the first research question a score per bicycle path was calculated. To achieve this, four criteria were obtained. First of all, the presence of obstacles on the bicycle path was noted. Secondly, it was checked whether an intersection with a bicycle path and a general road has sufficient painting to make the driver aware of the fact that they could expect a cyclist. Thirdly, the overall quality of the surface was marked. Lastly, the percentage of the bicycle that is shared with pedestrians, which can be seen as moving obstacles, is calculated. After each of these criteria received a weight, the final score per bicycle path was calculated. The result is a map of the city with the bicycle paths and their scores classified as colours. The low scoring paths got a red colour and the high scoring paths got a green colour.

In research question two, a 200 meter buffer area around the bicycle paths is compared to the area of the whole city. Two things are compared, the income and the population density. The average income in the buffer area is higher and the T-Test resulted into a significant statistical difference. The comparison of the population density showed no significant statistical difference.

In research question three, the location of the bicycle storage facilities (paraciclos) is analysed. The main conclusion is that 53% of these paraciclos are located within 30 meters of a bicycle path. In the city centre itself, 17 paraciclos are located outside the buffer area and 2 inside.

The conclusions after answering these three questions are as follows: Curitiba has potential to become one of the leading bicycle cities of Latin America, but some things have to improve. Most of the bicycle paths with a higher score were initially roads. The lower scoring bicycle paths were initially sidewalks, these paths have to cope with obstacles and softer surfaces. The average income of inhabitants who live within 200 meters of a bicycle path is higher than the average income of the total city. The locations of the paraciclos, especially in the city centre, are far away from the bicycle paths and therefore harder to find.

These conclusions let to recommendations. The most important one concerning the quality of the bicycle paths is to construct new paths on the same surface as the general road instead using a part of the sidewalk.

3. Terminology

This report contains some terms which need further explanation. These include several technical and Portuguese terms.

Attribute table (ArcMap): This is the table in ArcMap where all the values are stored. The visualized data is always gained from the attribute table.

Bicycle boulevard: This is a street designed for cycling, where cars are allowed, but considered as guests. Cyclists can use the whole road to cycle. These streets are mostly found in residential areas and the maximum speed is 30 km/h.

Bikeability index: A bikeability index will identify areas that are more bicycle friendly and less bicycle friendly within the city of Curitiba. This index takes various aspects into account such as the land use, population density and citizen's perceptions and preferences. (Winters, Brauer, Setton, & Teschke, 2013)

Bicycle friendly: Is when people feel comfortable to travel by bicycle. The bicycle friendliness can be increased by implementing certain policies and practices like city planning and bicycle infrastructure.

BRT: The Bus Rapid Transit is a bus-based transit system, but has more similarities with the subway than with normal bus lanes. The BRT has dedicated lanes with the station in the centre. Just as in the subway, the fare collection is off-board (What is BRT?, 2016). The BRT was established in Curitiba, the first line was opened in 1974. (Reed, 2015)

Distributor roads: These roads are built to transfer motorized vehicles in and out of the neighbourhood or city. They have a relatively high capacity and the main function of this type of road is to keep incoming and outgoing traffic flowing.

Individual motorized transport: Also called private motorized transport. This the most dominant form of transportation in the United States and it is a problem in Brazil too. There are too many cars and motorcycles in the streets of Curitiba, which leads to overcrowded roads.

Mass motorized transport: Another name is public transport. This category covers for example busses, trains, metros and planes. In Curitiba the only public transport is the bus.

SETRAN: This is the 'secretaria de municipal de transito', translated: 'Secretary of municipal transit'. This secretary is located in Curitiba and focuses on improving the cities' (bicycle) mobility.

ArcMap: ArcMap is a Geographic Information System which will help visualizing the quality of the bicycle paths in Curitiba.

CCO: This is the 'Centro de Controle Operacional'. This is a department of URBS, the company which controls everything that is related to the urbanization in Curitiba. The CCO focuses mainly on public transport and has 622 cameras above the road and in the bus tubes. CCO has the 'green times' of the traffic lights in the city centre.

Different types of bicycle paths in Curitiba.

Ciclovia: This is a separate lane, which is only used by cyclists. See: Figure 22

Ciclofaixa: This lane is only for cyclist, but it is not separate. The path lies next to the road and is separated by lines or little cubes. See: Figure 2: Ciclofaixa2

Figure 1: Ciclovia

Figure 2: Ciclofaixa

Via Calma: In this type of road where the car has a maximum speed of 30 km/h, The cyclist has the priority on this road on his own strip. This is seen at the intersections, where there is a special segment of the road reserved, at the front of the intersection, this is called a ´bike box´ Figure 4

Passeio Compartihado: This is a separated path for both pedestrians and cyclists. See Figure 3

Ciclorrota: The bicycle and the car share the road here. The maximum speed of the car is 30 km/h and the bicycle has the priority. On the road are big signs of cycles painted to remind the car drivers to drive careful. See Figure 5

Figure 3: Via Calma

Figure 2: Passaeio compartihado

Figure 5: Ciclorrota

4. Literature overview

Some of the literature that was used will be explained below.

The bicycle paths will be judged by the criteria mentioned in the section 6 'Empirical collected data', below. The criteria are obtained from (Foram, 2015). This article is about a comparable study done in Blumenau, a city located in Santa Catarina about 200 kilometres south from Curitiba. The data is useful, because it gives an insight in how Brazilians look at the roads and what they think is important. The bicycle paths quality will be marked more or less the same way as done in Blumenau. However there are some important criteria not studied in this article. This is the psychological comfort of the cyclist.

The type of road and especially other users (if present) have an influence on this. (J. D. Hunt & Abraham, 2007) have calculated the 'level of onerous' of cycling on another road type with other users. A designated cycle path has value '1', Cycling on a general road with other users is, according to the article, 4.1 times more onerous as cycling on a designated road. Cycling on a shared road with pedestrians is 1.4 times more onerous as cycling on a designated road. These number are used in the calculation to distinguish the separated bicycle paths with the shared ones.

All the ArcMap data that was used during the research was received from IPPUC (Instituto de Pesquisa e Planejamento Urbano de Curitiba). This is the planning institute of Curitiba.

5. Used methods to obtain data of the bicycle paths

5.1 Cycling:

The best way to obtain the data to measure the road quality is to see by yourself. The bicycle infrastructure that will be cycled is shown green in the map below (Figure 4: Figure 4). To make the scheduled cycled trajectories more clear, the name of each cycled street is mentioned in the map as well. The choice of these routes was done with help of both my supervisor from the UTFPR (technical university of Curitiba) and the supervisor from the company, SETRAN. The focus in this study lies on improving the utilitarian bicycle trips. Due to this, the chosen routes are mainly from the outskirts of the city to the city centre and vice versa.

The two outstretched routes in the southern part of the city are the main routes to connect Curitiba and São José dos Pinhais, a city, with 297.895 inhabitants (IBGE (Instituto Brasileiro de Geografia e Estatística), 2016). According to the supervisor from SETRAN, the Av. Mal. Floriano Peixoto is utilised more than the Av. Com Franco. Interested for them is to see how and why this is the case, so both routes will be analysed. The Av. Mal. Floriano Peixoto will not be analysed completely. The first trajectory from the city centre to São José dos Pinhais is a bad part which will be improved in May/June 2016. The name of that street is R. Conselheiro Laurindo. There is no need to evaluate this part now and no time to do it after the improvement. Between the aforementioned routes is a so called 'Ciclofaixa' located, the R. Iapó. This route connect the city centre with the university PUCPR, the catholic university of the city

Another route that will be cycled is the green line extending towards the west. The Av Sete de Setembro, number six on the map, is a 'Via Calma'. This street is designed for public transport. The street has two BRT lanes in the middle and only one lane for individual motorized transport in each direction. This makes it a relatively calm street and suitable for cycling. The rest of this route has a designated bicycle path, the Ciclovia. This part is indicated as number seven on the map

Three routes in the northern part of the city will be analysed. The choices of these routes have different underpinnings. The route located the most to the left connects the Passeio publico (in the city centre) with parque São Lourenço. This trajectory got a new surface last year, but does already have some complications. The next trajectory is from parque São Lourenço to the train station. The name of this street is Flavio Dallegrave. This bicycle path is built along the railway track. Trains cannot cope with a high declivity level, so this route is relatively flat and suitable for cycling.

Initially the plan was to cycle one of the two main routes to the east part of the city, The Av. Presidente Affonso Camargo, which connects the city centre with the suburb Pinhais with 127.045 inhabitants (IBGE (Instituto Brasileiro de Geografia e Estatística), 2016) This plan was rejected by my supervisor at SETRAN, because the quality of the path is bad and in short term the bicycle infrastructure will be renewed.

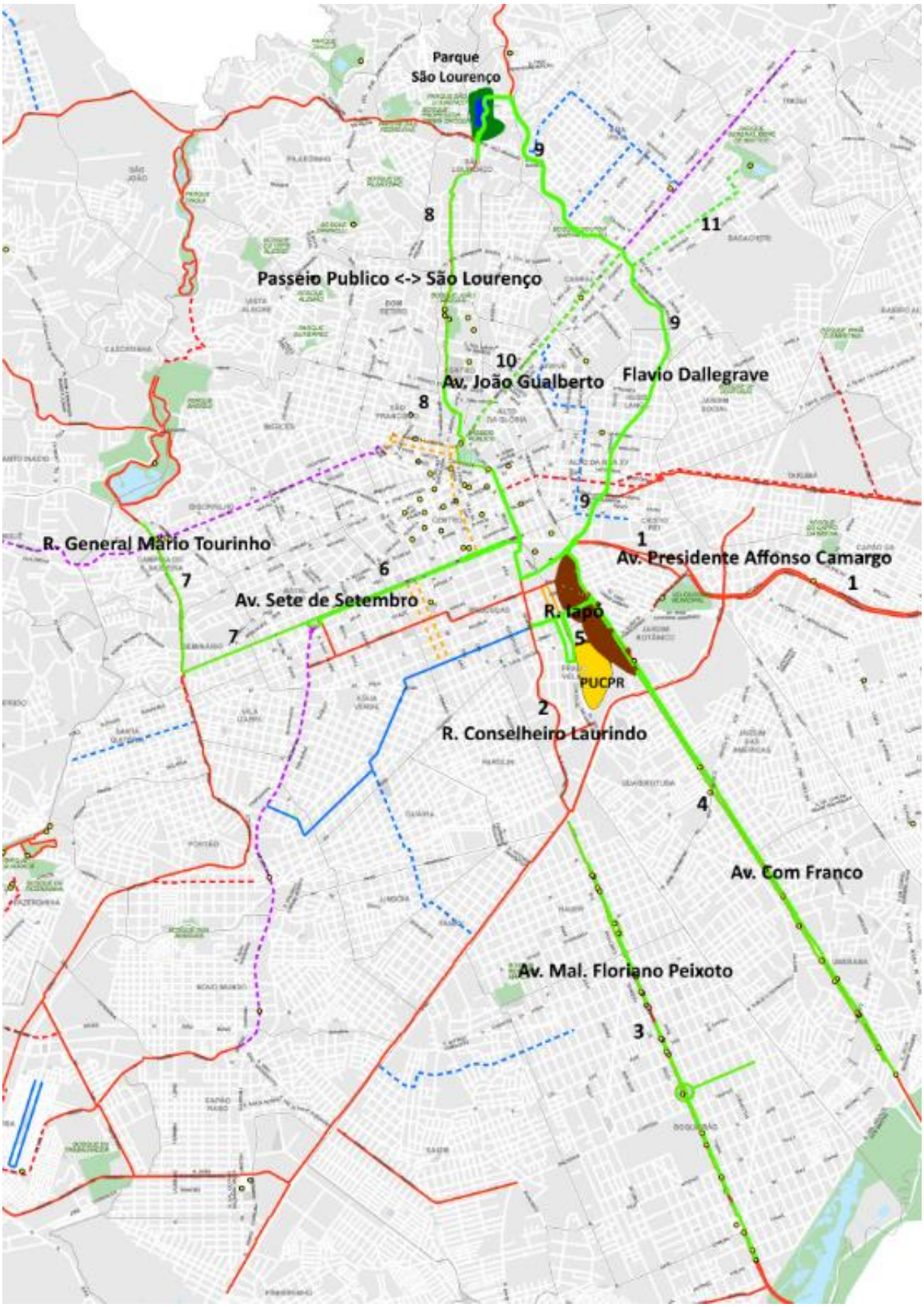

Figure 4: Locations of fieldwork

5.2 Google maps

The other bicycle path data was collected with the use of the street view extinction of google maps (see Figure 4, the lines, not the dobbed ones, that are not green). The main focus lied on the utilitarian routes (home to work, work to home), which are all analysed. The routes which are not analysed are the routes in the parks and the routes which are not connected to the 'network'. The location of these routes is further away from the city centre. The street view data is recent (October 2015 until February 2016), except one street which was being photographed in July 2013. The view of the bicycle infrastructure from the roads was agreeable. If present, the obstacles, signalization and intersection paintings were good visible.

6. Empirical collected data

To acquire an appropriate answer to the research questions various data has been obtained. It has been validated whether this data is still representative.

For answering the first research question, data from the roads in the city was using fieldwork and google maps. This included the road types, quality of the road and the estimated average travel speed. The data was collected in various parts of the city. Because a lot of bicycle paths were reviewed, it is important to keep the results clear. The best way to achieve this is to give a grade to each road on each variable and give the variable a weight. The weights that were given to the criteria are mentioned later in the report.

The following aspects of the road were marked during the research:
Type of roads where distinction is made

- Ciclovia
- Ciclofaixa
- Via Calma
- Passeio Compartihado

Level of 'straight forward' cycling
These criteria are constraining the cyclist in his/her cycle trip.

Signing: Mark if the signs are clear and do not lack (cyclist should not have to think about how it works). Especially when a cycle path has to cross a bus terminal, the designated route is often unclear. The situations where this happened were noted.

Security: Estimate if the route is safe at any time of the day.
Lighting along the road is an important factor to feel safer and the lighting was initially going to be part of this research. However in Brazil if there is lighting along the road, it does not mean that the lights turn on when it becomes dark. To prevent an oblique image, this criterion is not included in this research.

The bank of a bicycle route should in all cases be safe. Big height differences next to bicycle paths have to be protected with a fence or a barrier.

A phenomenon that is seen in Curitiba is a two way bicycle route right next to a one-way road. This means that the cyclist cycles close to the approaching vehicles and this can lead to dangerous situations. If there is a crash, the impact will be higher and the consequences will be bigger. This occurred in a few situations. This has been noted as well.

Indication of intersecting with a bicycle lane at an intersection: At every crossing with another road it has been checked whether the signalization is sufficient. The other traffic users have to be aware that they cross a bicycle path. There are three different outcomes possible: Yes, the signalization is clear. No, there is no signalization and third one being that signalization is present, but it needs to be repainted, because it is not sufficiently visible anymore.

Obstacles: This criterion was divided into two groups:

- Major: obstacles that you have to dodge
    - Poles in the route
    - Trees hanging over the route
    - Big elevation differences
    - Holes in the road
- Minor: obstacles you do not have to dodge, but you have to be aware of a little impact
    - Little elevation differences at crossings or in the road
    - Bumps in the road

Condition of the pavement: This gives a mark to the average quality of the road and the overall review of the bicycle path in total. A survey and an empirical review were given of each bicycle path. These two reviews lead to a total mark per road segment. A sensitivity analysis helped to validate whether the values are sufficient enough to give a proper mark.

For the analysis of the accessibility of the bicycle paths, population and income, data of the neighbourhoods is needed. This data is available in ArcMap as well as the data of the bicycle storage facilities.

7. Survey data

7.1 Motivation and reasons for this survey

Initially, the intention was to do the marking of the general quality of the road empirically. However according to some literature; to satisfy a sufficient survey was achievable. According to Sauro (2010), a survey is representative if you ask the right people. Three questions have to be answered correctly. Three questions are built for test whether a company should purchase a product or not (Sauro, 2010). The bicycle paths can be seen as products too. The cyclist (customer) has a certain experience with this product and gives a mark, which indicated if the respondent recommend or discourage the path. The three questions are shown below

1. Do your respondents have the authority to make purchasing decisions? (Sauro, 2010)
2. Are you surveying a user or system administrator? (Sauro, 2010)
3. Are only people from North America responding to your survey about international issues? (Sauro, 2010)

The question are answered below

Question 1: The respondents of the survey are achieved via Ciclo iguaçu (47 respondents) and World Bicycle Forum III (66 respondents). All these people cycle in and around Curitiba or have certain affection for cycling. This makes them suitable for this survey.

Question 2: The survey is sent directly to the e-mail addresses of the respondents. The program that was used to build this survey so that it will only accept one response per e-mail address. This makes it impossible to spread the survey to e-mail addresses which are not on the list. The only way to send the survey to respondents is to log in on the right 'SurveyMonkey' account and add more e-mail addresses. There is one administrator of this account, Paul Schilte. He is responsible for this.

Question 3: In this case the question applies to Curitiba. The survey is sent to people from two groups. The first group are the members of Ciclo Iguaçu, a non-governmental association dedicated to improving the bicycle infrastructure in Curitiba. The other group is the mail list of Curitiban people who joined the World Bike Forum in 2014, which was maintained in Curitiba. The list was given by a member of both organizations and the source of this list ensured that all the people in the lists are inhabitants of Curitiba (at least in 2014 when the World bike forum was held).

The survey is a rating scale. The aim of this survey is to achieve a Margin of Error of 5%, this is equal to 249 respondents for the main bicycle infrastructure (see Table 1 and Figure 5)

Margin of Error (+/-)	Rating Scale Sample Size	Binary (50%) Sample Size
1%	6073	9600
3%	686	1064
5%	249	381
10%	64	93
15%	30	39
20%	18	21

Table 1: Margin of error per sample size

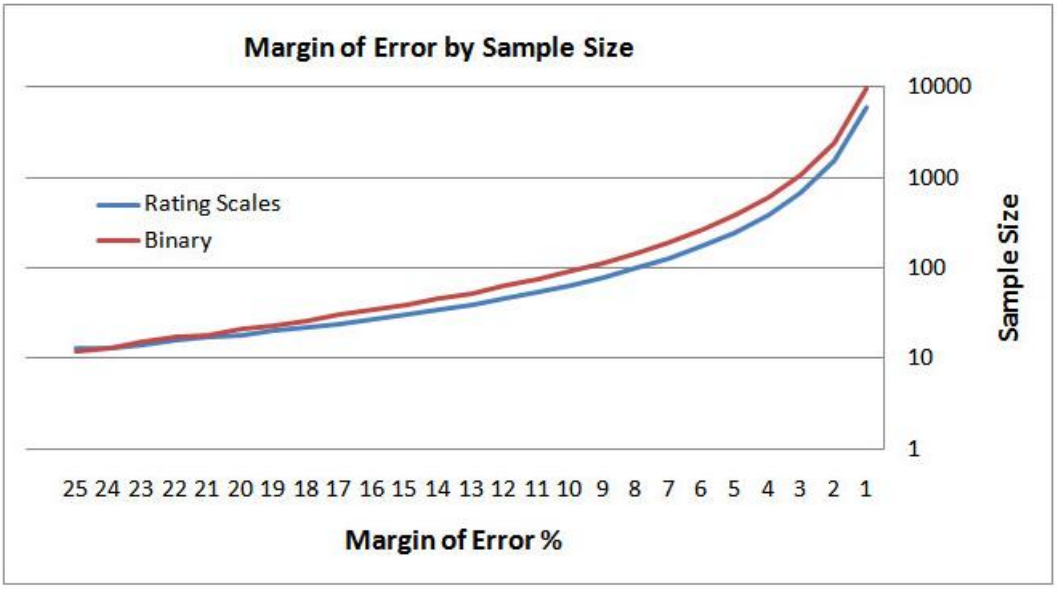

Figure 5: The margin of error per sample size

7.2 Design of the survey

The chosen design of the survey is simple. First the gender of the respondent is asked. Next the years of cycling experience is asked, this is the only open question in the survey. After this the evaluation of the road quality begins. The respondent is asked to evaluate the overall quality of the 35 bicycle paths the city has by giving a mark between 1 (bad quality) and 5 (good quality). The respondent received a list with all the bicycle paths that needed to be evaluated and per path, the respondent have to give a score. If the respondents do not know the path (good enough), he/she can, instead of giving a score, fill in: 'I do not know this route good enough'. To clarify the different roads the map with the bicycle infrastructure is added and each path is made distinguishable by a specific number. The final design of the survey is shown in Appendix 3. The survey is in Portuguese and starts with question 1, to define the gender of the respondent. In question 2, the years of cycle experience is asked. After that the map with the numbers of the paths is shown followed by the evaluation per bicycle per region.

A friend, who works for Ciclo Iguaçu told me he had the contact data of people who work at Ciclo Iguaçu and of the people who went to World Bicycle Forum III. This was the reason why the survey could be realized in this short time period.

7.3 Results of the survey

The total amount responses for the survey are 114. This was not enough to reach the Margin of Error of 5%. These results have a 10% Margin of Error. Besides the program that was used to spread the survey only allows seeing 100 respondents for free. So 100 responses have been used to calculate the average quality of the bicycle paths. The results per bicycle path can be found in the Appendix 2 in the last 'figure' of this appendix under the 'survey' column (page 44). The empirical results of the average quality per bicycle path are in the column 'empirical' to the right, bicycle path of the

	Survey	Empirical
Average	3.0	3.2
Maximum	3.8	4.0
Minimum	2.4	2.0
St. deviation	0.4	0.7
Variance	0.1	0.5

Table 2 shows only the average values. According to the survey none of the quality of the cities' bicycle paths is either very good or very bad. The low value of the standard deviation correspondents with this.

	Survey	Empirical
Average	3.0	3.2
Maximum	3.8	4.0
Minimum	2.4	2.0
St. deviation	0.4	0.7
Variance	0.1	0.5

Table 2: Average values of the survey results and the empirical results.

The percentage of the respondents that did not know a bicycle is useful to see how many people actually recognize and therefore, use a certain bicycle path. The results of this are visualized in ArcMap. The classification of the legend of this map is linear. If 0 – 20 % filled in: 'I do not know this bicycle path (good enough)', the bicycle path will achieve a usage score of one. From 20 – 40% the usage will be 2, etcetera. Figure 6 shows the usage per bicycle path. This map is not more than a simplified way of looking at the situation, because the trajectories that are asked to evaluate have different lengths. Therefore, the chance of recognizing a longer trajectory is bigger than chance of recognizing a short trajectory. The worst scoring bicycle paths are the short trajectories in the suburbs of the city. All the orange and red scoring paths are located outside the city centre.

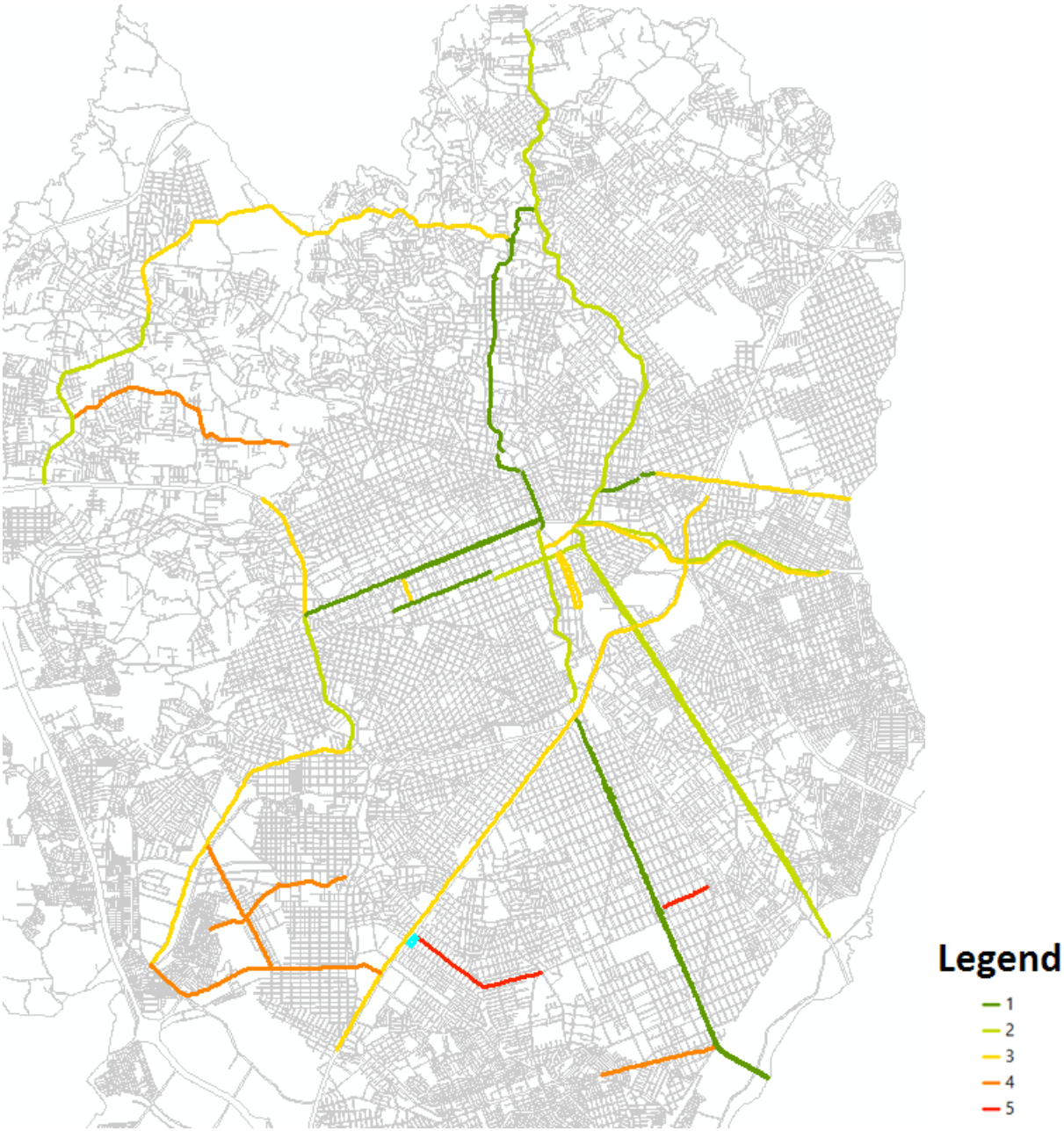

Figure 6: Usage of the bicycle paths

8. Qualitative results

8.1 Cycled routes

Some of the cycled routes will be elaborated below. This paragraph contains a short description of the data that is collected during the trips. I wanted to see this empirically to get a better picture of the bicycle infrastructure in Curitiba and how it works out. During the trips some pictures were made to clarify what cycling in Curitiba looks like. The numbers and the names of the streets of the bicycle paths can be found in Figure 4

Av. Mal. Floriano Peixoto: This connection between Curitiba and São Jose dos Pinhais has a BRT lane parallel to the route. Because of this, there is less space for individual motorized transport available (2 lanes per direction). There are two one-way bicycle paths, one for each direction. According to Appendix 1 this route should be a Ciclovia, but in practice this is a Ciclofaixa (Figure 9 and Figure 8). The width of the path was not the same the whole trajectory. About 30% of the route from the city centre towards São Jose dos Pinhais is the path narrowed down, see Figure 8. The signing on the trajectory is safe. The intersections have good paintings to let other road users know that they cross a bicycle path. For the cyclists it is clear what they are expected to do. Only at the two BRT terminals the route has, the signalization is insufficient. It was not clear how to get to the other side of the terminal and continue the trip. One safety problem that was noticed was in the first 500 meters of the route. The cyclist who wants to cycle to the city centre has to cycle against the traffic for this part (Figure 9). The two-way bicycle path lies next to a one-way general road. The overall quality of the path was good and there was almost no subsidence. This is because the bicycle path has the same hard subsoil as the general road. One part of the route is through a little forest and here were some bumps because of the tree roots and a few bumps along the trajectory, but nothing major. According to the survey and the empirical evaluation, the average quality score of this road is a 7.5

Figure 7: Ciclofaixa Av. Mal. Floriano Peixoto

Figure 8: Ciclofaixa Av. Mal. Floriano Peixoto

Av. Com Franco: See Figure 4. This is the other connection between Curitiba and São Jose dos Pinhais. This connection is more suitable for individual motorized transport than the av. Mal. Floriano Peixoto. This road has three lanes for each direction. Almost the whole trajectory is a Ciclovia, exept for the first 2 kilometres in the direction of the city centre of Curitiba which is a Passeio Compartilhado. The bicycle route is secluded of the general road. The width of the road and the signalization on the road is good and safe. However some of the intersections are not straightforward. For example Figure 9. The signalization is sufficient, but the location of the pedestrian and bicycle crossing does not make sense. There are more of these crossings on this trajectory. The paths have the facilities to be considered safe in case of accidents. However, the social safety is not guaranteed at every location. The brown area on the north side of the trajectory, Figure 4, is a slum. Part of the bicycle path is the limit of the slum. When it is dark it is not safe cycle there, even when the path is lighted. In both directions there were some major and minor obstacles (Figure 10, Figure 1012) especially the inhabitants of the slum have no space to park their car on their own property and live practically on the street. For instance a family used the part of the path for their barbecue, while they could it easily do it somewhere else. This example shows that the people in Brazil do not respect the cyclists like they do in the Netherlands. The overall condition of the pavement is sufficient, but the landscape is hilly along the whole trajectory. According to the survey and the empirical evaluation, the average quality score of this road is a 6.6.

Figure 9: Example of illogical painting at a crossing

Figure 10: Major obstacle

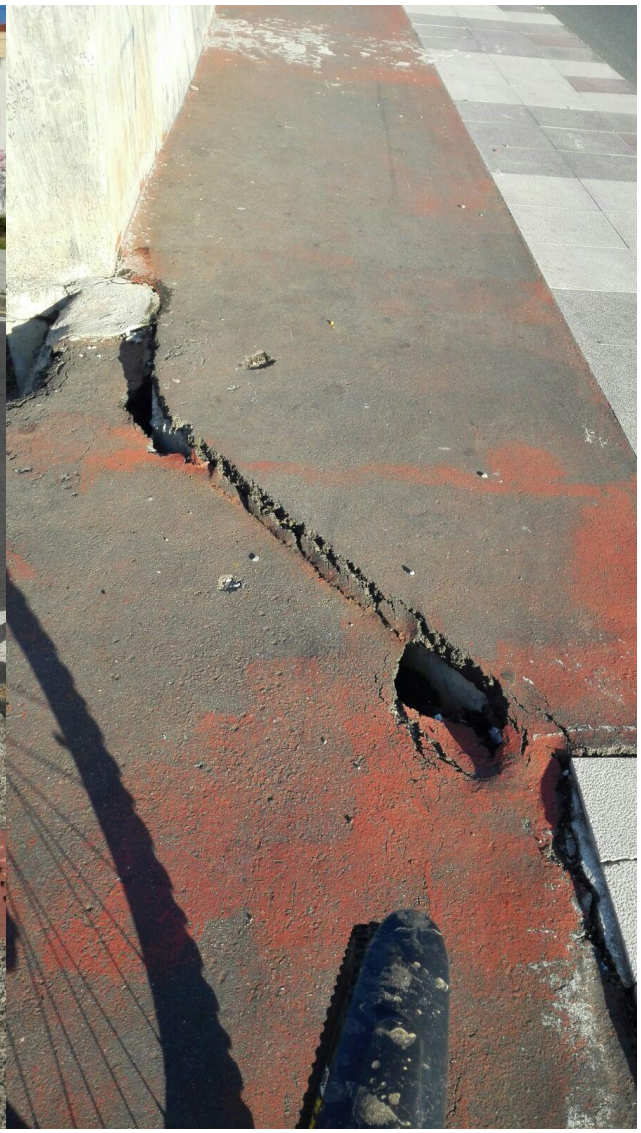

Figure 11: Example of bad engineering

In conclusion, the Av. Mal. Floriano Peixoto is on almost every front better than the Av. Com Franco. The straightforwardness on the Av. Mal. Floriano Peixoto is higher and there are no nearby obstacles. Another important advantage is the difference in declivity between the two trajectories. Nevertheless, the Av. Com Franco is a separate bicycle path, which gives a safer feeling.

The Av. Sete de Setembro is a Via Calma. Like the Av. Mal. Floriano Peixoto there is a BRT lane which divides the two directions of the road. There is one lane for individual motorized transport in each direction, which makes it a relatively calm road. Most of the traffic here is destination traffic. Transit traffic will take one of the parallel general roads, which are more suitable for high traffic flows. The width of the path on this trajectory is sufficient, except for two parts where a lack of space for the BRT-tube results in narrowing of the general road whereby the traffic has to use part of the Via Calma (Figure 12). The

signalization of this Via Calma is sufficient, but can be improved. Not all intersections do have bicycle crossing lines, but these ones have traffic lights to regulate the traffic. All the intersections without traffic lights do have sufficient signalization. The maximum speed for individual motorized vehicles is 30 km/h; this is another reason why this road has less traffic. On the parallel general road the maximum speed is 60 km/h. This gives the cyclist a safer feeling and the other safety factors are also fulfilled. This trajectory has no significant obstacles. However the where some 'temporary' obstacles, for example cars that cross the Via Calma when they have to park or leave their private property. There is some declivity. To the west, the route is uphill. According to the survey and the empirical evaluation, the average quality of this road is a 7.8.

Figure 12: Narrow general road

The Passeio publico to parque São Lourenço bicycle path connects the city centre with parque São Lourenço. This two-way bicycle path is located along a small river. There are no general roads nearby. Many trees and a river make it a beautiful path, so there is also much leisure traffic, especially in the weekends. The whole bicycle path is a ciclovia, except two sections that are shared with pedestrians. The path got a new surface about a year ago, but bad calculations have led to some complications. The river bank on the side of the bicycle path has partly collapsed. A reason could be too little counter pressure due to the low water levels and the extra weight of the new surface. The consequences of this are cracks in the road (Figure 15 and Figure 16). On the pictures can be seen that the cracks are big enough to get stuck. Approximately 1 kilometre north there is a tree partly hanging over the bicycle path. Especially when it is dark or twilight, this is hard to see and a collision may result in hazardous injuries (Figure 14). According to the survey and the empirical evaluation, the average quality of this road is a 7.1.

Figure 14: Cracks in the path

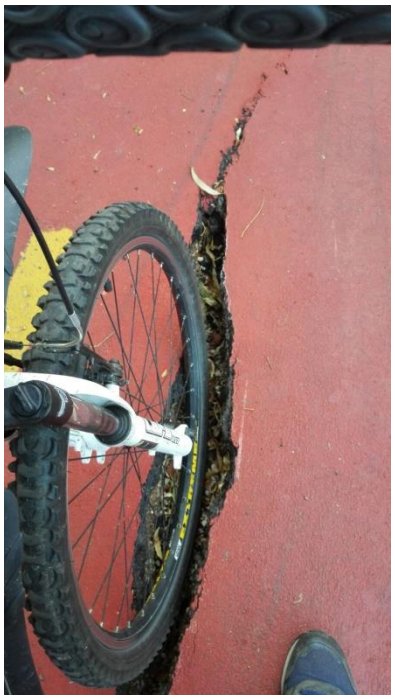

Figure 15: Crack in the path

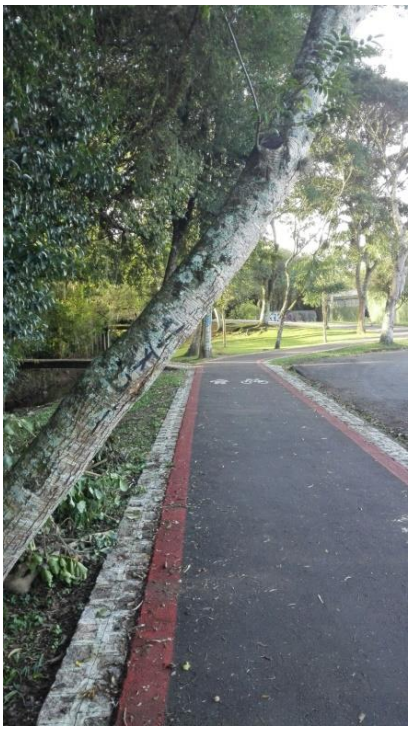

Figure 13: Tree hanging above bicycle path

9. Quantitative results

9.1 Available ArcMap data

For this research the ArcMap models were important. Below is the map shown that contains useful data that is available in ArcMap (Figure 16). The black lines are the current bicycle paths and the red dots are places where you can stall your bike safely (IPPUC, 2016).

For the analysation of the accessibility of the bicycle paths, population and income, data of the neighbourhoods is needed. This data is available through ArcMap; Figure 21 and Figure 22 show the data of the income and the population density per square kilometre. (IPPUC, 2016)

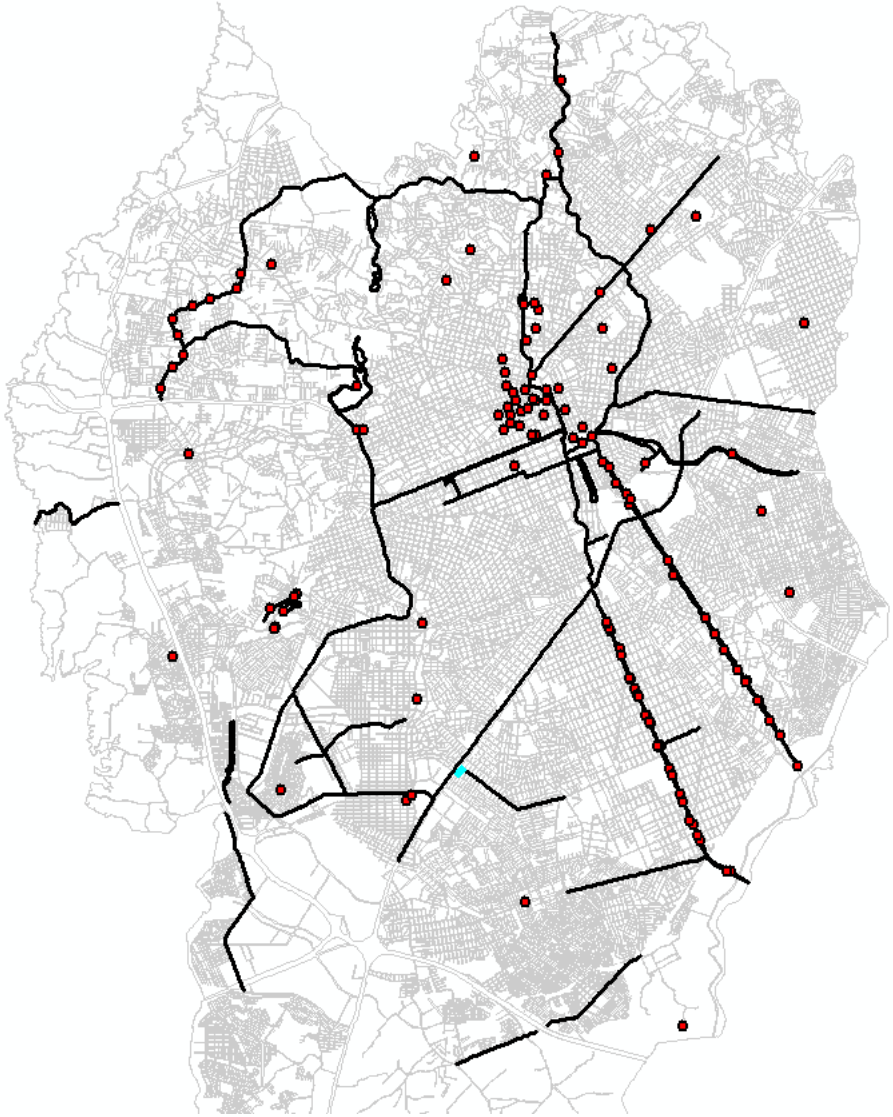

Figure 16: Bicycle paths and paraciclos

9.2 Calculations in Excel

The results and score of each bicycle route are stored and marked in excel. Four main subjects have been analysed. The existence of obstacles on the surface, the existence of sufficient painting at the intersections, the surface marks of each of the routes and the percentage of the route that is shared with pedestrians. These main subjects are divided into parts. The table below (Table 3) shows how the different subjects, their subdivided parts (criteria). The table also tells how the weight is divided.

Subject	Weight (%)	part of subject (criterion)	weight
Obstacles	25	No clear sign.	40
		Major obstacle.	20
		Minor obstacle.	10
		Temporary obstacle.	10
		Bad segment.	30
Intersection painting	10	No painting.	80
		Needs repaint.	20
General quality of the surface	50	Results of the survey.	50
		Empirical results.	50
Percentage of the road that is shared with pedestrians	15		
Total	**100**		

Table 3: Criteria and their weight

The scores per criterion of the obstacles and the intersection painting are calculated with the formulas shown below. The upper formula is used first.

$$Score\ per\ criterion = \frac{(count\ per\ criterion * weigth\ of\ criterion)}{Length\ of\ the\ route}$$

$$Score\ per\ subject = 10 - \frac{Sum(criterion)}{Max\big(sum(criteria)\big)} * 10$$

$$Score\ per\ bicycle\ route = sum(score\ per\ subject * weigth\ per\ subject)$$

The count of the criterion is the number of times this criterion occurs in the bicycle route. For example how many major obstacles were counted on that segment. The score per subject is relative. The tables with all the values that are used for these calculations can be found in Appendix 2.

The general quality of the road is calculated with the empirical and the survey results that is given to the segment. In both the survey and the empirical evaluation, the bicycle road is marked between a ‘one’ (bad quality) and a ‘five’ (good quality). These two score are added together for the final score. The lowest possible score for the general quality of the road is a ‘two’ and the highest possible score is a ‘ten’.

The last subject that is evaluated is the ‘percentage of the road that is shared with pedestrians’. This is performed with the ‘distance measure’ tool of google maps.

9.3 Sensitivity analysis

A sensitivity analysis is a study of how uncertainties in the results can be derived from input variables (Saltelli, 2002). The sensitivity analysis is done to validate the chosen percentages for the four subjects. The percentages have been changed and this lead into other results. These results were analysed and validated. If the new results show deviating values, the calculations were checked once more. This could have led to new conclusions and changes for the original chosen values. This sensitivity analysis has four scenarios. See Table 4

	Original (%)	S1 (%)	S2 (%)	S3 (%)	S4 (%)
Score on the amount of obstacles	25	20	35	25	15
Existence of painting at the intersections	10	20	10	0	10
General score of the quality of the pavement	50	50	40	60	50
Percentage of road shared with pedestrians	15	10	15	15	25

Table 4: values for the sensitivity analysis

Scenario 1: This scenario is the weight of the score for road paintings at intersections doubled, from 10 to 20 percent. The roads with bad intersection paintings score lower because of this change. The 10 percent is subtracted from the 'obstacles' and the 'shared with pedestrians' subjects (both 5 percent)

Scenario 2: In this scenario the weight of the obstacles is increased with 10 percent to 35 percent. The 10 percent is subtracted from the general quality of the road. The reason is to see whether the score of the obstacles and the score of the general quality of the surface have similarities or not.

Scenario 3: In this scenario is more focused on the general quality of the road. The subject 'existence of painting at the intersections' is not taken into account and the General score for the surface quality has the highest weight, 60 percent.

Scenario 4: This scenario has more or less the same support as scenario 2. However here the last subject, 'percentage of road shared with pedestrians' is increased with 10 percent. Pedestrians are considered as (moving) obstacles.

The result per bicycle paths can be found in Appendix 2, in the last of the three figures of the tables (page 44), under the column; 'sensitivity analysis'. The average results of the sensitivity analysis are shown in Table 5. The maximum change of the average score is a 0.2 increase and decrease. The maximum and minimum scores of the other scenarios shows no exceptional high or low values. The same can be said about the highest score decrease and increase per road. The maximum values for this are respectively 0.7 and 0.8. The conclusion after evaluating the average values is that the values are not very sensitive to change, which

	Normal	S1	S2	S3	S4
Average score	6,1	6,3	6,1	6	5,9
Maximum score	8,6	8,6	**8,9**	8,4	**8,9**
Minimum score	2,9	2,8	**2,4**	3,2	**2,4**
Highest score decrease		0,5	0,5	0,5	**0,7**
Highest score increase		**0,8**	0,5	0,6	0,4

Table 5: Results of the sensitivity analysis

10. Visualization of road quality and the classification

The program ArcMap will be used to visualize the gathered data into clear map which shows the quality of the analysed bicycle paths.

The buffer tool in ArcMap creates a polygon around a point or a line, with a specified distance to that point of line. With this tool can be seen what part of the city is covered when the created buffer is, for example, 200 metres and what kinds of people live in that areas. The buffer tool will be used as well for analysing the bicycles storage facilities as well.

The bicycle infrastructure data in ArcMap is already digitalized. Per bicycle route the data is digitalized in excel. The different kinds of gathered data will be multiplied with a certain factor to make a distinction in the different weights of each factor. After this, a total score per bicycle route is calculated. The score per bicycle path can be seen in Appendix 2 'final score'. The calculate value has been imported into ArcMap and have been added to the attribute table. This was done with the ´add data´ tool in ArcMap. The Excel file has to be connected to a mutual folder inside the program. After the data was added to the program it was joined with the attribute table of the Ciclovias (This data of the Ciclovias was already available). To join the Excel data with the attribute table of the Ciclovias one mutual value or word has to be in both tables. To achieve this, the names of the streets in the attribute table of the Ciclovias were copied and put together with the corresponding streets in the Excel table. After this, the join was made between the two tables and the calculated values. ArcMap has given the values a corresponding colour, green for the high scores, orange for the medium scores and red for the bad scores. The value 'one' and 'ten' have been added to the table as well for the normalization of the results.

10.1 Natural breaks (Jenks) classification method

The Jenks optimization method or Jenks natural breaks classification method is used to cluster data in the best arrangement of values into different classes. To do this, the minimum class' average deviation from the class mean is sought. George Jenks developed this method and his goal was to create a map which has the highest level of accuracy in the classification of the data's spatial attributes (The data model concept in statistical mapping, 1967). This method was first shown ArcMap, when the results had to be classified. First, the linear scale was used to visualize the calculated values, but this method did not give a sufficient result, because if there occurs a very low value, all the other values became relatively high. This gave a distorted image of the reality. The Jenks optimization method shows at a single glace which values are good and bad. Another asset of this method is that it anticipates on the data, every classification is created to display the optimum balance between the values and therefore, every classification is different.

10.2 ArcMap final result

The map below contains the analysed bicycle infrastructure in the city and their marks. This is not all the bicycle infrastructure of the city. The numeric score per bicycle paths can be found on page 44 (Appendix 2) in the column 'final score'. The highest score is a 8.6 for the R. Iapo and the lowest score is a 2.9 for the Rua Omar Raymundo Picheth. The reasons for these score are explained in the next chapters.

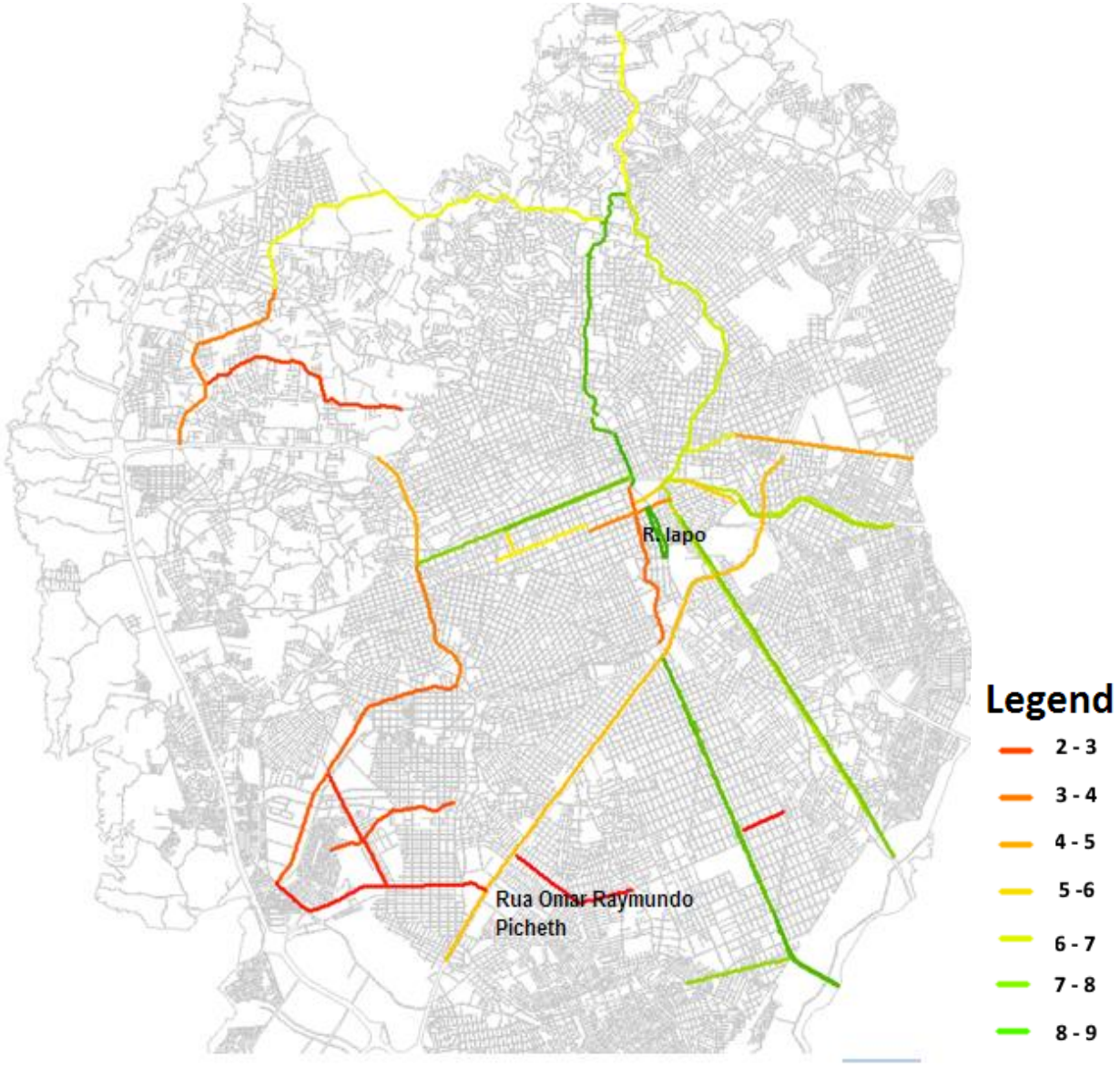

Figure 17: Final score per bicycle path

10.3 Relative scores of the obstacles per kilometer

The map below shows the relative scores of the obstacles per kilometre of bicycle path. The legend legend has a colour scheme according to the natural break (jenks) classification. The lowest possible score (0) is given to the bicycle path that is located along two streets: Rua Omar Raymundo Picheth and Waldemar Lodeiro Campos (

Figure 18). The reason for this low score is because there are a lot of major and minor obstacles. The four major obstacles on this road are poles within the path and the thirteen minor obstacles are mostly small bumps due to difference in elevation at the intersections. This can be improved to place ramps at these points. The highest possible score (10) is given to the bicycle path that is located along the Rua Iapó (

Figure 18). This path has no obstacles.

Notable is that almost all the bicycle paths in the west of the city score below average. These paths are old, but the biggest influencing factor on this low score is the high number of small obstacles. The intersections lack ramps for a smooth ride and have curb instead. If these curbs will be changed for ramps the score will increase significantly. The scores of all the bicycle paths can be found in Appendix 2 on page 45.

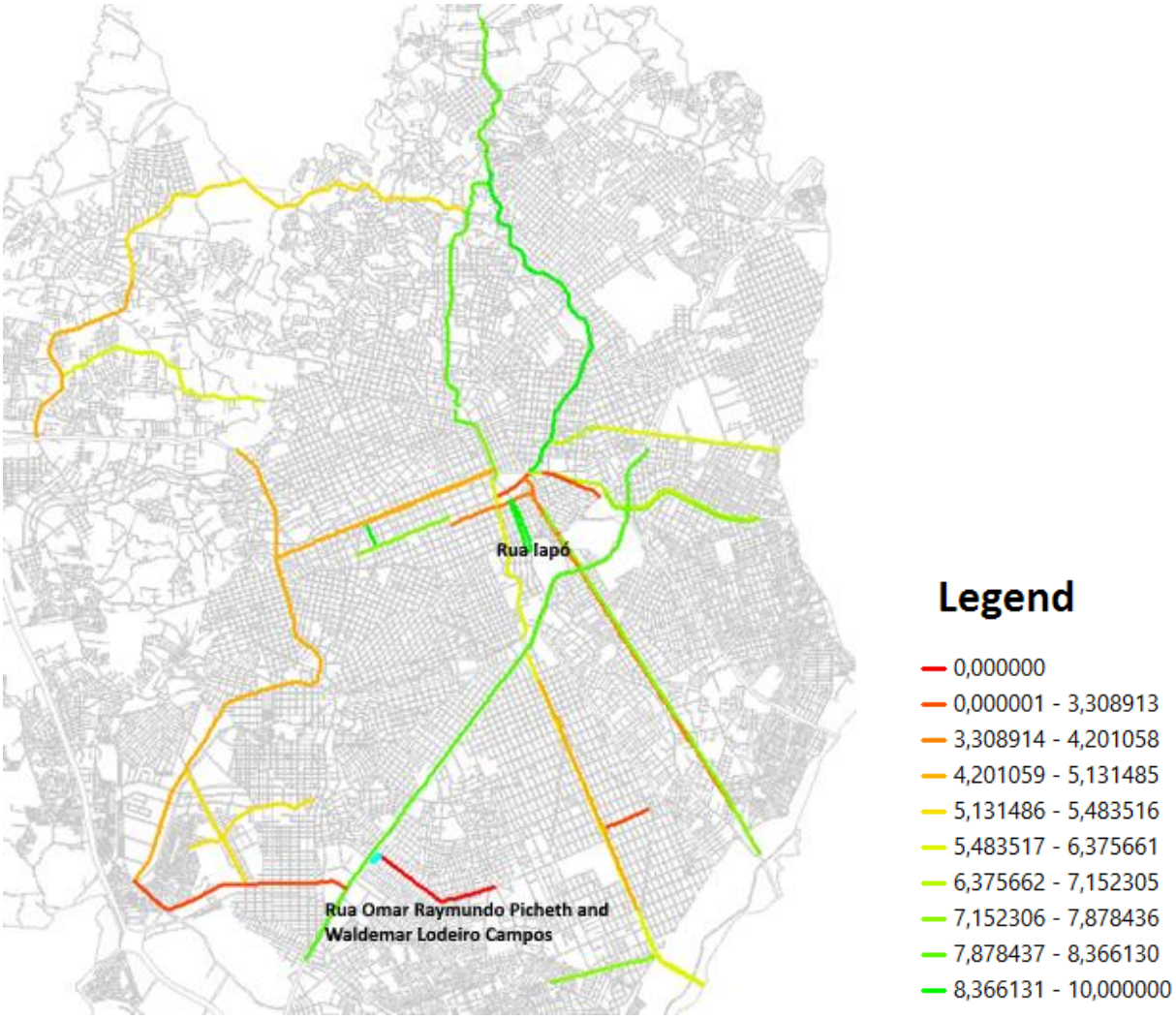

Figure 18: Relative score of the obstacles

10.4 Relative score of painting at intersections per kilometre

The map below shows the relative scores of the existence obstacles per kilometre of bicycle path. The legend has a colour scheme according to the natural break (jenks) classification. The Rua Napoleão Laureano, scored the lowest (0) and Rua Doutor Alexandre Gutierrez scored low as well (0.21). These are short paths, respectively 0.891 and 0.455 kilometres. None of the intersections on these roads have any paintings. Four paths have the highest possible score. The Rua Wilson Dacheux Pereira, the ciclofaixa next to the Rua Iapó and Rua Imaculada Conceição, the ciclovia next to the Rua Mariano Torres and the ciclovia between parque São Lourenço and Passeio Publico. The scores of all the bicycle paths can be found in Appendix 2 on page 46.

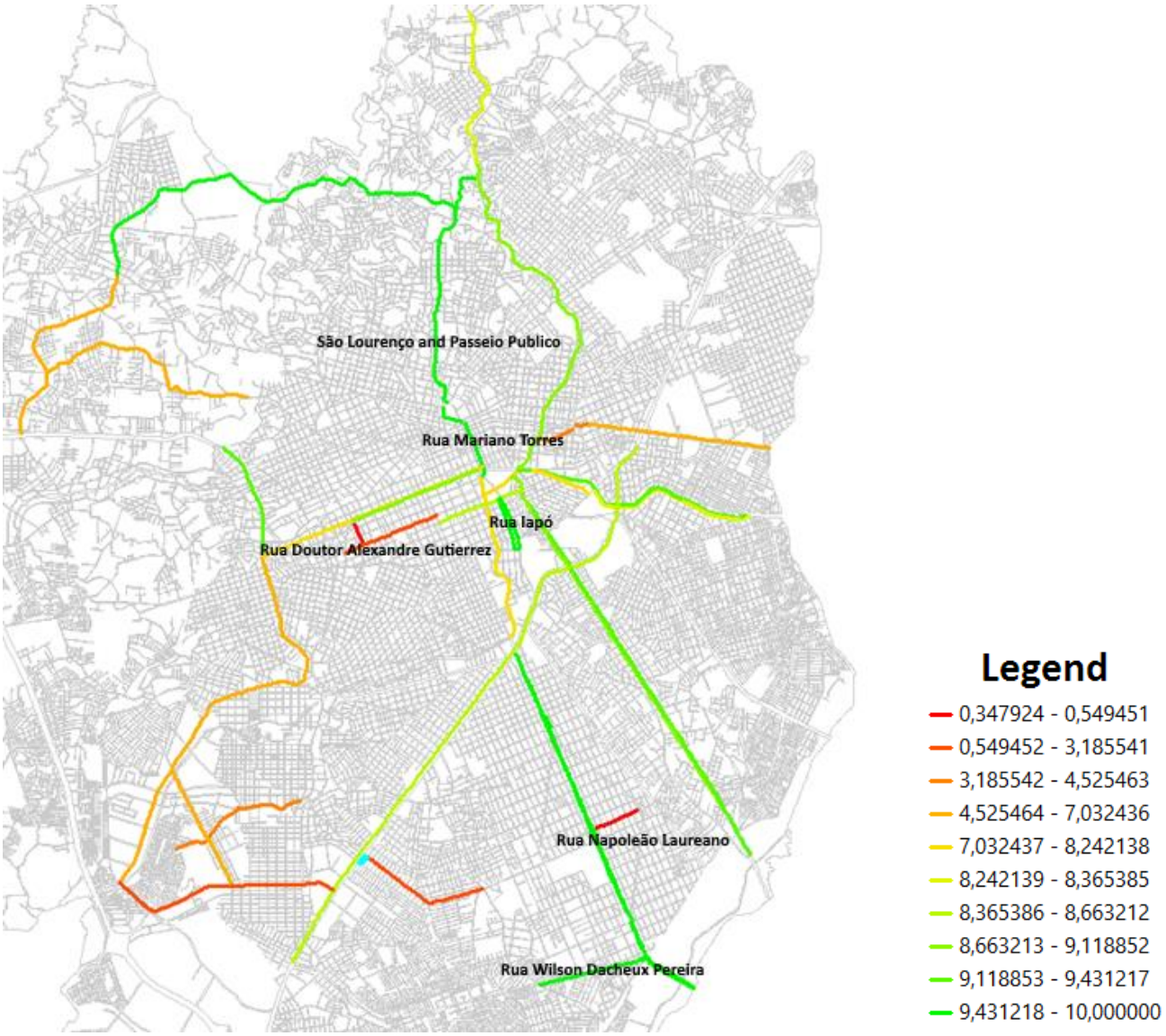

Figure 19: Intersection painting score

10,5 Score of the general road quality according to the survey and empirical observations

This criterion has the heaviest weight factor in the calculation. The results as shown below (Figure 20). The lowest score (4) was given to the Linha Verde, this path is located next to a busy road. This Ciclovia looks neglected and even though the length of this path (9.65 kilometres), the whole route needs to be improved to achieve a sufficient mark. Another low scoring path (4.44) is the Av. Das Indústrias. This bicycle path is located in a deserted area in the south west of the city. The path has lots of poles in the middle of the path. The path is narrow as well, this makes it hard to dodge the poles and keep cycling on the path itself. The two best scoring path are the Av Sete de Setembro (7.76) and the Av. Mal Floriano Peixoto (7.51). Both of these bicycle paths are Ciclofaixas, this is no coincidence, because Ciclofaixas are built on the same hard soil as general roads, this is a comfortable surface for cycling. The scores of all the bicycle paths can be found in Appendix 2 on page 46.

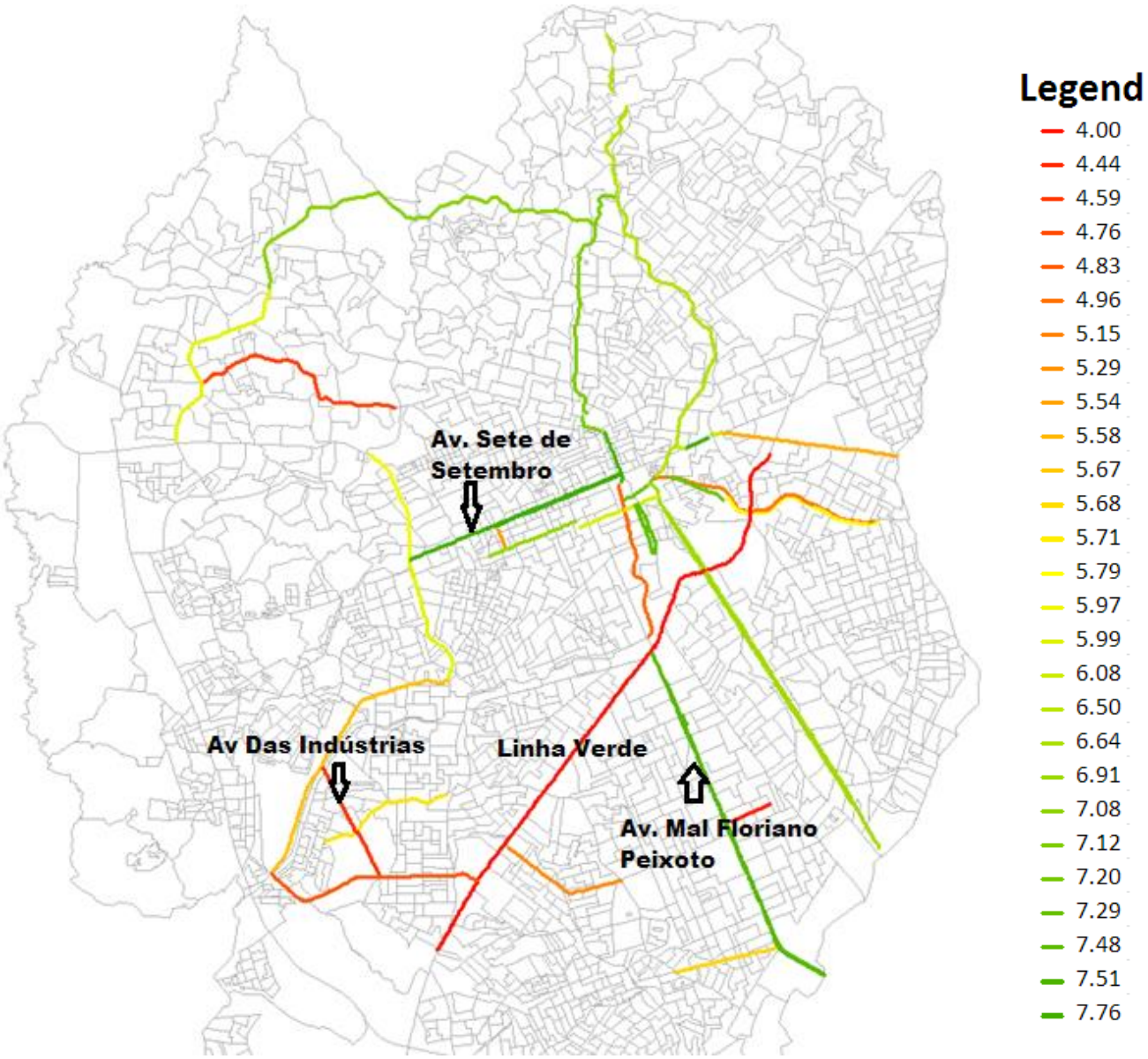

Figure 20: Pavement quality

10.6 Income and population density data

The entire bicycle infrastructure with a 200m buffer is shown below. The map also shows the income in Reais per capita.

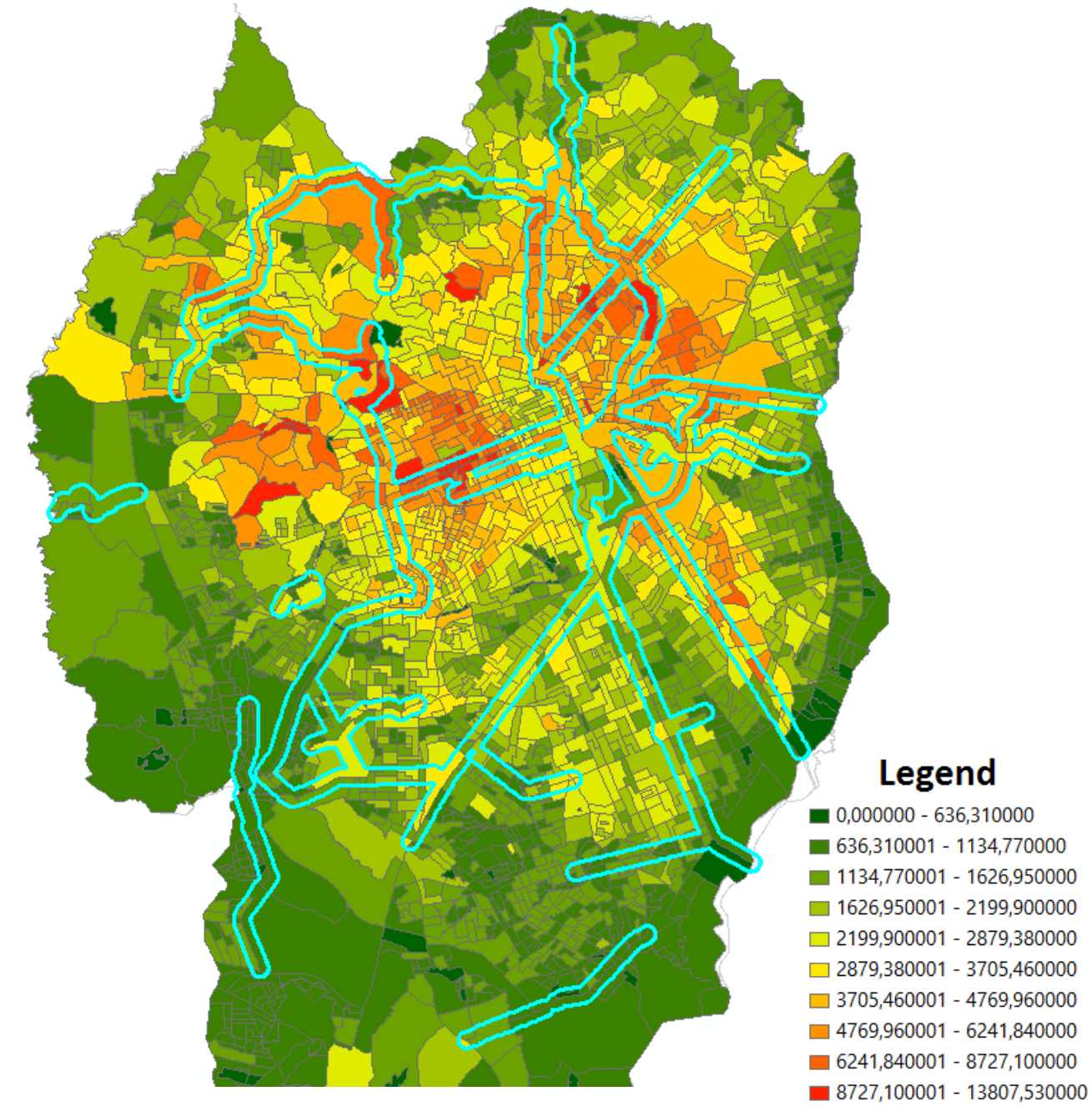

Figure 21: Income and buffer area

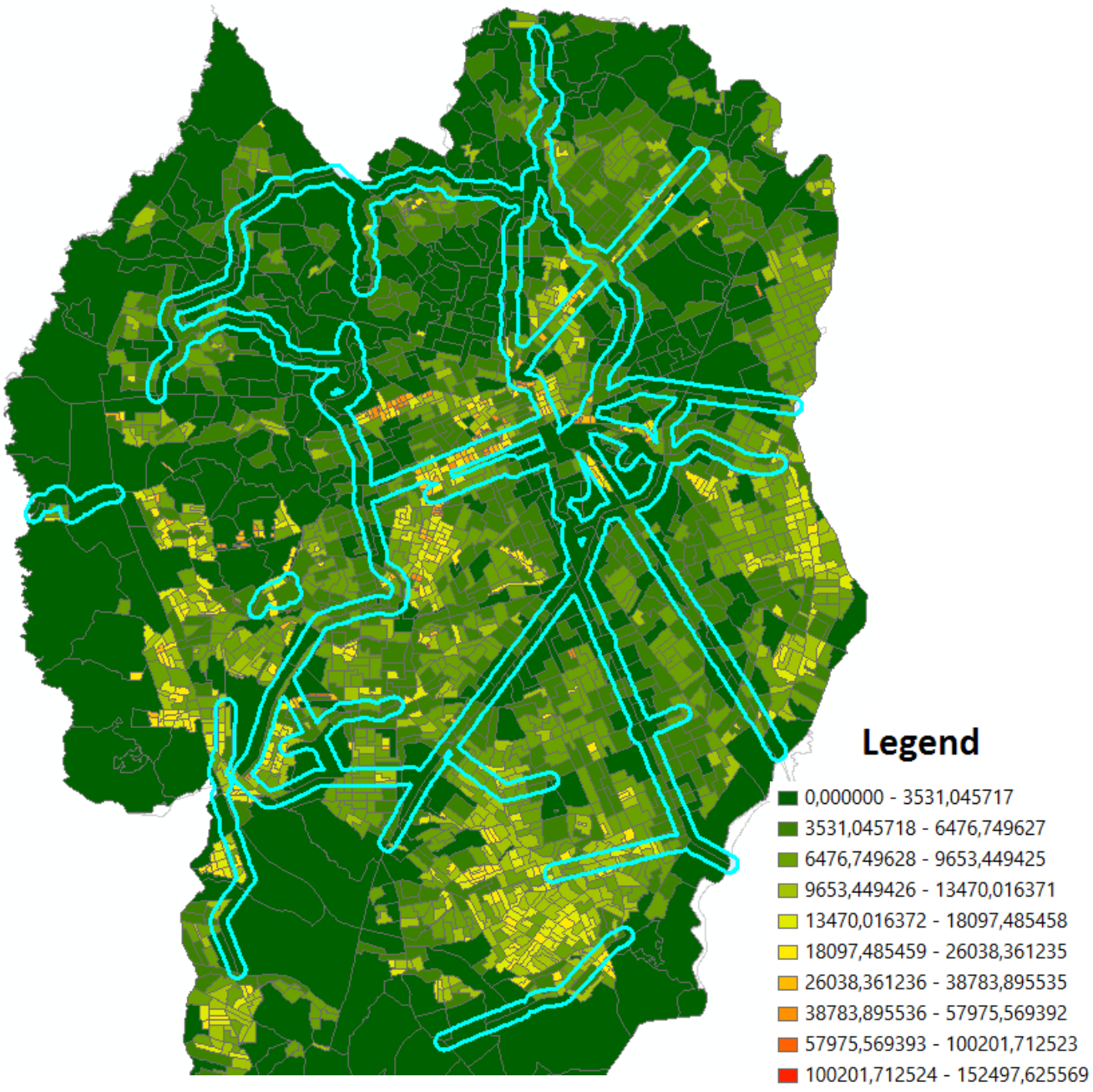

Figure 22: Population density and buffer area

10.7 Conclusions after comparing the data of the whole city with the data of the buffer area

In total 578533 inhabitants have access to a bicycle routes within 200 metres, which is (578533/1751907)*100 = 33% of the total inhabitants. In comparison to the area the buffer covers, this is a high percentage. The buffer area covers 13.6 percent of the city. Curitiba, especially the city centre and the area heading west and north from the city centre, have some high dense corridors. These areas have high buildings. See orange and red areas in Figure 22 and Figure 23. Most of these buildings are residential.

Figure 23: Example of corridor in the city

The population density of the whole city is 10465 people/km^2. The population density within the buffer is a little lower: 9704 people/ km^2. Although some of the ciclovia's are located in the higher dense parts of the city the average decreases because of the parks, which normally have no residential buildings within the buffer area.

The difference in Renda (income in reais) is rather big. The average income in the city is RS 2258 and the average income in the buffer area is RS 2766, which is 22% more. A possible reason for this is the higher number of wealthier people in the high dense areas in the city centre. The poorer inhabitants live in less dense areas outside the city centre, which has a higher population density.

11. Statistical analysis of the results

To validate whether the results from the buffer area and the whole city significantly differ, a statistical analysis of the data has to be done. A T-Test is a method that compares the means of two groups. The result of the T-Test is a value that shows the chance of a statistically significant difference between the means. It depends on the research what values are supposed as being sufficient. In most research a value 0.05 is used. This means that 95% of the times the means have a significant statistical difference (Trochim, 2006). In this report, the T-Test is used to compare the outcomes of the data within the buffer area of the bicycle paths and the data of the whole city. It is also being used to compare the empirical data with the results of the survey.

The T-Test value is calculated in Excel. So the data of the attribute table in ArcMap has to be imported into Excel first using the 'Table to Excel' tool. Before it is possible to calculate the T-Test value in Excel, some other values have to be known. First the two data sets that will be compared have to be selected and then there has to be made distinction in how many sides, one or two. In this case all the tests have two sides, which mean that it is possible that the deviation of the value can move into either direction. Furthermore the relation between the two rows of number needs to be determined. The income- and population density's tables have a heteroscedastic relation, because the random variables in the data set have the same variance. The relation between the survey and the empirical results is paired, because the values of these two rows are linked to each other. For example number 20 on the survey is a mark on the same bicycle path as number 20 on the empirical evaluation.

The first statistical analysis is applied on the data of the income in the buffer area and in the whole city. The averages differ circa R$ 500, which is equal to €120. The T-Test result is (far) below the 0.05 percent. In this case the probability of significant statistical difference is almost 100% and therefore, the conclusion can be: The people who live within 200 metres of any bicycle infrastructure are wealthier than the average inhabitant of Curitiba.

	Income buffer area	**Income whole city**
Count	805	2395
Average	2766,15	2258,20
St. Deviation	1984,08	1707,05
Sides	2	
Relation	heteroscedastic	
T-Test result	1,2E-10	
Accept	NO	

Table 6: T-Test on income in Reais per person

Results of the population density show no significant statistical difference.

	Population density buffer area	**Population density in whole city**
Count	805	2395
Average	9703,67	10465,43
St. Deviation	12168,82	12143,88
Sides	2	

Relation	heteroscedastic	
T-Test result	0,12	
Accept	YES	

Table 7: T-Test on the population density

Results of the survey and the empirical evaluation show no significant statistical difference either.

	Survey	**Empirical**
Count	35	36
Average	3,04	3,21
St. Deviation	0,34	0,70
Sides	2	
Relation	Paired	
T-Test result	0,11	
Accept	YES	

Table 8: T-Test survey score and empirical score

12. Bicycle parking facilities

The map below shows the bicycle infrastructure and the parking facilities for bicycles. These so called 'paraciclos' are bended red steel bars (Figure 24). The green checkmarks are parking facilities within 30 meters of a bicycle path. The red checkmarks are, obviously, located more than 30 meters away from any bicycle path. In total the city has 125 parking facilities, 66 of those are within the buffer. This is 53%.

In the most crowded part of the city, the city centre, are only a few green checkmarks and a lot of red ones. Along the two routes in the centre bordering the city, only three parking facilities are within the buffer area. The city has no signs for the parking facilities. Because of this, it is hard to find the facilities which are not directly located next to a bicycle path. Unlike in the Netherlands, where there exist no problem of finding a good and safe place to stall your bicycle, here in Curitiba, beforehand a plan has to be made how and where the bicycle will be parked when arriving at the destination.

There is no data about the locations of the places where many people congregate, like shopping malls, cinemas and congress halls. As a result, no buffer analysis on these locations in regards to the location of the bicycle parking facilities could be done.

The two main bicycle paths that connect the city centre with São José dos Pinhais (in the south-east of the city) do have a fair share in the total number of bicycle parking facilities. Av. Mal. Floriano Peixoto has a BRT lane in between the two road directions. The parking facilities are located next to the bus stations with the goal that people cycle to the bus station and continue their trip by bus. The other bicycle path, the Av. Com. Franco has some parking facilities close next to some of the bus stations as well.

Figure 24: Paraciclo in the city centre

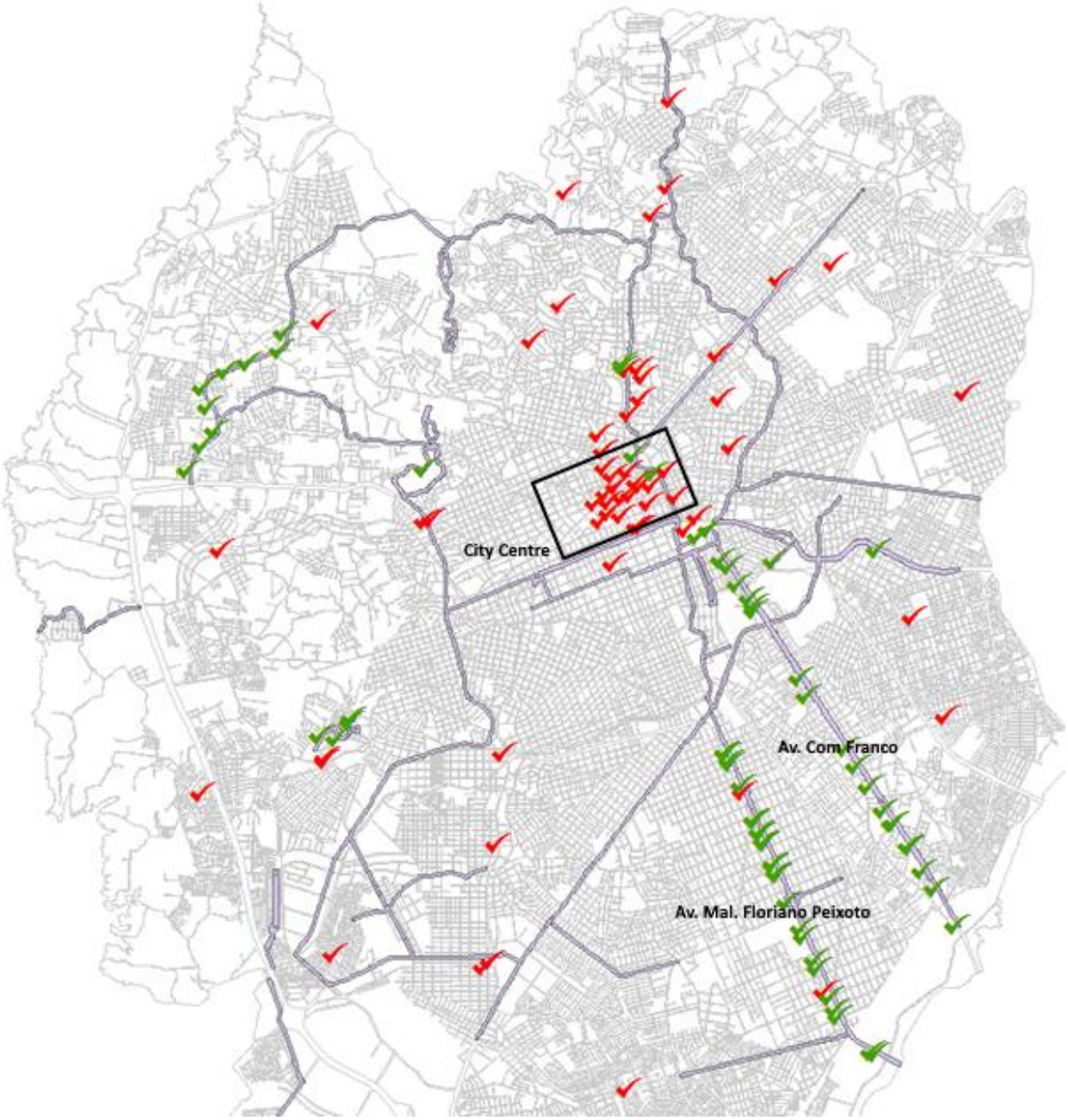

Figure 25: Paraciclos inside and outside the buffer area

13. Conclusions

Each research question has results. The conclusions followed out of these results are described below.

Research question 1: How bicycle friendly are the bicycle routes in Curitiba?
Figure 17 shows the final score per bicycle path and it is obvious that there are big quality differences within the city. Because of this, a general conclusion about the quality can be misleading for inhabitants. People who live in the north and south of the city, close to a bicycle path and inhabitants who live along the Av. Sete de Setembro, have access to good paths and are more likely to argue that Curitiba is a rather bicycle friendly city. However people who live in the western part and especially the southwestern part of the city have no close access to high scoring bicycle paths. They are more likely to argue that Curitiba is not a bicycle friendly city.

Most of the new bicycle infrastructure is built on former sidewalks. This results into obstacles (poles, holes and bumps) on the bicycle paths. This is seen on the Ciclovia's and the Passaeio Compartihado's. Bicycle paths that have been built on former general roads, like the Ciclofaixa does not have this problem. Also the quality of the surface is better, because these were initially made for cars and therefore have a harder soil. These combinations of circumstances result in the high score for the Ciclofaixa´s on the aspect of quality.

The average quality level of the bicycle paths in Curitiba has plenty of space to rise. When the quality is compared to the bicycle paths in the Netherlands, it is clearly insufficient. However it is not realistic to assess like this, because compared to the bicycle experience of the Netherlands, Curitiba is just a child.

Research question 2: How much inhabitants of Curitiba have access to the bicycle network and what is their position in the society?

A total of 33% percent of the inhabitants of Curitiba have access to a bicycle path within the 200 meters buffer area of their home. Most of these people live in or close to the city centre in the dense areas. The average income of inhabitants who live inside the buffer area is significantly higher than the average. The income of the people who live in the high dense earn more and have higher accessibility to the bicycle network.

Research question 3: What kinds of places have facilities to store bicycles and how are these facilities distributed throughout the city?

The plan for the city is to have 500 paraciclos (Coordenadoria de Mobilidade Urbana no Trânsito, 2014). However the source does not say anything about a time when this has to be realized. At the moment, the city has 125 paraciclos in total, see Figure 16 for the locations. There were some projects to build paraciclos next to the bus stations along the BRT lanes. There is no research and results about the number of users of these paraciclos, but my empirical samples showed that these are almost not used. This is not a scientific argument, but it makes sense, in a big city most things are relatively nearby and if you possess a bicycle it makes no sense to cycle to a bus. For the relation between the bicycle network and these paraciclos, see Figure 25. This figure shows that most of the paraciclos are located outside the buffer area, especially in the city centre.

After 10 weeks of working at SETRAN, cycling the bicycle paths of Curitiba and talking to various kinds of people with different perspectives. The last conclusion is not directly

followed from the research, but more a general conclusion about the possibilities and possible problems for this city in the future.

The temperate climate and flat surface gives Curitiba the potential to become one of the leading cycling cities in Latin America. However this is a process which could take decades and not mere years. The beginning of the process is promising, but the enthusiasm of the people could lead into rushed decisions and therefore inefficient results. The most important and clear examples of are already in the report (Figure 9, Figure 1010, Figure 15 and Figure 14) The bursts in a new bicycle road have been noticed in two places. This does not seem like a big problem, but it is not a coincidence that this has happened. The reason is simple: bad engineering calculations. These two examples show on little scale how sometimes the choices are made here, too rushed. These mistakes can be prevented easily if the time was taken to make the right calculations and in the case of the bursts next to the river (Figure 15), the maximum stress for the dike had to be calculated first. Instead of that, a new layer was applied above the old layer and the dike collapsed because of the higher stress level.

Another constraining factor to achieve this is that the culture has to change. At the moment the cyclists and the motorist are directly opposed to each other, which results in no mutual respect. The rules in Brazil are that the car has to wait for the cyclist at the painted crossings. In practice, this rarely happens. The cyclists, on the other side, do not respect the traffic lights. These conclusions are not directly connected to the research questions, but to achieve the goals that are set and keep this city growing, this has to change.

14. Discussion

Has the quality of the bicycle path influence on the number of users?

If the map with the average quality score and the map with the user score(Figure 6 and Figure 17) are compared is there any similarity between the quality score and the usage score. The maps show similarities in the colours, but as mentioned before, the map of the usage per bicycle paths has not a high credibility, because of the different lengths of the segments. Besides the length of the path, the location is an important parameter as well. If a bicycle path is located in an area with a high population density, the path is more likely to be used. When analysing the population density map, the usage map and the quality score map a certain pattern will stand out. The bicycle paths that score high on quality are used more and, in most cases, are located in high dense area in the city. How this pattern was emerged is hard to answer, it is a causality dilemma, so it could be approached from different angels.

The locations of the bicycle parking facilities regarding the location of the bicycle paths.

In September 2013 the aim was to install 500 so called 'paraciclos' or bicycle storage facilities. At the moment 125 are installed. Circa half of the paraciclos are located within 30 meters of a bicycle path. The other half is further away and can be considered as not or hard visible from a bicycle path. The usefulness of having bicycle storage facilities outside the buffer area is questionable. Especially the bicycle paths in and around the city centre lack storing facilities close by, only two next to a bicycle path. The other storage points in the city are very obvious. The cyclist has to know the spot to make sure he/she can store their bike safe.

15. Recommendations

The map with the final quality scores per bicycle path shows with paths are already good and the ones that need improvement. The score is not a direct classification of which paths should be improved first. Also important is who benefits from an improvement. A ratio between these two criteria has to be created. This investigation does not have enough data due to the time to give a sufficient scientific support, but some recommendations for what bicycle paths should be improved and the arguments will be given below.

In general the quality of the bicycle paths in the south-western part of the city has the lowest score. The usage of these paths has an average value. This south-west region of the city is the only region which has bicycle infrastructure, but none of these paths have been improved recently. Unlike this part, the other parts of the city have at least one good scoring path to connect the region with the city centre, as can be seen in the quality of the paths. My recommendation according to this would be to improve the paths next to the Rua João Bettega and Avenida Presidente Arthur da Silva Bernardes. These bicycle paths connect the south-west part with the city centre.

Another recommendation following from the discussion is that the paraciclo's and the bicycle paths should be connected more, especially in the city centre, where most of the human activity takes place. This can be achieved by constructing more bicycle paths or indicate the place where you can stall you bicycle. For example, the introduction of a little sign with directions and distances to the closest paraciclo.

The city has already planned to extent the bicycle network of the city. See the dotted lines on Appendix 1. To achieve an optimal score on the road quality on these new infrastructures I would recommend to construct these new paths directly next to the general road. In order to do this, the type of bicycle path has to be a Ciclofaixa or Via Calma. Some of the general roads in Curitiba are set spacious so in these roads it will be easy to implement a Ciclofaixa or Via Calma on the side of these roads. The research on the quality of the bicycle infrastructure in Curitiba shows that these two types of bicycle paths have the highest scores.

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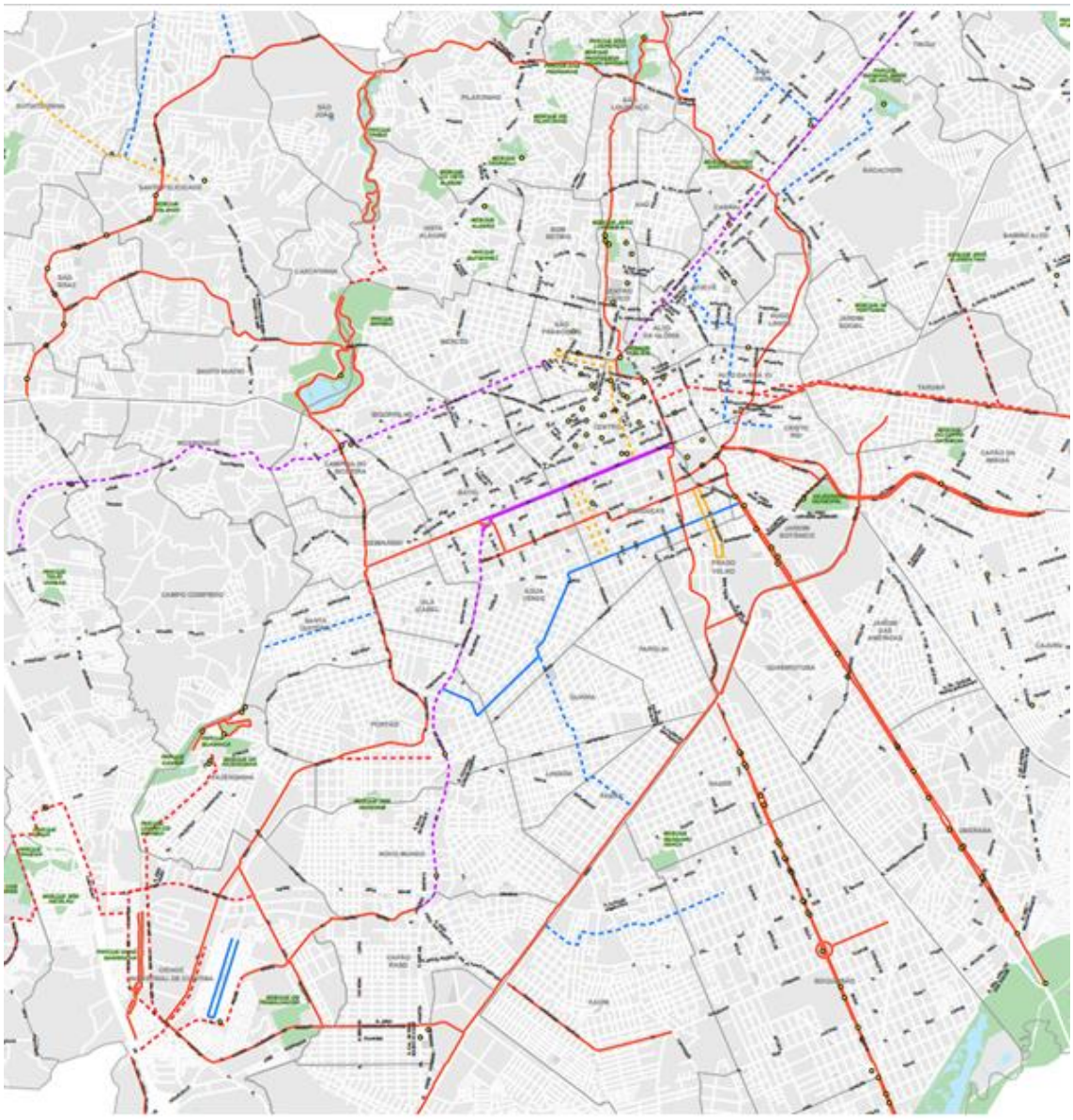
17. Appendices

Appendix 1



Appendix 1: Bicycle network of Curitiba

Appendix 2

												Obstacles	
Street	KM	no clear sign	40	major obs	20	minor obs.	10	Temporary	10	bad segment	30	score	
1: Av. Sete de Setembro (east to west)	5,3	1	7,5	2	7,55	13	24,5	0	0	0	0	39,6226	4,83019
1: Av. Sete de Setembro (west to east)	5,3	0	0	0	0	9	41,7	0	0	0	0	41,65	4,56543
2: Presidente Arthur da Silva Bernardes	2,41	0	0	1	8,3	7	29	0	0	0	0	37,3444	5,12745
4: R. Pedro Gusso	2,88	0	0	0	0	10	34,7	0	0	0	0	34,7222	5,46958
5: Av. das Industrias	2,6	1	15	0	0	1	3,85	1	4	1	12	34,6154	5,48352
6: R. João Rodrigues Pinheiro	4,68	1	8,5	3	12,8	7	15	1	2	2	13	51,2821	3,30891
9: Marginal Linha Verde áte UFPR	9,65	0	0	3	6,22	9	9,33	0	0	0	0	15,544	7,97187
10: Rua Omar Raymundo Picheth + Waldemar Lodeiro Campos	2,74		0	4	29,2	13	47,4		0		0	76,6423	0
11: Av. Mal. Floriano Peixoto (north - south)	6,7	2	12	3	8,96	5	7,46	1	1	0	0	29,8507	6,10519
11: Av. Mal. Floriano Peixoto (south - north)	6,7	3	18	2	5,97	9	13,4	0	0	0	0	37,31	5,13
12: R. Napoleão Laureano	0,891	0	0	0	0	5	56,1	0	0	0	0	56,1167	2,6781
13: R. WIlson Daecheux Pereira	3,28		0		0	6	18,3		0		0	18,2927	7,61324
14: Av. Com Franco (north-south)	8,01	1	5	11	27,5	8	9,99	3	4	0	0	46,1923	3,97301
14: Av. Com Franco (south - north)	8,01	0	0	3	7,49	8	9,99	0	0	0	0	17,4782	7,71952
17: R. Iapó + R. Imae. Conceição	1,83	0	0	0	0	0	0	0	0	0	0	0	10
19: R. Dr. Alexandre Gutierrrez	0,455	0	0	0	0	0	0	0	0	0	0	0	10
21: R. Engenheiro Rebouças	1,8	0	0	4	44,4	0	0	0	0	0	0	44,4444	4,20106
22: R. Conselheiro Laurindo	3,95	1	10	3	15,2	2	5,06	0	0	0	0	30,3797	6,03617
23: Av. Dr. Dario Lopes dos Santos	2,38	1	17	3	25,2	2	8,4	1	4	0	0	54,6218	2,87315
24: R. Mariano Torres	1,23	0	0	1	16,3	0	0	0	0	0	0	16,2602	7,87844
25: Av. Presidente Affonso Camargo	5,04	1	7,9	2	7,94	3	5,95	0	0	0	0	21,8254	7,15231
26: Av. Prefeito Maricío Fruet	3,35	1	12	0	0	2	5,97	0	0	0	0	17,9104	7,66311
27: Av. Sete de Setembro (parte oriental)	0,905	0	0	0	0	2	22,1	0	0	0	0	22,0994	7,11655
28: Av. Victor Ferreira do Amaral	2,88	1	14	1	6,94	2	6,94	0	0	0	0	27,7778	6,37566
29: Flavio Dallegrave - Trajeto ao Longo da ferrovia onder SL	7,32	0	0	0	0	6	8,2	0	0	0	0	8,19672	8,93052
29: Flavio Dallegrave - Trajeto ao Longo da ferrovia boven SL	3,86	0	0	3	5,37	2	7,2		0		0	12,52	8,37
30: Passeio Publico <---> São Lourenço	4,95	0	0	2	8,08	0	0	0	0	1	6	14,1414	8,15488
31: Av. Fredolin Wolf	7,9	1	5,1	8	20,3	2	2,53	0	0	2	8	35,443	5,37553
32: Av. Ver. Toaldo Tulio	5,56	2	14	5	18	12	21,6	0	0	0	0	53,9568	2,95992
33: R. Antônio Escorsin	4,83	1	8,3	0	0	9	18,6	1	2	0	0	28,9855	6,21808
34: R. General Mário Tourinho	2,5	1	16	1	8	4	16	0	0	0	0	40	4,78095
35: Av. João Gualberto / Av Paraná (north - south)	7,05	1	5,7	0	0	0	0	0	0	0	0	5,67376	9,25971
35: Av. João Gualberto / Av Paraná (south - north)	7,05	1	5,7	0	0	0	0	0	0	0	0	5,67376	9,25971

Appendix 2: Table with the excel calculations

						intersection paiting				Painting		Mark pavement		Pavement
Street	**KM**	**no bank(m**	**50**	**Against traffic (m)**	**50**	**No**	**80**	**Repaint**	**20**			**Survey**	**Empirical**	**score**
1: Av. Sete de Setembro (east to west)	5,3	**0**	0	**0**	0	**4**	60,4	**0**	0	**60,37736**	**8,9**	3,758242	4	**7,8**
1: Av. Sete de Setembro (west to east)	5,3	**0**	0	**0**	0	**4**	60,4	**10**	37,736	**98,11**	**8,2**	3,76	4	**7,8**
2: Presidente Arthur da Silva Bernardes	2,41	**0**	0	**0**	0	**7**	232	**0**	0	**232,3651**	**5,7**	2,969231	3	**6,0**
4: R. Pedro Gusso	2,88	**0**	0	**0**	0	**11**	306	**0**	0	**305,5556**	**4,3**	2,676471	3	**5,7**
5: Av. das Industrias	2,6	**0**	0	**0**	0	**8**	246	**0**	0	**246,1538**	**5,4**	2,59375	2	**4,6**
6: R. João Rodrigues Pinheiro	4,68	**0**	0	**0**	0	**22**	376	**1**	4,2735	**380,3419**	**2,9**	2,833333	2	**4,8**
9: Marginal Linha Verde áte UFPR	9,65	**0**	0	**0**	0	**9**	74,6	**0**	0	**74,6114**	**8,6**		4	**4,0**
10: Rua Omar Raymundo Picheth + Waldemar Lodeiro Campos	2,74		0		0	**14**	409		0	**408,7591**	**2,4**	2,777778	2,5	**5,3**
11: Av. Mal. Floriano Peixoto (north - south)	6,7	**0**	0	**0**	0	**0**	0	**1**	2,9851	**2,985075**	**9,9**	3,475	4	**7,5**
11: Av. Mal. Floriano Peixoto (south - north)	6,7	**0**	0	**500**	557	**0**	0,00	**2**	5,97	**5,97**	**9,9**	3,48	4,00	**7,5**
12: R. Napoleão Laureano	0,891	**0**	0	**0**	0	**6**	539	**0**	0	**538,7205**	**0,0**	2,444444	2	**4,4**
13: R. WIlson Daecheux Pereira	3,28		0		0		0		0	**0**	**10,0**	2,666667	3	**5,7**
14: Av. Com Franco (north-south)	8,01	**200**	156	**0**	0	**5**	49,9	**2**	4,9938	**54,93134**	**9,0**	3,140845	3,5	**6,6**
14: Av. Com Franco (south - north)	8,01	**0**	0	**0**	0	**4**	40	**1**	2,4969	**42,44694**	**9,2**	3,140845	3,5	**6,6**
17: R. Iapó + R. Imae. Conceição	1,83	**0**	0	**0**	0	**0**	0	**0**	0	**0**	**10,0**	3,292683	4	**7,3**
19: R. Dr. Alexandre Gutierrrez	0,455	**0**	0	**0**	0	**3**	527	**0**	0	**527,4725**	**0,2**	2,785714	2,5	**5,3**
21: R. Engenheiro Rebouças	1,8	**0**	0	**0**	0	**1**	44,4	**3**	33,333	**77,77778**	**8,6**	2,986667	3	**6,0**
22: R. Conselheiro Laurindo	3,95	**0**	0	**0**	0	**5**	101	**0**	0	**101,2658**	**8,1**	2,961039	2	**5,0**
23: Av. Dr. Dario Lopes dos Santos	2,38	**0**	0	**0**	0	**3**	101	**0**	0	**100,8403**	**8,1**	3,195652	4	**7,2**
24: R. Mariano Torres	1,23	**0**	0	**0**	0	**0**	0	**0**	0	**0**	**10,0**	3,511111	4	**7,5**
25: Av. Presidente Affonso Camargo	5,04	**0**	0	**0**	0	**2**	31,7	**0**	0	**31,74603**	**9,4**	2,651515	2,5	**5,2**
26: Av. Prefeito Maricío Fruet	3,35	**0**	0	**544**	2424	**4**	95,5	**0**	0	**95,52239**	**8,2**	2,705882	3	**5,7**
27: Av. Sete de Setembro (parte oriental)	0,905	**0**	0	**0**	0	**4**	354	**0**	0	**353,5912**	**3,4**	3,0375	3	**6,0**
28: Av. Victor Ferreira do Amaral	2,88	**0**	0	**0**	0	**7**	194	**0**	0	**194,4444**	**6,4**	2,54386	3	**5,5**
29: Flavio Dallegrave - Trajeto ao Longo da ferrovia onder SL	7,32	**0**	0	**0**	0	**2**	21,9	**10**	27,322	**49,18033**	**9,1**	3,078125	3	**6,1**
29: Flavio Dallegrave - Trajeto ao Longo da ferrovia boven SL	3,86		0		0	**10**	71,56	**11**	19,68	**91,23**	**8,4**	3,08	2,50	**5,6**
30: Passeio Publico <---> São Lourenço	4,95	**0**	0	**0**	0	**0**	0	**0**	0	**0**	**10,0**	3,616279	3,5	**7,1**
31: Av. Fredolin Wolf	7,9	**0**	0	**300**	240,3	**1**	10,1	**0**	0	**10,12658**	**9,8**	3,407407	3,5	**6,9**
32: Av. Ver. Toaldo Tulio	5,56	**0**	0	**0**	0	**0**	0	**5**	17,986	**17,98561**	**9,7**	**3**	3,5	**6,5**
33: R. Antônio Escorsin	4,83		0		0	**10**	166		0	**165,6315**	**6,9**	2,756757	2	**4,8**
34: R. General Mário Tourinho	2,5	**0**	0	**0**	0	**1**	32	**0**	0	**32**	**9,4**	2,793103	3	**5,8**
35: Av. João Gualberto / Av Paraná (north - south)	7,05	**0**	0	**0**	0	**0**	0	**0**	0	**0**	**10,0**	3,078947	4	**7,1**
35: Av. João Gualberto / Av Paraná (south - north)	7,05	**0**	0	**0**	0	**0**	0	**0**	0	**0**	**10,0**	3,078947	4	**7,1**

					UseARC		ScoreARC	Sensitivity analysis						
Street	KM	shared(%)	Score	Usage score	arcMAP	Finalscore	arcMAP	Sense1		Sense2		Sense3		Sense4
1: Av. Sete de Setembro (east to west)	5.3	0	10	5	1	7.5	3.5	7.6	-0.1	7.2	0.3	7.4	0.1	7.7
1: Av. Sete de Setembro (west to east)	5.3	0.00	10.00	5	1	7.3	3.7	7.4	-0.1	7.0	0.3	7.3	0.0	7.6
2: Presidente Arthur da Silva Bernardes	2.41	100	0	4	2	4.8	6.2	5.1	-0.3	4.8	0.1	4.9	0.0	4.2
4: R. Pedro Gusso	2.88	100	0	2	4	4.6	6.4	4.8	-0.2	4.6	0.0	4.8	-0.1	4.1
5: Av. das Industrias	2.6	100	0	2	4	4.2	6.8	4.5	-0.3	4.3	-0.1	4.1	0.1	3.8
6: R. João Rodrigues Pinheiro	4.68	100	0	2	4	3.5	7.5	3.7	-0.1	3.4	0.2	3.7	-0.2	3.1
9: Marginal Linha Verde áte UFPR	9.65	85	1.5	3	3	5.1	5.9	5.5	-0.4	5.5	-0.4	4.6	0.5	4.8
10: Rua Omar Raymundo Picheth + Waldemar Lodeiro Campos	2.74	100	0	1	5	2.9	8.1	3.1	-0.2	2.4	0.5	3.2	-0.3	2.4
11: Av. Mal. Floriano Peixoto (north - south)	6.7	0	10	5	1	7.8	3.2	7.9	-0.2	7.6	0.1	7.5	0.2	8.0
11: Av. Mal. Floriano Peixoto (south - north)	6.7	0.00	10.00	5	1	7.5	3.5	7.7	-0.2	7.3	0.2	7.3	0.2	7.8
12: R. Napoleão Laureano	0.891	100	0	1	5	2.9	8.1	2.8	0.1	2.7	0.2	3.3	-0.4	2.4
14: Av. Com Franco (north-south)	8.01	0	10	4	2	6.7	4.3	6.9	-0.2	6.4	0.3	6.5	0.2	7.0
14: Av. Com Franco (south - north)	8.01	19.7	8.0	4	2	7.4	3.6	7.5	-0.1	7.5	-0.1	7.1	0.3	7.5
17: R. Iapó + R. Imae. Conceição	1.83	0	10	3	3	8.6	2.4	8.6	0.0	8.9	-0.3	8.4	0.3	8.9
19: R. Dr. Alexandre Gutierrrez	0.455	100	0	3	3	5.2	5.8	4.7	0.5	5.6	-0.5	5.7	-0.5	4.6
21: R. Engenheiro Rebouças	1.8	100	0	4	2	4.9	6.1	5.5	-0.6	4.7	0.2	4.6	0.3	4.3
22: R. Conselheiro Laurindo	3.95	100	0	4	2	4.8	6.2	5.3	-0.5	4.9	-0.1	4.5	0.3	4.3
23: Av. Dr. Dario Lopes dos Santos	2.38	100	0	3	3	5.1	5.9	5.8	-0.7	4.7	0.4	5.0	0.1	4.4
24: R. Mariano Torres	1.23	10.9	8.9	5	1	8.1	2.9	8.2	-0.2	8.1	0.0	7.8	0.2	8.2
25: Av. Presidente Affonso Camargo	5.04	12.7	8.7	4	2	6.6	4.4	6.8	-0.1	6.8	-0.2	6.2	0.4	7.0
26: Av. Prefeito Maricío Fruet	3.35	16.2	8.4	3	3	6.8	4.2	6.9	0.0	7.0	-0.2	6.6	0.3	7.1
27: Av. Sete de Setembro (parte oriental)	0.905	45.0	5.5	5	1	6.0	5.0	5.7	0.3	6.1	-0.1	6.2	-0.3	5.9
28: Av. Victor Ferreira do Amaral	2.88	100	0	3	3	5.0	6.0	5.3	-0.3	5.1	-0.1	4.9	0.1	4.5
29: Flavio Dallegrave - Trajeto ao Longo da ferrovia onder SL	7.32	100	0	4	2	6.2	4.8	6.6	-0.5	6.5	-0.3	5.9	0.3	5.6
29: Flavio Dallegrave - Trajeto ao Longo da ferrovia boven SL	3.86	100	0	4	2	5.7	5.3	6.1	-0.4	6.0	-0.3	5.4	0.3	5.2
30: Passeio Publico <---> São Lourenço	4.95	27.7	7.2	5	1	7.7	3.3	7.9	-0.2	7.8	-0.1	7.4	0.3	7.7
31: Av. Fredolin Wolf	7.9	100.0	0.0	3	3	5.8	5.2	6.5	-0.7	5.6	0.2	5.5	0.3	5.1
32: Av. Ver. Toaldo Tulio	5.56	100	0	3	3	5.0	6.0	5.8	-0.8	4.6	0.4	4.6	0.3	4.3
34: R. General Mário Tourinho	2.5	100	0	3	3	5.0	6.0	5.7	-0.7	4.9	0.1	4.7	0.4	4.5
35: Av. João Gualberto / Av Paraná (north - south)	7.05	0	10	4	2	8.4	2.6	8.4	0.0	8.6	-0.2	8.1	0.3	8.6
35: Av. João Gualberto / Av Paraná (south - north)	7.05	0	10	4	2	8.4	2.6	8.4	0.0	8.6	-0.2	8.1	0.3	8.6

Appendix 3

Avaliando os caminhos da bicicleta em Curitiba

Esta pesquisa é para a tese de Paul Schilte, um estudante holandês que está atualmente a fazer um estágio na Coordenação de Mobilidade da SETRAN. O objetivo desta pesquisa é avaliar as estruturas cicloviarias atuais de Curitiba.

A pesquisa levará cerca de 10 minutos e sua ajuda será muito apreciada!

Dê a qualidade media do trajeto uma pontuação de 1 (ruim) a 5 (bom).

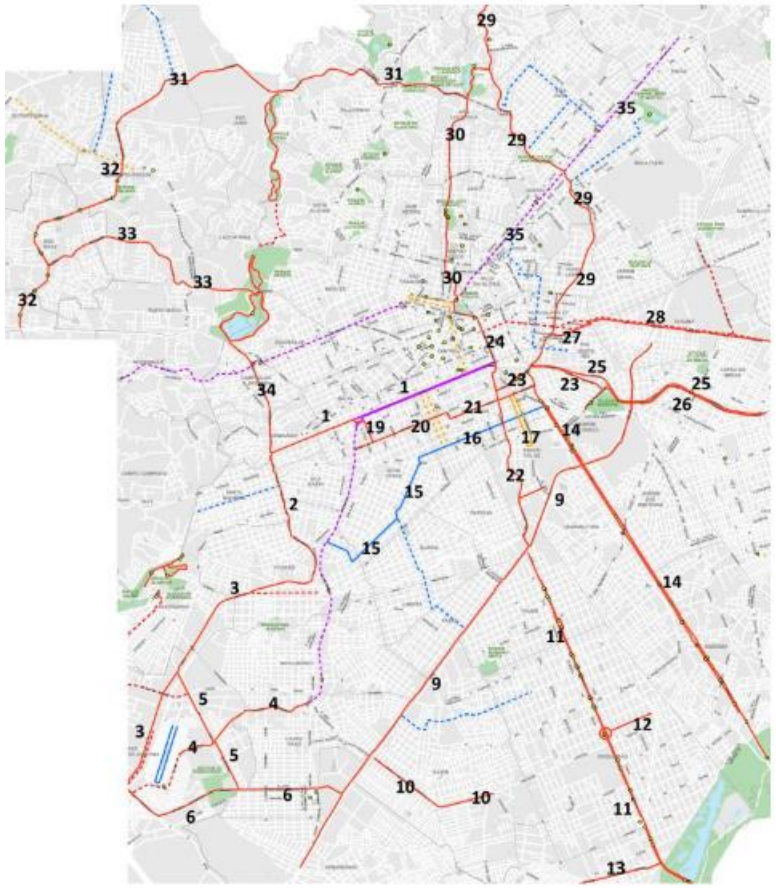
O número da rua na questão correspondender com o número no mapa.

Agradeço antecipadamente!

1. Sexo

- ○ Masculino
- ○ Feminino

2. Anos de experiência de ciclismo?



Appendix 3: Design of the survey

5. Região Sudoeste

	1	2	3	4	5	Eu não conheço esta via/ciclovia
1: Av. Sete de Setembro	○	○	○	○	○	○
2: Presidente Arthur da Silva Bernardes	○	○	○	○	○	○
3: João Bettega	○	○	○	○	○	○
4: R. Pedro Gusso	○	○	○	○	○	○
5: Av. das Industrias	○	○	○	○	○	○
6: R. João Rodrigues Pinheiro	○	○	○	○	○	○

6. Região Sul

	1	2	3	4	5	Eu não conheço esta via/ciclovia
9: Marginal Linha Verde áte UFPR	○	○	○	○	○	○
10: Rua Omar Raymundo Picheth + Waldemar Lodeiro Campos	○	○	○	○	○	○
11: Av. Mal. Floriano Peixoto	○	○	○	○	○	○
12: R. Napoleão Laureano	○	○	○	○	○	○
13: R. Wilson Daecheux Pereira	○	○	○	○	○	○
14: Av. Com Franco	○	○	○	○	○	○
15: Ótavio Francisco Dias + R. Pará	○	○	○	○	○	○
16: R. Baltasar Carrasco dos Reis	○	○	○	○	○	○
17: R. Iapó + R. Imae. Conceição	○	○	○	○	○	○

7. Região Central

	1	2	3	4	5	Eu não conheço esta via/ciclovia
18: Av. Iguaçu	○	○	○	○	○	○
19: R. Dr. Alexandre Gutierrrez	○	○	○	○	○	○
20: Av. Pres Getálio Vargas	○	○	○	○	○	○
21: R. Engenheiro Rebouças	○	○	○	○	○	○
22: R. Conselheiro Laurindo	○	○	○	○	○	○
23: Av. Dr. Dario Lopes dos Santos	○	○	○	○	○	○
24: R. Mariano Torres	○	○	○	○	○	○

8. Região Leste

	1	2	3	4	5	Eu não conheço esta via/ciclovia
25: Av. Presidente Affonso Camargo	○	○	○	○	○	○
26: Av. Prefeito Maricío Fruet	○	○	○	○	○	○
27: Av. Sete de Setembro (parte oriental)	○	○	○	○	○	○
28: Av. Victor Ferreira do Amaral	○	○	○	○	○	○

9. Região Norte

	1	2	3	4	5	Eu não conheço esta via/ciclovia
29: Flavio Dallegrave - Trajeto ao Longo da ferrovia	○	○	○	○	○	○
30: Passeio Publico <--> São Lourenço	○	○	○	○	○	○
31: Av. Fredolin Wolf	○	○	○	○	○	○
32: Av. Ver. Toaldo Tulio	○	○	○	○	○	○
33: R. Antônio Escorsin	○	○	○	○	○	○
34: R. General Mário Tourinho	○	○	○	○	○	○
35: Av. João Gualberto / Av Paraná	○	○	○	○	○	○