CHALMERS

An app as a tool for future bicycle planning in Gothenburg

Evaluation of a bicycle track by using generated data from the function *Min cykeltur*

Master of Science Thesis in the Master's Programme Infrastructure and Environmental Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover:
The bicycle track along Nya Allén (Broberg, 2012).

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ABSTRACT

Gothenburg is a growing city and the current traffic system therefore needs to be reformed and designed in a way that facilitates for public transports, cyclists and pedestrians. One of the city of Gothenburg's objectives is to become a bicycle friendly city. The app called *Cykelstaden* is developed by the Traffic & Public Transport Authority and was launched in May, 2013. The most recent feature of the app is the function *Min cykeltur*, which enables the cyclists to log their route. The Traffic & Public Transport Authority are developing a new bicycle plan that proposes to divide the bicycle network in Gothenburg into three network classes and to set standards, so called functional demands, for each network class. The purpose of this MSc thesis was to find out if the function *Min cykeltur* could be used as a basis for bicycle planning. The function's generated data was further used to investigate if Nya Allén fulfills the existing functional demands. Furthermore, the purpose included exemplifying of a method for how the function's generated data could be handled. The processing of data was performed in the two programs Excel and Quantum GIS (QGIS), version 2.2 Valmiera. The results from the investigation along the stretch Nya Allén showed that the functional demands connected to velocity and velocity distribution was fulfilled. The functional demand connected to mobility and flow was not met, which probably was due to the junctions along Nya Allén. The method for processing of data, developed in this MSc thesis, was considered as usable, although improvements might be necessary for analyses of greater volume of data. The analyses performed in this MSc thesis indicate that the function *Min cykeltur* can be used as a tool to evaluate how, where and when people cycle. Thereby, the function may form a basis for future bicycle planning.

Key words: Min cykeltur, GPX-file, QGIS, Functional demands, Traffic analysis

En app som ett verktyg för framtida cykelplanering i Göteborg
Utvärdering av en cykelbana genom att använda genererad data från funktion *Min cykeltur*
Examensarbete inom Infrastructure and Environmental Engineering
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SAMMANFATTNING

Göteborg är en växande stad och det nuvarande trafiksystemet måste därför förändras och designas på ett sätt som underlättar för stadens kollektivtrafik, cyklister och gångare. Ett av målen för Göteborgs stad är att utvecklas till en cykelvänlig stad. Göteborgs Stads Trafikkontoret har utvecklat appen *Cykelstaden*, som lanserades i maj 2013. Den senaste funktionen i appen heter *Min cykeltur*, vilken gör det möjligt för cyklister att logga sin cykeltur. Trafikkontoret arbetar med att ta fram en ny cykelplan, som innehåller ett förslag på att dela in cykelnätet i Göteborg i tre nätverksklasser och att utforma så kallade funktionskrav för varje nätverksklass. Syftet med detta examensarbete var att ta reda på om funktionen *Min cykeltur* kan användas som ett underlag för cykelplanering. Funktionens genererade data användes till att undersöka om Nya Allén uppfyller de uppsatta funktionskraven. Syftet innefattade även att ge ett exempel på hur den genererade datan kan behandlas. I detta examensarbete har Excel och Quantum GIS (QGIS), version 2.2 Valmiera, används för att behandla datan. Resultaten från undersökningen längs Nya Allén visade att funktionskraven som är kopplade till hastighet och hastighetsfördelning var uppfyllda. Funktionskravet kopplat till framkomlighet och flöde var inte uppfyllt, vilket troligtvis beror på korsningarna längs Nya Allén. Den metod, som i detta examensarbete har tagits fram för att behandla datan, ansågs vara användbar, även om förbättringar kan bli nödvändiga vid analyser av större mängder data. Analyserna som utförts i detta examensarbete visar på att funktionen Min cykeltur kan användas som ett verktyg för att utvärdera hur, vart och när göteborgarna cyklar. På så sätt kan funktionen utgöra underlag för framtida cykelplanering.

Nyckelord: Min cykeltur, GPX-fil, QGIS, Funktionskrav, Trafikanalys

Contents

Preface

This MSc thesis was conducted at the Traffic & Public Transport Authority in Gothenburg, for the department of Civil and Environmental Engineering, Chalmers University of Technology.

The MSc thesis was carried out by the authors Johanna Aalto and Johanna Nyström between January and June 2014. The work was performed in collaboration with the supervisors Noel Alldritt, Project Manager ITS, at the Traffic & Public Transport Authority and Jan Englund at the Road and Traffic Research Group at Chalmers University of Technology.

Thank you to everyone who has helped us with this MSc thesis. A special thanks to our supervisor Noel Alldritt and to Gunnar Lannér who have given us valuable input to our thesis. We would also like to thank Malin Månsson, Lars-Erik Lundin, Eva Eriksson, Malin Andersson and Mattias Junemo who have supported our work with this MSc thesis.

Göteborg June 2014

Johanna Aalto & Johanna Nyström

Vocabulary

Commuter cycling network	Aims to connect areas located at a distance of approximately 5 km or longer from each other and is also supposed to connect present and future so called main points.
Functional demands	Standards for how the bicycle tracks should be designed.
General cycling network	Intends to link areas in a smaller scale, i.e. shorter distances, and to create connections to the commuter cycling network.
Local cycling network	Represent the finest mesh in the cycling network, which for instance may be the last stretch to the parking lot or target point.
Main point	An area or location that is characterized by a variety of housing, jobs, shops, services, cultural and leisure activities.
Mobility and flow	In Swedish; *Framkomlighet och flöde*. Mobility is defined as the ability to move forward and flow refers to the ability to contain a specific velocity.
Orientation and recognition	Orientation and recognition refers to the cyclists' ability to orient and recognize themselves.
Shortcut factor	Describes how much the bicycle track digresses from the shortest way (as the crow flies).
Target point	Relates to a location or an area where people go in order to accomplish a particular errand.

1 Introduction

Gothenburg is a growing city that in year 2035 is expected to have 150 000 more residents and 80 000 more job opportunities, compared to today (Hellberg, Bergström Jonsson, Jäderberg, Sunnemar, & Arby, 2014). The increased number of residents, employees and visitors will consequentially result in that more people will travel, both in and out of Gothenburg and within the city. To manage the increased travelling, the current traffic system needs to be reformed and designed in a way that facilitates for public transports, cyclists and pedestrians. This prioritizing of more environmental friendly modes of transport can also be reflected in one of the city of Gothenburg's objective, which is to become a bicycle friendly city (Göteborgs Stad Trafikkontoret, 2013a).

1.1 Background

In the years from 2000 to 2013, the Traffic & Public Transport Authority's investments in the bicycle infrastructure have continually increased (Göteborgs Stad Trafikkontoret, 2013a). In 2013 the Traffic & Public Transport Authority put extra effort in communicative measures, where one example is the app called *Cykelstaden*. The app is developed by the Traffic & Public Transport Authority and was launched in May 2013 (Alldritt, 2014). The expectation is for the app to further improve the Traffic & Public Transport Authority's communication with the cyclists, while it also allows the cyclists to be part of the development of the bicycle infrastructure. The latest function is called *Min cykeltur,* which enables the cyclists to log their route. The function might thus provide data about cyclists' movement pattern, which currently are information that the Traffic & Public Transport Authority has limited knowledge about. Since the function *Min cykeltur* is a relatively new part of the app, its potential use as a tool for analyzing and planning of the bicycle infrastructure have not been defined yet. Also, a method for processing the function's generated data is currently absent.

During the last 10 years, the development of the bicycle infrastructure in Gothenburg has been based on the bicycle program that was conducted by the Traffic & Public Transport Authority in 1999 (Göteborgs Stad Trafikkontoret, 2013a). Since 2012, however, the Traffic & Public Transport Authority has continuously been working with the development of a new bicycle plan, which main objective will be to increase the number of bicycle journeys (Göteborgs Stad Trafikkontoret, 2013a). The plan proposes to divide the bicycle network into the following three network classes; the commuter cycling network, the general cycling network and the local cycling network (Göteborgs Stad Trafikkontoret, 2013b). Furthermore the plan also proposes to set standards, so called functional demands, for each network class. The network class of focus in this MSc thesis is the commuter cycling network, which the bicycle track along Nya Allén will be part of. Nya Allén is approximately 1985 meters long, located between Järntorget and Ullevigatan and is marked with a dashed line in Figure 1. The closer view of the bicycle track, also shown in Figure 1, shows that the bicycle track divides into two tracks at Rosenlundsbron. However, it is only the south part of the bicycle track, marked with a dashed line, which will be studied.

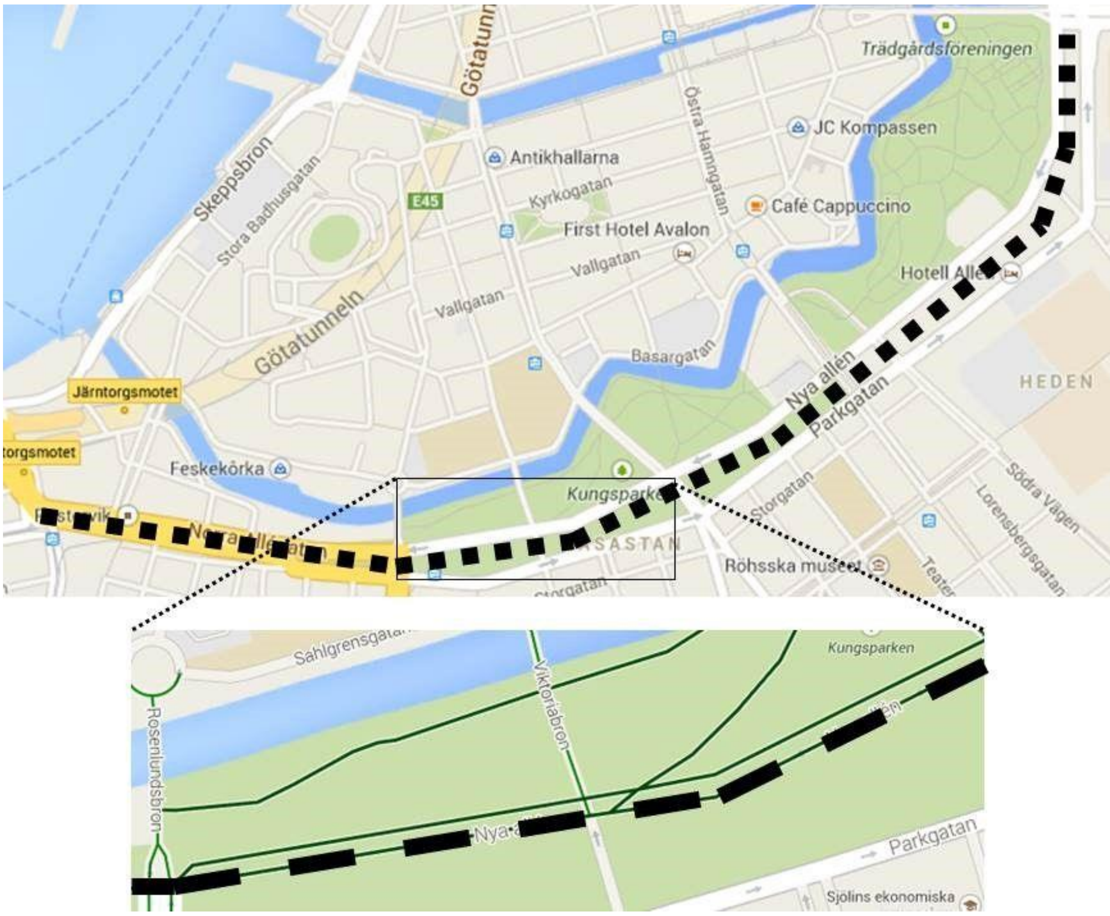

Figure 1 *The bicycle track Nya Allén is marked with a dashed line. At Rosenlundsbron, where the track divides, only the south bicycle track is part of the investigation.*

1.2 Purpose & Objectives

The purpose of this MSc thesis is to find out if the function *Min cykeltur* could be used as a basis for bicycle planning. This will be tested by the performance of an investigation in which cyclists use the function, simultaneously as they cycle the bicycle track along Nya Allén. The function's generated data will further be used to investigate if Nya Allén fulfills the existing functional demands for bicycle commuting routes. Furthermore, the purpose includes exemplifying of a method for how the function's generated data could be handled. This MSc thesis also has the objective to describe the Traffic & Public Transport Authority's work, mainly from 2010 until today, to develop and improve the bicycle infrastructure in Gothenburg.

1.3 Limitations

Only the bicycle track Nya Allén will be investigated. This means that even though some of the cyclists may cycle on other bicycle tracks, only the part that intersects with Nya Allén will be investigated. The investigation will be performed during two days and data from other days will not be taken into account. Only three of the eight functional demands, which are connected to velocity, will be controlled. The app *Cykelstaden* contains different functions, but the function called *Min cykeltur* is the one which is evaluated in this MSc thesis.

1.4 Methodology

The work with this MSc thesis can be divided into five major parts, where each part is briefly described in the sections 1.4.1-1.4.5 below. Also, report writing was done throughout the entire process of conducting this thesis. The process of the methodology can be visualized in Figure 2.

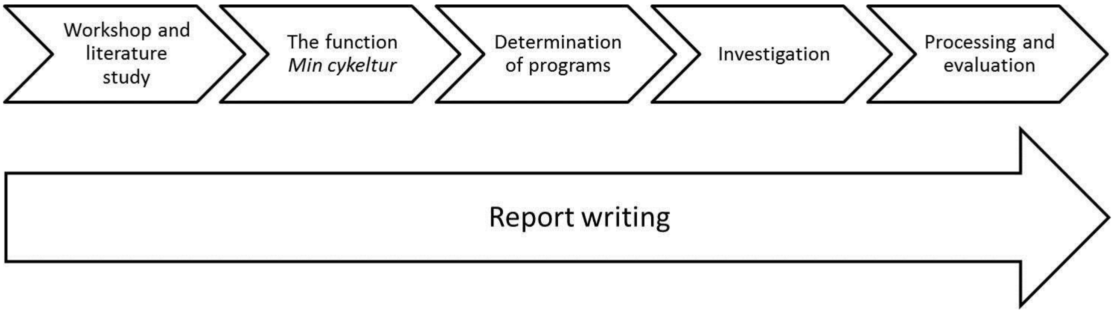

Figure 2 The entire process of conducting this MSc thesis. This chart does not consider the time spent in each step, only visualizes the order.

Figure 2, along with the brief descriptions of each part in the following sections, aims to give an overview of the methodology. Preparations prior the investigation, the determination of programs and the method for processing of data, will be further described in Chapter 4. The processing of the data is described in detail in Appendix I, so that the process may be repeated by the Traffic & Public Transport Authority.

1.4.1 Workshop and literature study

In order to gain different ideas of how the Traffic & Public Transport Authority may utilize the function *Min cykeltur* as a basis for bicycle planning, a workshop was held in the beginning of this MSc thesis. Based on this workshop, the idea of using the function to evaluate the functional demands was chosen. It was further decided to evaluate the function and the functional demands for a smaller stretch, to be able to perform a thoroughly investigation. After discussions with the Traffic & Public Transport Authority, the bicycle track Nya Allén was chosen due to its central location and interactions with different types of road users.

In order to obtain knowledge about how the Traffic & Public Transport Authority previously has worked with cycling and what measures that have been made the past few years, a literary study of documents, publications and websites was carried out. Additionally knowledge and information within the subject was obtained by interviewing several employees at the Traffic & Public Transport Authority.

1.4.2 The function *Min cykeltur*

The second step was to study the function *Min cykeltur*, in order to understand how it operates and to find out what type of data it generates. The authors, together with the supervisor at the Traffic & Public Transport Authority, tested this by cycling the stretch Nya Allén simultaneously as the function was operating. The files that each cycle route resulted in were thereafter opened in Google Earth, where the data that the function generates was visualized.

1.4.3 Determination of programs

The third step, which will be further described in section 4.2, was to determine the method for how and in which programs the function's generated data would be processed. As mentioned in section 1.4.2, the data was first visualized in Google Earth. The two programs that eventually were chosen for processing of the data was, however, Excel and the Geographical Information System (GIS) called Quantum GIS (QGIS), version 2.2 Valmiera. More information of QGIS can be found in Appendix II.

1.4.4 Investigation along Nya Allén

The investigation along Nya Allén was carried out as a forth step. In order to engage cyclists to participate, information about the investigation was announced in several ways. On the same days of the investigation, information sheets describing the investigation were handed out to the cyclists who cycled along Nya Allén. The information sheet was written in Swedish, but a translated version in English can be seen in Appendix III. Information about the investigation was also emailed to selected companies, published at the Traffic & Public Transport Authority's website, on the blog named *Gbgcyklaren*, on the Facebook page *Cykla i Göteborg* and *Yimby Göteborg*. The investigation was carried out on Wednesday 19 and Thursday 20 March and the procedure was as follows; cyclists had the function *Min cykeltur* running, simultaneously as they cycled the bicycle track along Nya Allén. After completion of the cycle route, the cyclists were told to state their gender and age and thereafter send their cycle routes to the Traffic & Public Transport Authority.

1.4.5 Processing and evaluation of data

Step five includes the processing and evaluation of the function's generated data. All data, i.e. all cycle routes, were thereafter processed in Excel and QGIS according to section 4.3 and Appendix I. The results of all cycle routes were then presented in the form of figures, diagrams, tables and text. Furthermore, the results were analyzed and discussed and eventually, the findings of this MSc thesis were concluded.

2 Bicycle planning

As already mentioned, the development of the bicycle infrastructure in Gothenburg has during the 10 last year’s been based on the bicycle program that was conducted by the Traffic & Public Transport Authority in 1999 (Göteborgs Stad Trafikkontoret, 2013a). The program’s purpose was to improve the bicycle network, which therefore has been the overall focus for the years 1999 to 2013. The work have included development of a more connected bicycle network, adjustments and reconstruction of the existing bicycle infrastructure and improvements of the traffic safety for the cyclists. Other measures that facilitates for cyclists have also been implemented, which will be further described in Chapter 3. The Traffic & Public Transport Authority’s work has resulted in that the traffic safety has significantly increased, as the number of reported bicycle accidents in 2013 was 50 percent less compared to 1999. Another result is that the length of the bicycle network has increased from around 360 kilometers of separated bicycle roads in 1999 to approximately 486 kilometers in 2013. The total bicycle network[1] in Gothenburg currently corresponds to a length of 793 kilometers, which is longer than the 763 kilometers long bicycle network in Stockholm.

However, Gothenburg is a growing city and its population is expected to increase by 150 000 until year 2035 (Hellberg, Bergström Jonsson, Jäderberg, Sunnemar, & Arby, 2014). To manage the increased number of residents and in order to achieve the city of Gothenburg’s objective to become a bicycle friendly city, the bicycle infrastructure must continue its development. Since most of the objectives stated in the bicycle program from 1999 have been achieved, Gothenburg is now in need of a new bicycle plan. The ongoing process with the development of the new bicycle plan is presented in the next section.

2.1 Development of a new bicycle plan

The Traffic & Public Transport Authority has since 2012 continuously been working on a new bicycle plan (Månsson, 2014). The plan is expected to be completed, in a preliminary form, by the middle of June 2014 and will thereafter be consulted by the Transportation Committee (Trafiknämnden). When the Transportation Committee has given their comments, the bicycle plan will be revised and thereafter approved. Hence, exactly what the plan will include upon completion cannot be determined at present. Therefore, this section only presents what currently are its content as well as the developing process of the plan.

The bicycle plan is based on the traffic strategy, which was approved by the Transportation Committee in February 6, 2014 (Hellberg, Bergström Jonsson, Jäderberg, Sunnemar, & Arby, 2014). The traffic strategy is a guide for how to develop the traffic system in Gothenburg, in order to achieve the determined goals and to manage the challenges the city faces over the next 20 years. The main objective of the bicycle plan will be to significantly increase the number of bicycle journeys and it will include visions and strategies necessary for Gothenburg to become an attractive cycling city (Göteborgs Stad Trafikkontoret, 2013b). The following two visions have been stated;

- It is easy to cycle in densely, urban areas

[1] The total bicycle network includes separated bicycle roads, mixed traffic roads and local roads (Göteborgs Stad Trafikkontoret, 2013a).

- Commuting with bicycle is fast, easy and secure

The way, in which the visions may be achieved, are described by the following three strategies that so far have been formulated;

- Bicycle is a separate mode of transport and must have its own structure
- The cyclists’ needs form the basis for the bicycle planning
- Anchor and quality assurance

The first strategy is based on the new approach where bicycle is considered as a separate mode of transport and must therefore have its own structure, i.e. be separated from other road users (Göteborgs Stad Trafikkontoret, 2013b). The second strategy is to develop the bicycle network based on the cyclists’ needs, both in the context of reconstruction as well as new construction. The third strategy is anchoring and quality assurance of the Traffic & Public Transport Authority’s own work (Månsson, 2014). This is important in order to make sure that the bicycle infrastructure is developed in a way that is requested, both by the Traffic & Public Transport Authority and the cyclists. Thus, this strategy also includes informing the cyclists about the measures that the Traffic & Public Transport Authority has carried out.

The new bicycle plan will also include a suggestion of the bicycle network structure, i.e. how the network will look like in 2035, as well as a division of the network (Göteborgs Stad Trafikkontoret, 2013b). The division that the Traffic & Public Transport Authority has decided to use consists of three levels, based on network class, which are called; the commuter cycling network, the general cycling network and the local cycling network. The three types of network classes have different purposes, where the commuter cycling network mainly aims to connect areas located at a distance of approximately 5 km or longer from each other (Göteborgs Stad Trafikkontoret, 2013b). The commuter cycling network is also supposed to connect present and future so called main points. The general cycling network intends to link areas in a smaller scale, i.e. shorter distances, and to create connections to the commuter cycling network. The local cycling network represents the finest mesh, which for instance may be the last stretch to the parking lot or target point.

2.2 Functional demands

Based on the different functions of the three network classes the Traffic & Public Transport Authority has proposed to set standards for each network class, so called functional demands (Göteborgs Stad Trafikkontoret, 2013b). The development of functional demands was started in the spring of 2013 and Gothenburg is the first city in Sweden where such requirements are under progress (Månsson & Lundin, 2014). Since the development of functional demands is still an ongoing process, nothing is yet completely established, and what exists at present is only a suggestion. The current proposal implies that the functional demands will differ depending on which network class the bicycle track belongs to and will concern the following parameters; velocity, mobility and flow, velocity distribution, comfort, orientation and recognition, shortcut factor, traffic safety and security (Göteborgs Stad Trafikkontoret, 2013b). The functional demands for the commuter cycling network, which is the network class of focus in this MSc thesis, and a description to what each functional demand implies are shown in Table 1 below.

Table 1 Functional demands for the commuter cycling network.

Parameter	Functional demand	Description of the functional demand
Velocity	Possibility to cycle in a velocity of 30 km/h between two junctions	The high velocity requires separated bicycle tracks and put higher demands of the track’s geometry and surface
Mobility and flow	Be able to keep a minimum average velocity of 20 km/h on a 2000 m long stretch	Relates to the design of junctions and its priority of road users
Velocity distribution	Possibility to cycle in different velocities	All types of cyclists (children, elderly, fast-going cyclists etc.) and different kind of bikes shall have the possibility to use the bicycle track
Comfort	Good comfort	High smoothness and friction of the bicycle track
Orientation and recognition	Easy for cyclists to orient themselves and high recognition factor	For example by road markings, route guidance and traffic signals
Shortcut factor	Lower than 1.25 between main points	Describe how much the bicycle track digresses from the shortest way (as the crow flies)
Traffic safety	High traffic safety	Avoid interaction with other road users
Security	High security	High security is required 24/7

Not all of the demands have yet been completely defined, which primary concerns the demands for the parameters named comfort, orientation and recognition, traffic safety and security. The implication of these demands are currently very vague, due to the absent of a target value to relate to, which may result in difficulties in determine whether the demands are met or not. At the time when the development of the functional demands is fully completed, most of the parameters will probably have some kind of target value (Månsson, 2014). However, the idea is that the functional demands will represent a measure rather than a demand and thus do not need to be fulfilled. Therefore, a clear target value of each parameter might not be necessary. In the next section, the development of the functional demands is presented.

2.2.1 Development of functional demands

The functional demands are based on the three strategies mentioned in section 2.1 as well as assumptions and experiences obtained partly from other cycling cities, such as Copenhagen and Amsterdam (Månsson & Lundin, 2014). Interviews and surveys made with cyclists have also formed a basis for the development of the functional demands. In addition, analyses of cyclists' travelling habits, bicycle flows and the potential for bike commuting have also contributed to the development (Göteborgs Stad Trafikkontoret, 2013b). The analyses aim to evaluate the capacity of todays' network, i.e. its prerequisites and potential to manage the expected increase of cyclists. Their results can further be used in order to evaluate how the future bicycle network may look like and how to plan it.

The analysis of cyclists' travelling habits, performed in 2011, showed that approximately 75 000 number of bicycle journeys was carried out during a workday (Göteborgs Stad Trafikkontoret, 2013b). The travel by bike hence accounts for around 6 percent of the total amount of travels in Gothenburg. However, the cycling is strongly dependent on the weather since the bicycle journeys are twice as many in the summer season, April – September, as in the winter season, October – March. The most common type of bicycle journey is the journey to and from work, where 10 percent of this type of journey is accomplished by bike. Furthermore, the analysis shows that two-third of the bicycle journeys is shorter than 5 kilometers and just over 90 percent is shorter than 10 kilometers.

Regarding the flow of bicycles, the Traffic & Public Transport Authority has permanent bicycle counters which continuously measure the bicycle flow (Göteborgs Stad Trafikkontoret, 2013b). These are located at about twenty places in connection with the bicycle network, as can be seen in Figure 3 below. The measurements show that the flow of bicycles varies during the day and that the most intense hours are in the afternoon. The highest bicycle flows are located in the central parts of Gothenburg such as Vasagatan, Pustervik and Götaälvbron, where the flows during an average workday during summer season in 2012 corresponded to a flow of 3590, 2960 respectively 2800 bicycles.

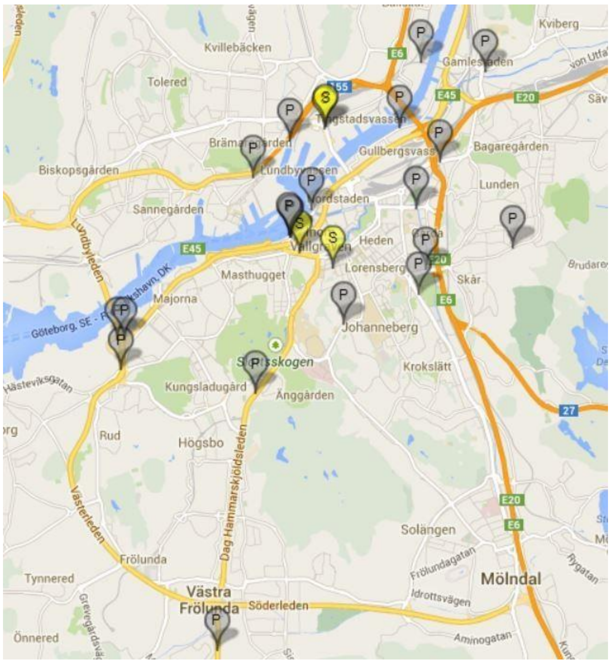

Figure 3 *The locations of the bicycle counters. The "S-markings" show where the highest bicycle flows have been measured, i.e. at Vasagatan, Pustervik and Götaälvbron.*

In order to evaluate the potential for bike commuting, an investigation was performed in 2011 by the Traffic & Public Transport Authority (Göteborgs Stad Trafikkontoret, 2013b). The results showed that the distance between home and workplace was shorter than 10 kilometers for about half of the residents and shorter than 5 kilometers for a quarter. In view of the relatively short distances, the potential for accomplish a large proportion of journeys to and from work by bike is considered to be great. Due to that as much as approximately one-third of the car journeys are shorter than 5 kilometers, a distance that easily could be traveled by bike instead, also indicate that there is a potential for an increase in number of cyclists.

3 Investments in cycling

In addition to the Traffic & Public Transport Authority's work to improve the bicycle network, investments in other measures that facilitates for cyclists have been made (Göteborgs Stad Trafikkontoret, 2013a). Between year 2000 and 2013, these investments in cycling have continually increased and both physical and communicative measures have been carried out. The physical measures mainly aim to facilitate the cycling and improve the bicycle infrastructure, while communicative measures focusing in increasing the communication with the cyclists and encourage more people to cycle. The measures hence contribute, in different ways, to an increased cycling and to the city of Gothenburg's objective to become a bicycle friendly city. In section 3.1, some of the physical measures that were carried out by the Traffic & Public Transport Authority during the years 2010-2013 will be presented. The Traffic & Public Transport Authority's work with increasing the communication with the cyclists, starting from 2008, and the communicative measures performed during 2010-2013 will be presented in section 3.2.

3.1 Physical measures

In August 2010, the bicycle hire system called *Styr & Ställ* was introduced which aimed to show the advantages of using bicycle as a means of transport and hence encourage people to cycle more often (Göteborgs Stad Trafikkontoret, 2013a). The hire system was also intended to reduce the amount of short car journeys within the central parts of Gothenburg and to serve as a complement to the public transport, which thereby contributes to the reduction of carbon dioxide (JCDecaux). During 2013, the number of bicycles available for hiring was expanded to 1000 and the amount of journeys was doubled compared to 2012 (Göteborgs Stad Trafikkontoret, 2013a). The system has proven to be appreciated by the users, as 93 percent are satisfied with the system according to a survey performed by SIFO.

In order to make it easier for cyclists to cross the Göta Älv, the number of ferries accessible by bike was expanded in April 2011 (Göteborgs Stad Trafikkontoret, 2013a). Two ferries are currently available, Älvsnabbaren (line 286) and Älvsnabben (line 285), which both are running between Rosenlund and Lindholmen as seen in Figure 4 below. Line 286 is free of charge, whereas line 285 demands a ticket purchased from Västtrafik.

Figure 4 Location of the ferry stops Lindholmen and Rosenlund.

During 2013, there has been extensive construction within central Gothenburg (Göteborgs Stad Trafikkontoret, 2013a). Along the boulevard Kungsportsavenyn, several so called bike boxes have been introduced. A bike box is a painted square that is placed at an intersection and that gives cyclists a separated space in front of the car traffic, as can be seen in Figure 5 below (Hjertberg, 2013).

Figure 5   Example of a bike box (Växjö Kommun, 2014)

To increase the ability to park the bicycle, 300 new parking lots for bicycle have been set up adjacent to public transport stop (Göteborgs Stad Trafikkontoret, 2013a). In total there are about 8000 bicycle parking lots, where the frame of the bicycle may be locked by the stand. Another physical measure that the Traffic & Public Transport Authority has carried out is to install bicycle pumps in the city center and on strategically places such as Hjalmar Brantingsplatsen, Lindholmsallén and Angered center. The Traffic & Public Transport Authority cooperate with bicycle stores and service facilities, which provides additional places for pumping and also allows cyclists to borrow tools for minor self-services. Both pumping and loan of tools are free of charge for cyclists.

A final example of a physical measure is the so called bicycle map, which is developed by the Traffic & Public Transport Authority (Göteborgs Stad Trafikkontoret, 2013a). In 2013, the map has been updated with new bicycle roads. Except for visualizing paths for cycling, the map shows where bicycle pumps and stations for *Styr & Ställ* are localized and includes information about the app *Cykelstaden*.

3.2 Communicative measures

Since 2008, the Traffic & Public Transport Authority has performed an annual survey (Splitvision Research & Trafikkontoret Göteborgs Stad, 2012). The survey is based on telephone interviews with randomly selected inhabitants of Gothenburg and aims to give indications of the inhabitants' opinions regarding the bicycle environment. The results from the interviews also serve as a measure for how the public experience the Traffic & Public Transport Authority's work for improving the bicycle infrastructure.

In 2013, the Traffic & Public Transport Authority has had an increased focus in improving the communication with the cyclists (Göteborgs Stad Trafikkontoret, 2013a). This can be seen in Table 2 below, where the investments in communicative measures are significantly greater in 2013 compared to earlier years. An increased communication with the cyclists will help the Traffic & Public Transport Authority to find out of what the cyclists think about the bicycle infrastructure in Gothenburg (Alldritt, 2014). Thereafter, the cyclists' opinions could form a basis for bicycle planning and the bicycle infrastructure could thus be designed in a way that fulfills the needs of the cyclists. This new approach of bicycle planning differs from the prior way of working, where the bicycle planning mainly has been based on earlier experiences and assumptions.

Table 2 The Traffic & Public Transport Authority's investments in communicative measures

Year	2008	2009	2010	2011	2012	2013
Investment [MSEK]	3	2.5	2.5	0.8	1.3	5.4

One way to increase the communication and to create a dialog with the cyclists is by using the app *Cykelstaden* (Alldritt, 2014), which functions and objectives will be further explained in section 3.2.1. In addition to the app, several communicative measures in order to inform, affect and increase the public's willingness to cycle have been performed during the years 2010-2013 (Göteborgs Stad Trafikkontoret, 2013a). One of the measures was the campaign named *Ease your bicycle heart (Lätta ditt cykelhjärta)*, started in September 2012, in which the public were given the opportunity to give their opinions regarding cycling in Gothenburg. Opinions could be submitted either in the suggestion box placed at Gustav Adolfs Torg or at www.forslagsladan.nu. The webpage is still active and new comments keep on coming in.

Another communicative measure, invented in 2013, was the award *Bicycle friendly working place (Cykelvänlig arbetsplats)* (Göteborgs Stad Trafikkontoret, 2013a). The award aims to encourage companies to carry out actions in order to make it easier for their workers to choose to cycle. The engagement among companies was great and the work of the award continues in 2014.

With the aim of changing people's travel habits and encourages them to choose more environmental friendly means of transports such as public transports or bicycle, a festival called *Streetsmart festival* was arranged in 2012 and 2013 (Göteborgs Stad Trafikkontoret, 2013a).

A final example of a communicative measure is the three-year European project named CARMA (CARMA, 2013). The project ran from February 2010 until February 2013 and in which the Traffic & Public Transport Authority in Gothenburg had the overall responsibility as the project coordinator. The main goal of the project was to obtain a better understanding of how the beliefs and behavior of target residents may be changed. Six cities, including Gothenburg, participated in the project and together they have structured and streamlined communication activities regarding cycling (Göteborgs Stad Trafikkontoret, 2013a).

3.2.1 The app *Cykelstaden*

The app *Cykelstaden* is developed by the Traffic & Public Transport Authority and was launched in May, 2013 (Alldritt, 2014). The cyclists requested a way of easily access information from the Traffic & Public Transport Authority, which was the main reason for the creation of the app (Eriksson, 2014). The app is thereby a way of increasing the communication and to create a dialog with the cyclists, as already mentioned in section 3.2. With the purpose of facilitating cycling, the following nine functions are currently included in the app; service points, pump stations, bicycle parking lots, bicycle hire system *Styr & Ställ*, links, fault reporting, *Min cykeltur*, travel planner and bicycle routes (Göteborgs Stad Trafikkontoret, 2013c). Figure 6 below shows the front page of the app, where the name of each function is written in Swedish and the function *Min cykeltur* is marked with a dashed square.

Figure 6 The front page of the app Cykelstaden, with the function Min cykeltur marked with a dashed square.

3.2.2 The function *Min cykeltur*

The most recent feature of the app is the function *Min cykeltur*, which was added to the app in the early spring of 2014 (Eriksson, 2014). The function enables cyclists to log their route and might thus provide information about how cyclists in Gothenburg cycle, information that the Traffic & Public Transport Authority currently has limited knowledge about. The planning of the bicycle infrastructure has previously been based mainly on assumptions and experiences, from earlier work or from other cities. The function thus allows a new approach, which instead implies that actual facts of the cyclists' movement patterns may be the basis for bicycle planning. The bicycle infrastructure could thereby be designed in a way that better meets the cyclists' requirements and hopefully result in an increased cycling.

The function is a convenient tool for the cyclists, as it is a part of an app that easily could be downloaded to a smartphone (Eriksson, 2014). In order for the Traffic & Public Transport Authority to utilize the function, however, cyclists must be aware of the function's existence and use it simultaneously as they cycle. The function is programmed to update the cyclist's position every second and utilizes the smartphone's GPS (AB, 2014). In conjunction with the startup of the function, the text box *Waiting for GPS…*, seen in Figure 7, is the first information that a user of the function will receive on the smartphone's screen. When the loading of the GPS is finished, the function may be started by clicking on the text box *Start the cycle route* according to Figure 8.

Figure 7 *In conjunction with the startup of the function, the text box "Waiting for GPS…" is the first information that the user will be given.*

Figure 8 *The function is started by clicking on the text box marked with the dashed square.*

However, the user has the possibility to discontinue the loading of the GPS by clicking on the text box *Waiting for GPS…*. A warning is then displayed on the screen, according to Figure 9, where the user may choose to start the function even though the accuracy of the GPS is not sufficient. If the function is running without having the GPS operating properly, the function may not be able to register the cyclist's position. The GPS must thus be working, in order for the function to generate the intended data.

Figure 9 *The text box asks the user if the function "Min cykeltur" shall be started, despite the fact that the accuracy of the GPS is not sufficient.*

After completion of a cycle route, as long as the GPS has been operating properly, the data shown on the smartphone's screen is the following; time, distance and average velocity. Also a map of the cycled route is shown, which can be seen in Figure 10 below. Furthermore, the cyclist may choose to share the information with the Traffic & Public Transport Authority by clicking on the button marked with a square in Figure 10.

Figure 10 *After completion of a cycle route, the time, distance, average velocity and a map of the cycled route are shown on the smartphone's screen.*

The cycle route is sent to the Traffic & Public Transport Authority as a so called GPX[2]-file, which is a file format that may be opened in several programs. However, it appears that the included data in the GPX-file displays slightly different depending on in which program the file is opened. Differences in how the data is displayed in the programs that have been used in this MSc thesis will be further described in Chapter 4.

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[2] The GPS Exchange Format (GPX): An Extensible Markup Language (XML) data format that support interchange of GPS data, e.g. waypoints, routes and tracks, between different programs and Web services (GPX - The GPS Exchange Format).

4 Preparations prior the investigation and method for processing of data

Prior the investigation along Nya Allén, which was carried out as described in section 1.4.4, it was necessary to find appropriate programs for processing of the function's generated data. Another essential part was to determine a way to control if Nya Allén fulfills the functional demands. The preparations before the investigation, as well as the method for how the data was processed, are described in section 4.1-4.3.

4.1 Measurements for functional demands

Only the functional demands connected to velocity, mobility and flow and velocity distribution will be evaluated in this MSc thesis. This is due to that the other functional demands cannot be evaluated by the data that the function generates in. Measurements that specify how each of the chosen functional demand may be controlled, were further determined according to Table 3 below. The measurements thus show the results that the processing of the function's data is expected to generate and that are needed in order to control whether Nya Allén fulfills the functional demands or not.

Table 3 The functional demands and desirable measurements.

Parameter	Functional demand	Measurement
Velocity	Possibility to cycle in a velocity of 30 km/h between two junctions	Identify where on the stretch the demand is met and how many percent that reach a velocity of at least 30 km/h
Mobility and flow	Be able to keep a minimum average velocity of 20 km/h on a 2000 m long stretch	Calculate the average velocity, the number of stops, the stops' duration and their locations along the stretch
Velocity distribution	Possibility to cycle in different velocities	Divide the velocities in interval (0-5 km/h, 5-10 km/h etc.) in order to visualize the velocity distribution along the stretch

4.2 Determination of programs

When the measurements for the functional demands were determined, the next step was to test possible programs for processing of the function's data. The purpose was to find one or more programs that manage to receive the desirable results, stated as measurements in Table 3 in section 4.1, to be able to control the functional demands.

4.2.1 Google Earth

As already mentioned in section 3.2.2, the data from the function arrives to the Traffic & Public Transport Authority in form of a GPX-file. This is a file format that may be directly opened in Google Earth, which therefore was the first program that was studied.

When the GPX-file is opened in Google Earth, the same data as the cyclist receives is shown. Besides the time, distance, average velocity and a map of the cycled route, elevation changes along the route are also visualized. In Appendix IV, an example of how a cycle route may look like in Google Earth is shown. Google Earth also shows a graph of the time, distance and velocity and elevation changes along the cycled stretch, which Appendix IV visualizes. However, the graph appeared to be visualized only for one GPX-file at time. Google Earth was thus not considered as an appropriate program for analyzing of the great number of files that the investigation along Nya Allén was expected to result in.

4.2.2 Excel and QGIS

Another program for visualization of the data is the GIS-program QGIS, which is further described in Appendix II. However, to directly open the GPX-files in QGIS appeared to be difficult although QGIS uses the file format. After further studies of QGIS, it was therefore decided to use it in combination with Excel. Excel manages to handle multiple GPX-files, unlike Google Earth, and to transform the data into another file format that can be opened in QGIS. Other advantages with Excel are its ability to organize the data and to perform necessary calculations in order to receive the desirable results.

When a GPX-file was opened in Excel instead of Google Earth, a difference in the displayed data was noticed; the velocities were replaced by latitude and longitude coordinates. This resulted in that the velocities had to be calculated.

4.3 Overview of the processing of data

In order to give an overview of how the data was processed, a brief description of the procedure is given in this section. The data was processed in the following order; Excel, QGIS, Excel, QGIS and eventually in Excel again, as Figure 11 below visualizes. A detailed description of the procedure can be found in Appendix I.

Figure 11 Flow chart of the procedure for processing of data. This chart does not consider the time spent in each step, only visualizes the order.

The processing of data was thus started in Excel in order to collect all the cycle routes, sort out relevant data and calculate the velocities. The velocities for all collected cycle routes were calculated according to the formula that can be seen in Appendix V. The file format was transformed into another file format and the file was thereafter opened in QGIS. In QGIS, a 40 meters wide buffer zone was created in order to sort out the points that interacted with the stretch Nya Allén. Before analyses of the data in QGIS could continue it was necessary to carry out minor adjustments in Excel. The file was thereafter reopened in QGIS, where the velocities were filtered by defining different criteria which sorted out velocities within specific intervals. All intervals of velocity were added as different layers, as can be seen in Figure 12 below. The velocity intervals were thereafter visualized on a map and the velocity distribution along Nya Allén could thus be analyzed. An example of how the velocities are shown in QGIS can be seen in Figure 13 below, where the dots represent velocities equal to 0 km/h.

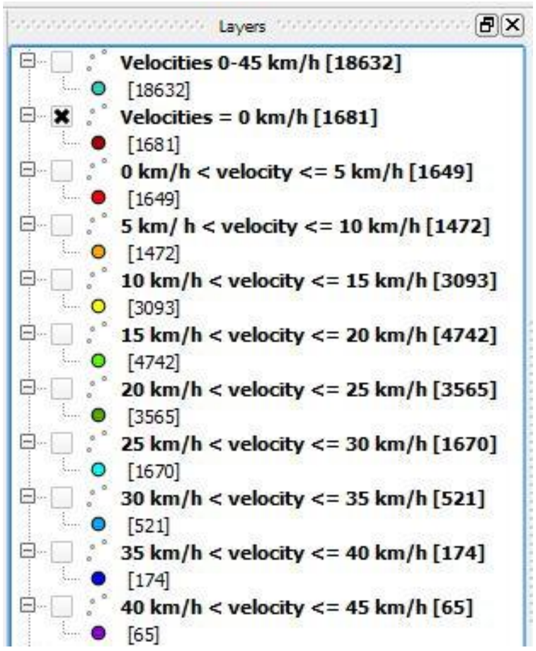

Figure 12 *The different intervals of velocities made it possible to visualize the velocity distribution along the stretch Nya Allén.*

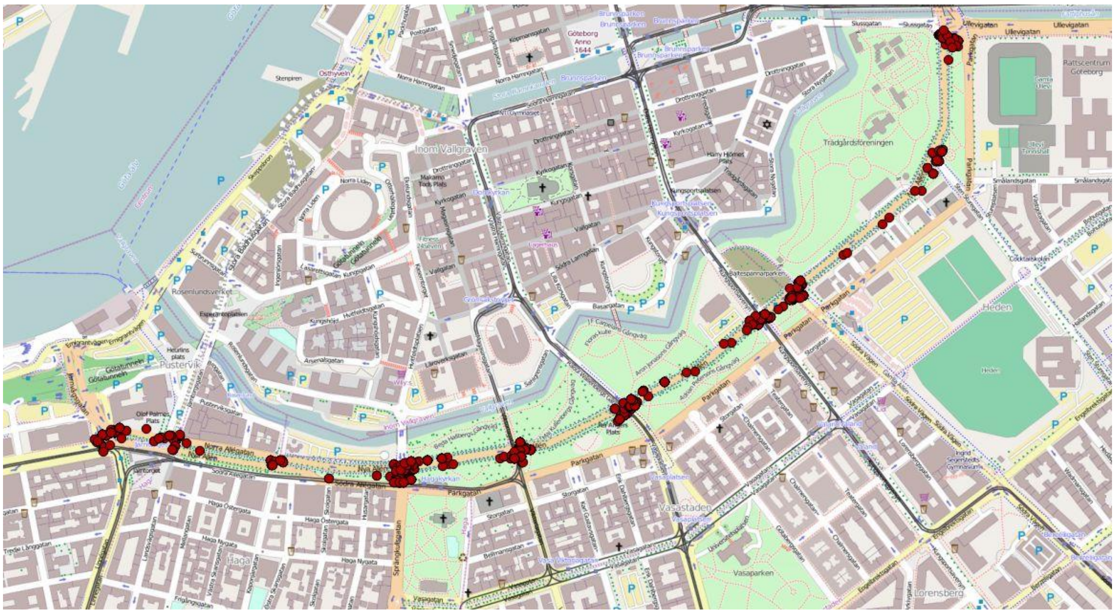

Figure 13 *The layer called Velocities = 0 km/h is shown as dots and visualize where the stops take place along the stretch Nya Allén.*

The layer that included all cycle routes within the chosen criteria, called *Velocities 0-45 km/h* in Figure 12, was further analyzed in Excel. This was done by copying the attribute table[3] of the layer in QGIS and pastes it into Excel. The data in this layer were the basis of the calculations that were carried out in Excel. Examples of what the calculations included are; average velocity, number of cycle routes, velocity distribution (illustrated in a table and a pie chart diagram) and percentage of time standing still (mean value). The results from the calculations are presented in Chapter 5. Additional calculations were also made, which results are included in the detailed description in Appendix I.

[3]Each layer is connected to an attribute table, which contains additional information of the layer.

5 Results

A total of 88 cycle routes, corresponding to 91265 points, were obtained during the two days when the investigation was performed. 16 of the files did not contain any data and were therefore excluded from further analysis. This resulted in 72 files, including 67 files that interacted with the stretch Nya Allén. The 67 files corresponded to 22084 numbers of registered points, of which 3461 points were removed due to their inaccurate content. This resulted in a number of 18632 points, which thus is the amount of points that have been analyzed. In Table 4, a summary of the number of received routes and their registered points is shown. The 67 cycle routes do not necessarily correspond to 67 cyclists, since a single cyclist might have cycled the stretch more than once.

Table 4 Summary of the number of received cycle routes and associated points.

Total number of received cycle routes	88
Total number of registered points	91265
Number of files containing no data	16
Number of cycle routes intersecting with Nya Allén	**67**
Total number of registered points along Nya Allén	22084
Number of points containing inaccuracies along Nya Allén	3461
Percentage of points containing inaccuracies	6.4 %
Number of analyzed points on the stretch Nya Allén	**18632**

Table 5 shows that velocities from 30 km/h up to 45 km/h have been reached in 762 points, which corresponds to a percentage of 4.1 percent. The locations of these points are visualized in Figure 14.

Table 5 Velocities between 30 km/h and 45 km/h.

Number of registered points	**Percentage of number of registered points [%]**
762	4.1

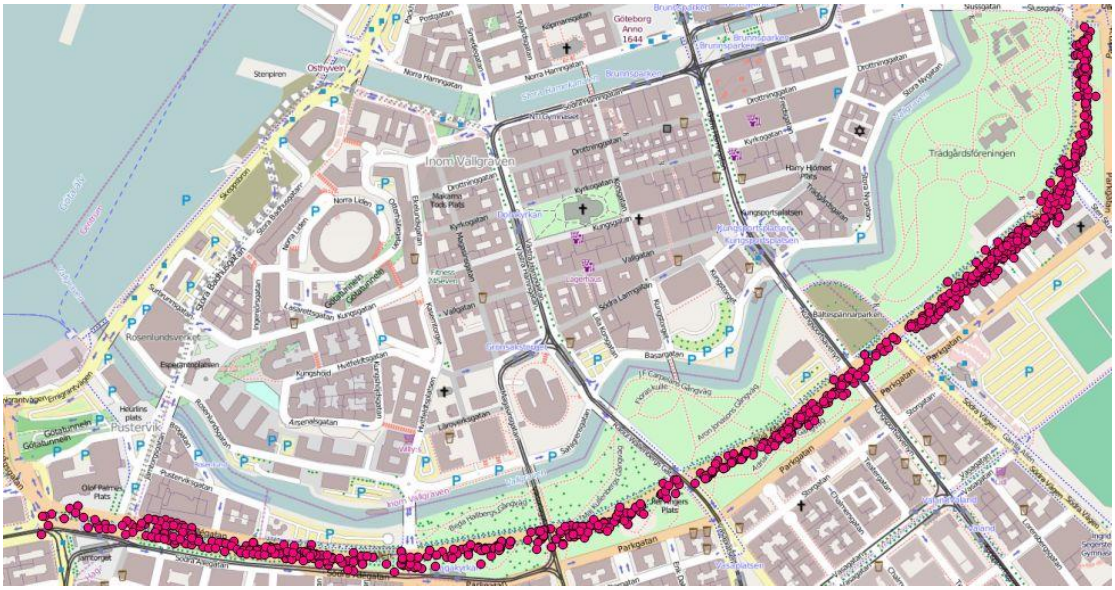

Figure 14 *The dots show where on the stretch velocities between 30 km/h and 45 km/h are achieved.*

The average velocity has been calculated in two ways; one where velocities of 0 km/h have been included and one where velocities of 0 km/h have been excluded. The two different average velocities are shown in Table 6 below.

Table 6 *Average velocity for the stretch Nya Allén.*

Average velocity [km/h]	
Included velocities of 0 km/h	15.5
Excluded velocities of 0 km/h	17.0

The time that each cycle route lasted for have been summarized and resulted in a total time for all the 67 cycle routes. The same procedure was done with the time of stops, which consequently resulted in a total time of stops for all registered cycle routes. This corresponds to that the duration of each stop, on an average, is equal to approximately 6 seconds. Hence the average time of stops per cycle route, i.e. the total time that each cyclist stood still along the stretch, corresponds to 28 seconds. The mentioned times are presented in Table 7 below.

Table 7 *Time data [hh:mm:ss]*.

Total time of all 67 cycle routes	05:40:30
Total time of stops for all 67 cycle routes	00:29:04
Average duration of each stop	00:00:06
Average time of stops per cycle route	00:00:28

Another way of showing how much of the time that the cyclists, on an average, stood still is by using percentage. When the total time of stops, i.e. the time when the cyclists stands still, was set in relation to the total time that the cyclists have cycled, it corresponded to 9 percent. The total number of stops for all 67 cycle routes and how many times, on an average, each cyclist had to stop along the stretch can be seen in Table 8. Furthermore, the locations of the stops along Nya Allén are visualized in Figure 15.

Table 8 – Stops along the stretch Nya Allén.

Number of stops	312
Average number of stops per cycle route	4.7

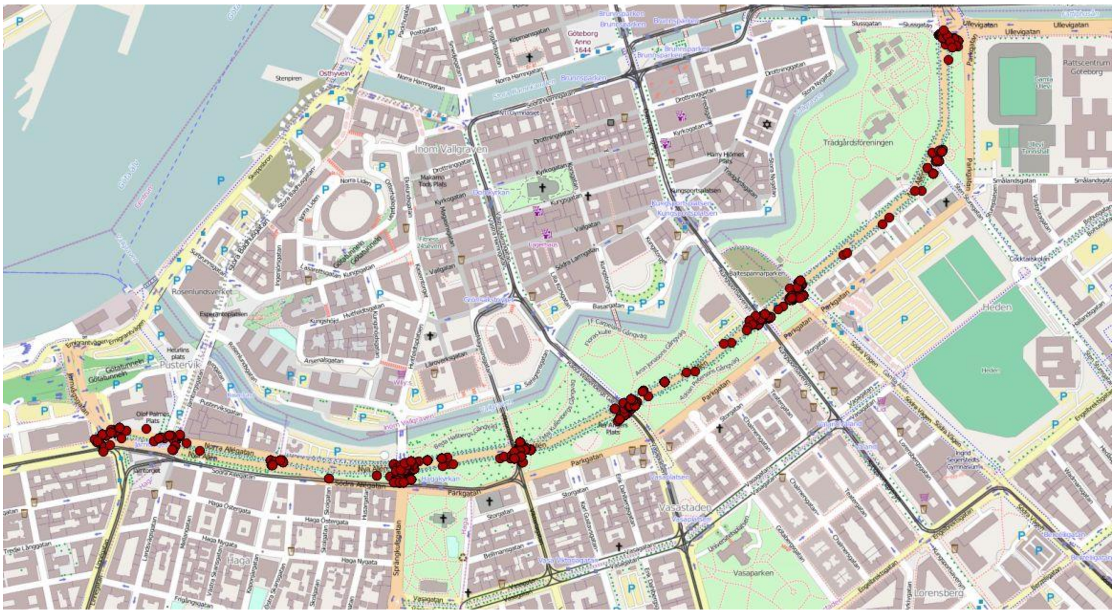

Figure 15 The dots show where on the stretch the stops are located.

The velocity distribution, represented by the number of registered points and by a percentage for each velocity interval, is shown in Table 9 and Figure 16. The locations of each velocity interval are shown in Figure 15 above and Figure 17 – Figure 25 below.

Table 9 Velocity distribution.

Velocity distribution [km/h]	Number of registered points	Percentage of number of registered points
0	1681	9.0
0 < velocity ≤ 5	1649	8.9
5 < velocity ≤ 10	1472	7.9
10 < velocity ≤ 15	3093	16.6
15 < velocity ≤ 20	4742	25.5
20 < velocity ≤ 25	3565	19.1
25 < velocity ≤ 30	1670	9.0
30 < velocity ≤ 35	521	2.8
35 < velocity ≤ 40	174	0.9
40 < velocity ≤ 45	65	0.3

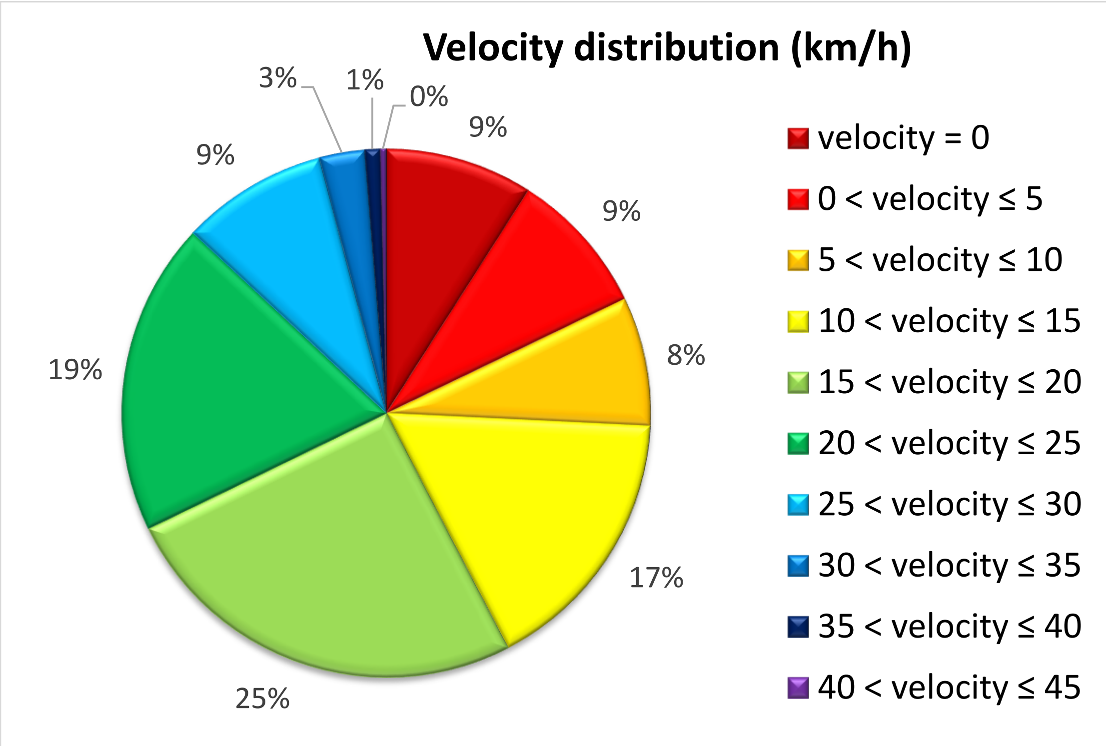

Figure 16 Velocity distribution visualized in a pie chart diagram.

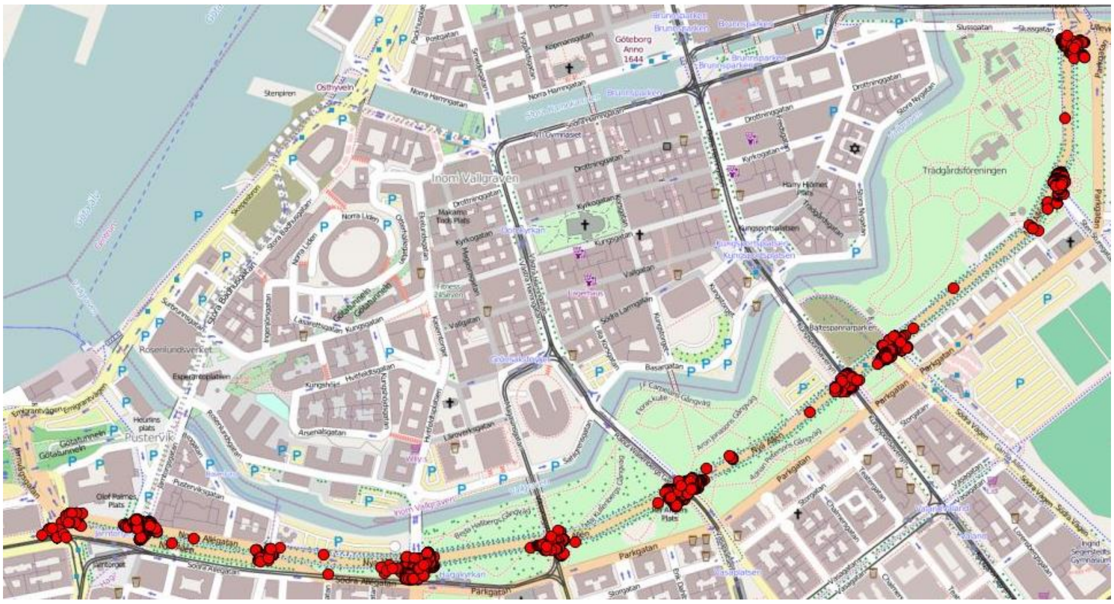

Figure 17 *The distribution of velocities higher than 0 km/h and lower or equal to 5 km/h along the stretch Nya Allén.*

Figure 18 *The distribution of velocities higher than 5 km/h and lower or equal to 10 km/h along the stretch Nya Allén.*

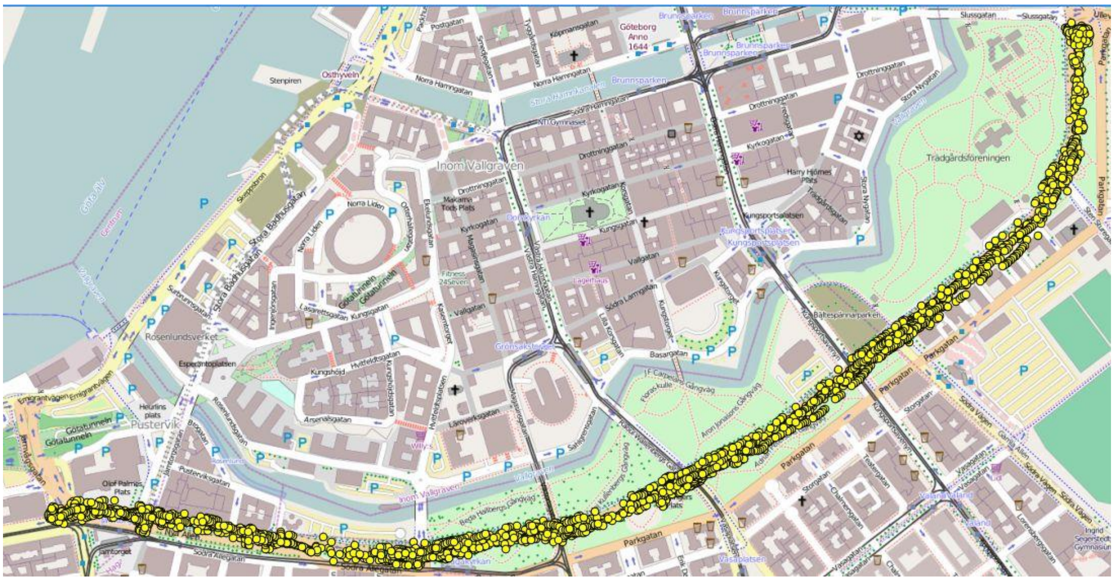

Figure 19 The distribution of velocities higher than 10 km/h and lower or equal to 15 km/h along the stretch Nya Allén.

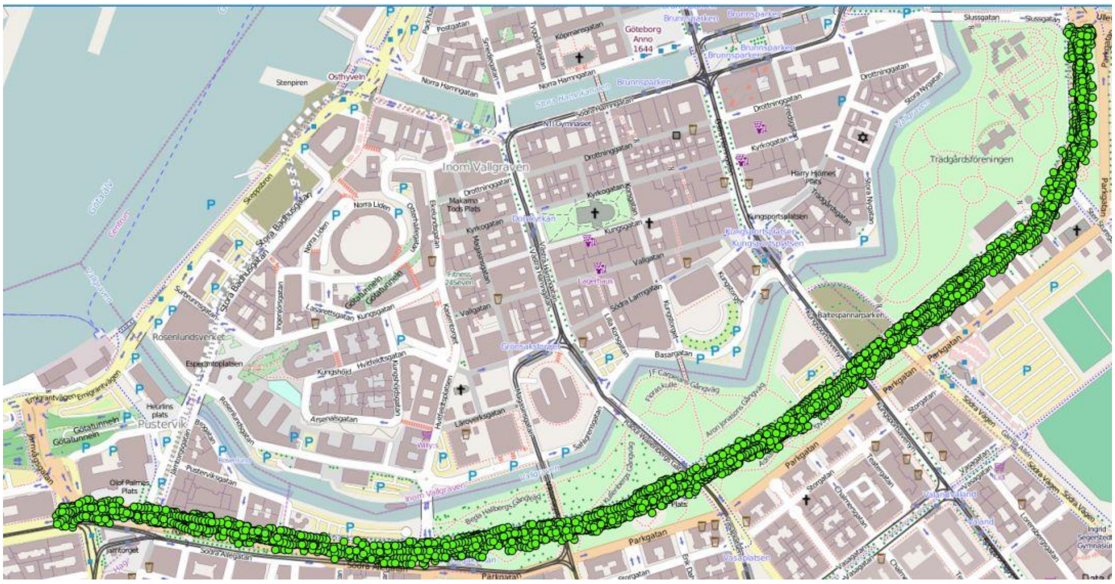

Figure 20 The distribution of velocities higher than 15 km/h and lower or equal to 20 km/h along the stretch Nya Allén.

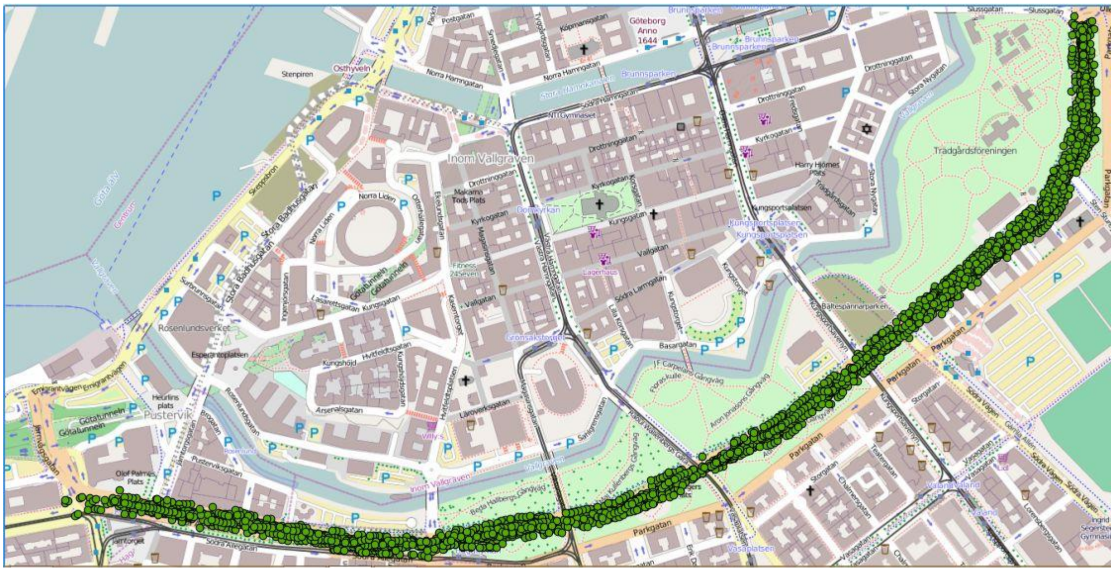

Figure 21 The distribution of velocities higher than 20 km/h and lower or equal to 25 km/h along the stretch Nya Allén.

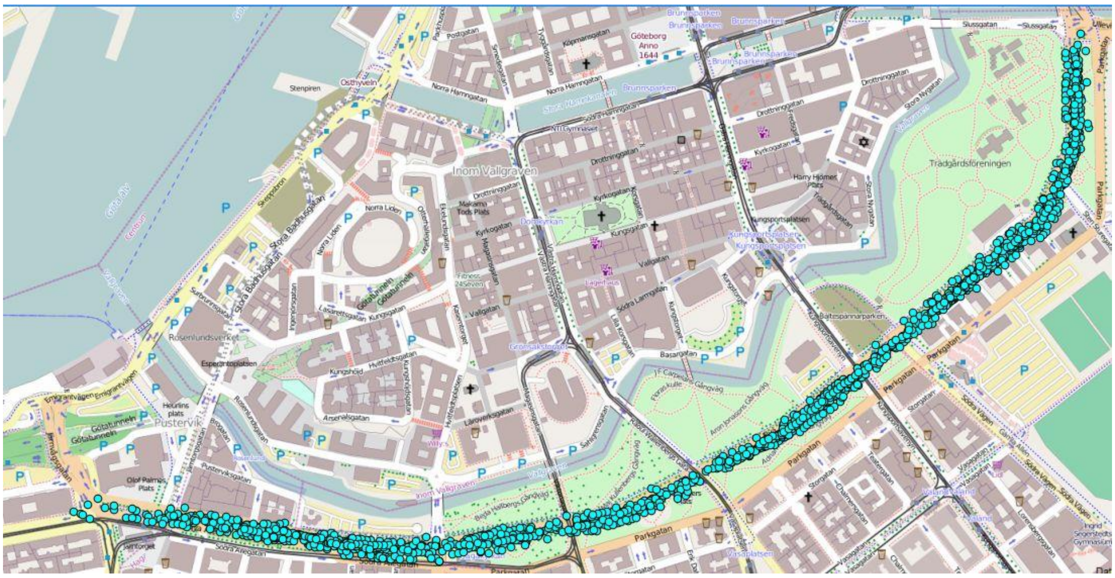

Figure 22 The distribution of velocities higher than 25 km/h and lower or equal to 30 km/h along the stretch Nya Allén.

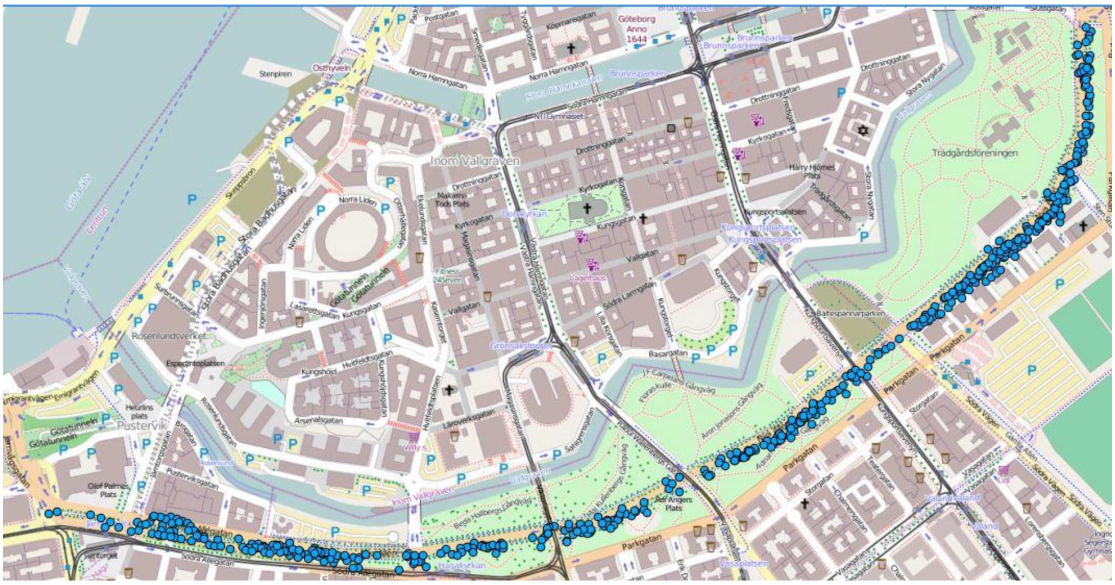

Figure 23 *The distribution of velocities higher than 30 km/h and lower or equal to 35 km/h along the stretch Nya Allén.*

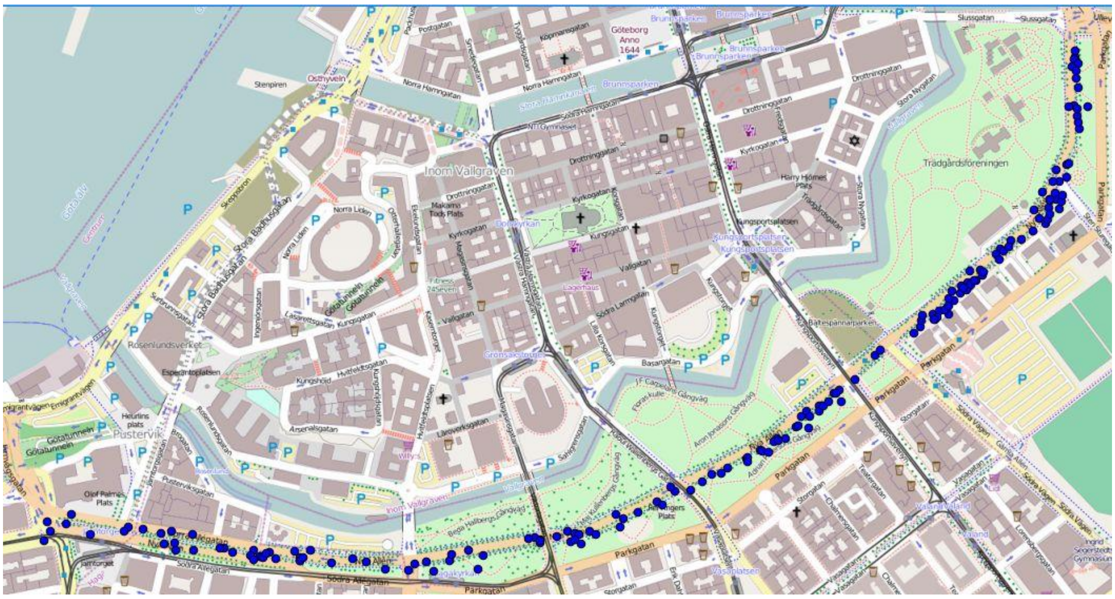

Figure 24 *The distribution of velocities higher than 35 km/h and lower or equal to 40 km/h along the stretch Nya Allén.*

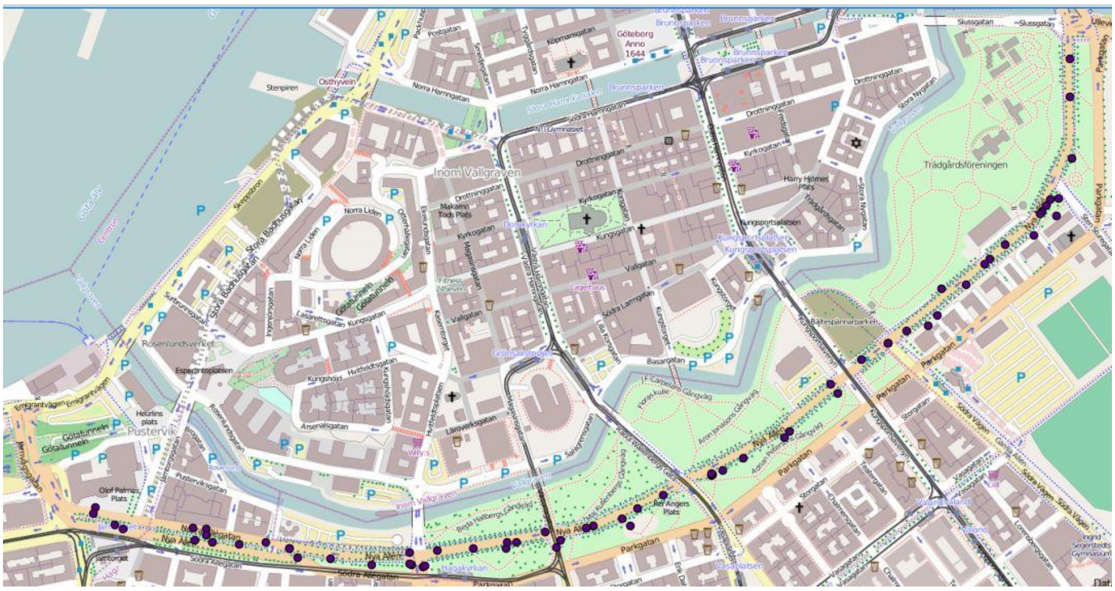

Figure 25 *The distribution of velocities higher than 40 km/h and lower or equal to 45 km/h along the stretch Nya Allén.*

6 Analysis

Figure 14 in Chapter 5 shows that velocities within the interval 30-45 km/h are located along the entire stretch Nya Allén, which indicates that the functional demand connected to velocity is fulfilled. Of the total number of registered points along the stretch, 4.1 percent of these are representing velocities within the interval. The rather low percentage is probably due to several factors, such as weather conditions, design of the bicycle track and its junctions, the flow of cyclists, interaction with other road users etc. These factors may prevent the cyclists' possibility to cycle in the relatively high velocity of 30 km/h. However, the result implies that the ability to cycle in a velocity of at least 30 km/h still exists and the functional demand connected to velocity is thereby considered to be fulfilled.

The functional demand connected to mobility and flow is defined in the following way; b*e able to keep a minimum average velocity of 20 km/h on a 2000m long stretch.* According to Table 6 in Chapter 5 the average velocity, including and excluding velocities equal to 0 km/h, is 15.5 km/h respectively 17.0 km/h for the 1985 meter long stretch Nya Allén. The average velocity for the stretch, in both cases, is lower than the defined minimum average velocity of 20 km/h and the functional demand is thus not fulfilled. The average velocity of 15.5 km/h is obviously affected by the number of stops and the average time that the cyclists stood still along the stretch. The relatively high number of 4.7 stops per cycle routes is probably due to the many crossings located along the stretch, as Figure 15 in Chapter 5 shows that most of the stops occur in connection with these crossings. However, each crossing does not necessarily imply that the cyclist need to stop but simply a decrease in velocity might be enough. This can be seen in Chapter 5 in Figure 17 and 18, which show that even velocities greater than 0 km/h and up to 10 km/h mainly are located at crossings. The average velocity of 17 km/h thus also seems to be affected by the crossings, where the cyclists interact with other road users and therefore often need to reduce their velocity. Another design of the junctions along Nya Allén, where cyclists would be prioritized, may contribute to a higher average velocity.

In order to evaluate the functional demand connected to the velocity distribution, specific intervals were defined and the number of registered points in each interval was calculated. As can be seen in both Table 9 and Figure 16 in Chapter 5, most points are found within the intervals $15 < velocity \leq 20$, $20 < velocity \leq 25$ and $10 < velocity \leq 15$ which corresponds to percentages of 25.5, 19.1 respectively 16.6. This indicates that the most common velocities along the stretch are between 10 - 25 km/h. The location of these velocities can be found along the entire stretch, as Figure 19 – 21 in Chapter 5 shows. The results also show that all of the ten velocity intervals include registered points, which indicates that it is possible to cycle in a wide range of velocities along the stretch. Thereby, the functional demand regarding velocity distribution is considered as fulfilled.

The result shows that 16 of the 88 cycle routes did not contain any data, which probably is connected to the smartphones' GPS. The GPS must in fact be running simultaneously as the function *Min cykeltur*, otherwise no points will be registered. However, as many as 3461 number of points, corresponding to 6.4 percent, contained inaccurate data. This indicates that, even when the GPS has been running, it may still result in points with errors. The points with inaccurate velocities and time differences were however easily removed and have consequently not affected the results. The results, received from the data included in the remaining 18632 number of points, are therefore considered to be reliable. Thereby, the function *Min cykeltur* seems to be a usable tool in order to evaluate data regarding how, where and when people cycle.

7 Discussion

This chapter will discuss the different parts in this MSc thesis and critically examine the performance of the entire thesis.

7.1 The development of the new bicycle plan and its content

The Traffic & Public Transport Authority's work to develop a new bicycle plan was, and still is, an ongoing process throughout the conduction of this MSc thesis. Most of the information regarding the plan was obtained by interviews and literature studies of unfinished documents, which included preliminary and not completely established material. Chapter 2 in this MSc thesis thus describes the current content of the bicycle plan, which may differ from the content of the completed bicycle plan. An example of a possible change of the bicycle plan is which bicycle tracks that will be part of the commuter cycling network. As the results of this MSc thesis indicate that Nya Allén does not fulfill the functional demand connected to mobility and flow, the bicycle track may be excluded from the commuter cycling network in the future. Another possibility may be to lower the demand, since the results show that a velocity of 20 km/h seems to be a relatively high velocity for cyclists to attain on a stretch like Nya Allén. The same argument could be applied for the other functional demands, analyzed in this MSc thesis, which also might be in need of adjustments.

7.2 The performance of the investigation along Nya Allén

One of the difficulties with the investigation was to evolve cyclists to participate. Even though several cyclists were informed in person and many of them seem to react positive to the investigation, it still resulted in a relatively low number of cycle routes. The expectation was to receive a significantly higher number of participants, at least about 200 cyclists, in order to obtain a more representative result. However, the fact that the app *Cykelstaden* with its function *Min cykeltur* was launched quite recent probably resulted in that many of the cyclists were not aware of that the app's existence. If more cyclists had been familiar with the app, it might have resulted in more participants.

Another aspect that probably affected the number of participants is that the information about the investigation was emailed and published merely a week in advance. The idea of informing the cyclists on site came up even later, unfortunately, and thus the cyclists got the information in person the same two days that the investigation was performed. If the investigation would be repeated in the future, the cyclists would be informed far further ahead and the information on site would probably be prioritized.

During the two days of the investigation, the weather was not optimal for cycling; quite cold, windy and light rain showers. This is yet another factor that most likely has influenced the number of participants and more people had probably cycled if the investigation was performed later in the spring. The time limit for this MSc thesis was however the reason why the investigation was carried out as early, since a lot of time was needed for processing of the data and for the analysis.

To be able to perform the investigation and to come up with a result within the time that this MSc thesis was going for, it was decided to focus at the bicycle track Nya Allén. Hopefully, the function *Min cykeltur* also could be used to collect information about cyclists independent of where they cycle. The entire bicycle network in Gothenburg could then be planned and designed based on actual facts about how, when and where the cyclists are moving. In turn, this would facilitate the Traffic & Public Transport Authority's work with bicycle planning and most likely result in that the bicycle network would be more adapted to the cyclists' needs. This would though result in a much greater volume of data to handle and a more smooth method may therefore be preferable, since the current method might be too time consuming.

Another decision that was made was to limit the duration of the investigation to only two days. This is due to that there were uncertainties regarding the time consumption of handling the data and it was therefore desirable to start with the processing as soon as possible, in order to avoid delays. Uncertainties regarding how much data, i.e. how many participants, the investigation would result in was also a reason for this limitation of two days. The current method was expected to manage up to around 500 participants, i.e. 500 GPX-files, before the time of processing the data would be too long and the risk for delays would be too high. To evolve more than 500 cyclists to participate in a two days long investigation did not seem reasonable and the duration of the investigation was therefore set to two days.

7.3 Choice of method for the processing of data

A major part of this MSc thesis describes the method that has been used to handle the incoming data from the function. The very detailed description in Appendix I will hopefully enables the Traffic & Public Transport Authority to follow each step and redo the process. Appendix I also aims to be a help for the Traffic & Public Transport Authority to understand exactly how the data have been processed, which might make it easier to find out how the method could be improved. As the method in this MSc thesis only is an initial proposal, several improvements and alternative methods could be invented. The current method is quite long and could most likely be shortened in many ways, maybe by using other programs or by programming a new program. However, even though the method is not optimized, the processing of data in Excel and QGIS did deliver the requested results. Thereby, the method described in this MSc thesis is usable and does fulfill its purpose.

7.4 Handling of inaccuracies and reliability of the results.

As mentioned in Appendix I, the incoming data from the function sometimes contained errors regarding registration of coordinates, the time difference and velocity. Poor quality and connection errors of the GPS in the smartphones are probably the most crucial factors why these errors occur. Some of the incoming GPX-files were completely empty, i.e. did not contain any registered points at all, which probably also depends on connection errors of the GPS in the smartphones. In this case, the cyclists have probably started the function without waiting for the GPS to start. The function has consequently been running without the GPS, which results in that the function cannot register any points and the incoming file will thereby be empty. To prevent these empty files, the function might be programmed so that it cannot be started before the GPS has achieved sufficient accuracy.

A part of the processing of the incoming data included the creation of a buffer zone, in order to sort out the points that interacted with the stretch Nya Allén. The buffer zone was determined to be 40 meters wide, i.e. 20 meters on each side of the bicycle track, due to the fact that several of the registered points were located a few meters beside the bicycle track. As these points were connected to realistic velocities, it indicated that only the coordinates had been improperly registered and the points thus seemed reasonable to include in the analysis. The dislocations of these points were probably, again, caused by the smartphones' GPS, where a higher quality of the GPS may have placed more points on the bicycle track instead of beside it. However, an important and crucial factor regarding the reliability of the investigation in this MSc thesis was, as mentioned in section 7.2, the amount of participants. The relatively low amount of participants in the investigation made each cycle route, and its corresponding data, particularly important to take into account. A less wide buffer zone would have given much fewer points to analyze, which in turn would have given less representative results. Another reason for having a 40 meters wide buffer zone was thus to obtain more points, in order to receive as trustworthy results as possible.

One way to remove inaccuracies was to set up a velocity criterion, which sorted out the velocities that were considered as reasonable. Velocities lower than 0 km/h had been registered, which obviously was not reasonable and thereby had to be excluded by the velocity criterion. On a stretch like Nya Allén, where different types of road users are sharing the space and several crossings have to be passed, velocities greater than 45 km/h were not considered as very likely. The velocity criterion was therefore chosen to include velocities within the interval 0-45 km/h, which resulted in that inaccuracies were greatly reduced. This criterion was chosen despite the fact that not all of the velocities higher than 45 km/h might have been improperly registered, but might instead belong to cyclists who actually kept a velocity higher than 45 km/h. Most of the velocities excluded by the criterion are, however, far greater than 45 km/h, which most likely is a result of inaccurate data regarding registration of coordinates. Thereby, only a small amount of the excluded velocities are considered as reliable and the chosen criterion has simply a minor impact of the final results regarding velocities.

The buffer zone and the velocity criteria was not enough in order to sort out the correctly registered points, but a criterion for the time difference between the points was also necessary. As mentioned in section 3.2.2, the function *Min cykeltur* is programmed to register a new location (point) every second. However, observations of the registered data showed that the time difference between registrations of points sometimes was far longer than one second. The great time differences affected the velocities, which in turn would affect the final result regarding velocity distribution, mean velocity etc. The time difference criterion was set to be 1-60 seconds, since the other connected data, such as velocities and coordinates, of points with a time difference of up to 60 seconds appeared to be realistic. It would have been preferable to instead set up a criterion that included only time differences of 1 second, as the function is programmed to register points every second, but this had resulted in a smaller amount of points to analyze. If more cyclists had participated in the investigation, more points had been registered and the criterion of 1 second may have been chosen in order to get the most reliable points.

7.5 Possibilities with the method and the generated data from the function *Min cykeltur*

It would have been interesting to investigate is how the mean velocity and velocity distribution along the stretch would had changed during a day. It would then have been possible to see if the functional demands were fulfilled throughout the whole day or only for some hours a day. For instance, maybe the demands are fulfilled during the day traffic but not during the morning or afternoon traffic when most of the bike commuters are cycling. To analyze how the velocity changes during a day is possible by defining different time criteria, in the same way as for the velocity and time difference. This analysis was, however, not performed in this MSc thesis, due to the low amount of participants in the investigation. The same applies for evaluation of possible connections between ages, gender and velocity, an analysis which could have been performed according to Figure 100 and Figure 101 in Appendix I. Neither this analysis was performed, due to that most of the participants in the investigations did not state their gender and age.

It would also be interesting to investigate where most of the stops occur, i.e. where the concentration of stops is highest. This analysis could have been carried out by creating many smaller buffer zones around each junction, since most of the stops along Nya Allén seemed to occur in connection to the crossings. Another possibility could be to create a so called heat map that visualizes where the highest/lowest concentrations of a chosen attribute occur, by coloring areas in different colors. The economic aspect of the stop time could also be interesting to analyze, as long durations of stops may contribute to a cost for the society. Long durations of the stops also lead to unhappiness among the cyclists, which is not preferable when an increase of cycling in Gothenburg is requested.

Another possible aspect that would be interesting to take into account is the changes in elevation that the function provides, where possible connections between elevation and, for instance, velocity could be analyzed. However, no method for how this analysis may be performed has been developed in this MSc thesis. This is due to that the elevations seemed to have different scales, maybe dependent on the type of smartphone, when the files were opened in Excel. This made it difficult to understand exactly what the elevation showed and also to determine a way to process the data. The exception was if the files were opened in Google Earth, where the evaluation changes could be seen in a diagram according to the Figure in Appendix IV.

In further studies of the function it had been interesting to perform the investigation in a larger geographical scale, e.g. for all or several bicycle tracks in Gothenburg. The entire stretch that each cyclist cycle could thereby be investigated and the location of the start and end point of each cycle route could be determined. It would also be interesting to compare one day to another, one week to another etc., in order to evaluate if and in that case how, for instance, the weather condition influences the velocities and cycling patterns.

8 Conclusion

The results from the investigation along the stretch Nya Allén show that the functional demands connected to velocity and velocity distribution are fulfilled. Regarding the third functional demand, the one connected to mobility and flow, the junctions along Nya Allén is probably the main reason for why the demand cannot be met. The method for processing of data, developed in this MSc thesis, managed to remove inaccurate data and delivered the requested results. This method is therefore considered as usable, although improvements might be necessary for analyses of greater volume of data. The analyses performed in this MSc thesis indicate that the function *Min cykeltur* can be used as a tool to evaluate how, where and when people cycle. The function may thereby form a basis for bicycle planning and enables the Traffic & Public Transport Authority to design the bicycle infrastructure based on actual facts about the cyclists' movement patterns.

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Appendix I – Method for processing of data

This appendix contains a detailed description of the method that has been used to process the incoming data from the function.

1. Excel

The first step was to open one of the GPX-files, i.e. a cycle route, as a XML-table in Excel. The content of the GPX-file was shown as a table with a number of rows and columns. The rows represented all registered points along the cycle route and the columns contained different types of information connected to each point. In order to separate all cycle routes, and simplify the processing of data later in the analysis, a new column named *ID* was created. The same procedure, i.e. to open the GPX-file in Excel and create the ID-column, was done one by one for all cycle routes. Each cycle route was given a unique ID number, where the first opened GPX-file was given number 1, the second number 2 etc.

It was noticed that variations in the GPX-files regarding the order of the elevation column and the time column, named *ns1:ele* and *ns1:time* in Figure 26, could appear. In the GPX-file shown in Figure 26, column I contains the elevation and column J contains the time. In other GPX-files, these columns might have switched places. The order of these columns was therefore controlled, and modified where necessary, in order to make sure that each Excel sheet had the same structure.

All GPX-files were thereafter pasted separately into the same Excel sheet, in order to create one uniform table. The rows were then sorted after ID number, from lowest to highest. Column B, C, F and I, seen in Figure 26, were removed since they contained irrelevant information for the analysis in this MSc thesis. After these adjustments, the Excel sheet looked as in Figure 27.

A	B	C	D	E	F	G	H	I	J
ID	creator	ns1:name	ns1:name2	ns1:cmt	ns2:DisplayColor	lat	lon	ns1:ele	ns1:time
1	http://dlg.krakow.pl/gpx	iPhone - 7.0.2	iPhone - 7.0.2	underbart sopat hela väge	Green	57,66115522	11,86424254	19,59893799	2014-03-19 06:54
1	http://dlg.krakow.pl/gpx	iPhone - 7.0.2	iPhone - 7.0.2	underbart sopat hela väge	Green	57,66115522	11,86424254	19,7802124	2014-03-19 06:54

Figure 26 The headlines and content before adjustments.

	A	B	C	D	E	F
1	ID	ns1:name2	ns1:cmt	lat	lon	ns1:time
2	1	iPhone - 7.0.2	underbart sopat hela väge	57,66115522	11,86424254	2014-03-19 06:54
3	1	iPhone - 7.0.2	underbart sopat hela väge	57,66115522	11,86424254	2014-03-19 06:54

Figure 27 The headlines and content after adjustments.

As can be seen in Figure 27 above, column F contained both date and time. It was desirable to separate this column into one column containing date and one column containing time. This was done by the commando called *Text To Columns* and the procedure is described step by step in Figure 28 - Figure 32 below.

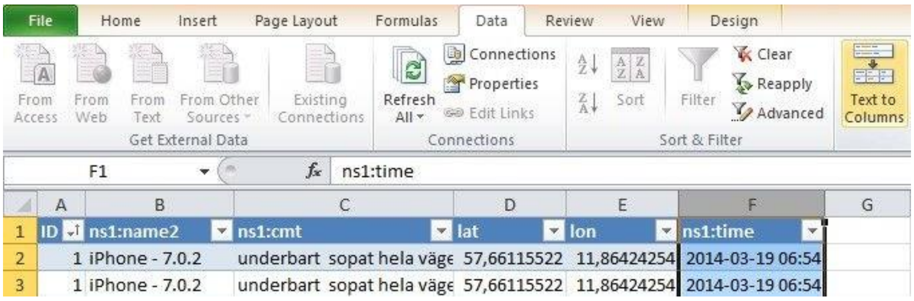


Figure 28 Mark column F and click on the command “Text To Columns”.

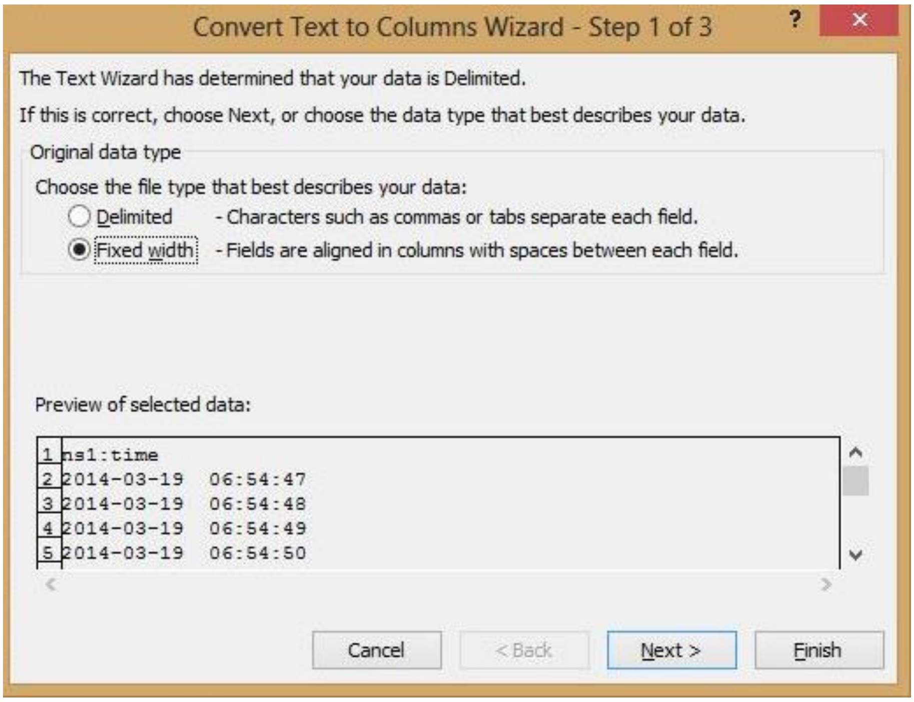


Figure 29 Check the box “Fixed width” and click "Next".

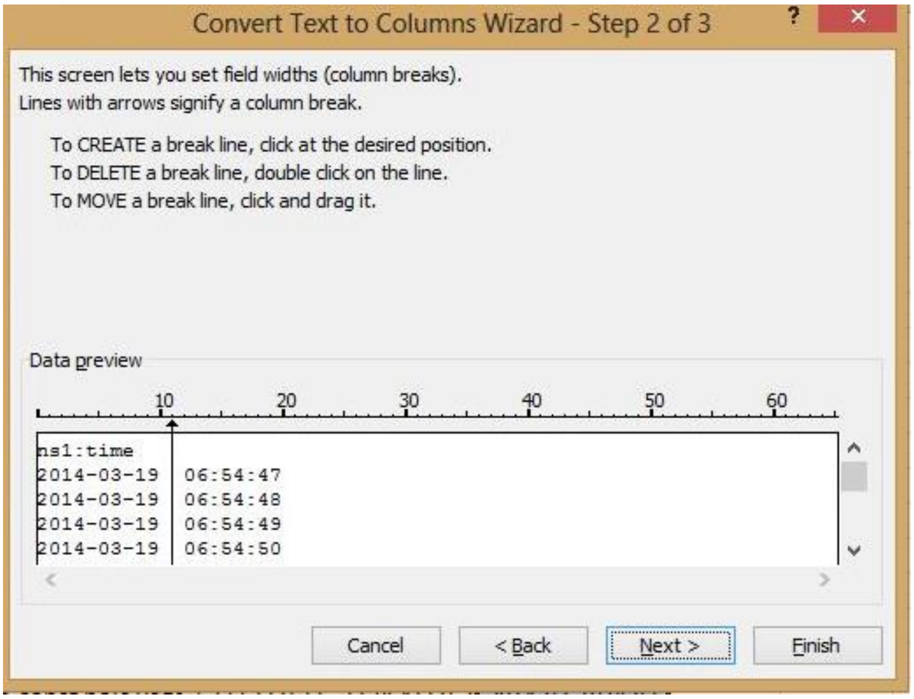


Figure 30 *Mark the position of the column break by clicking between the date and time in the field called "Data preview". Click "Next".*

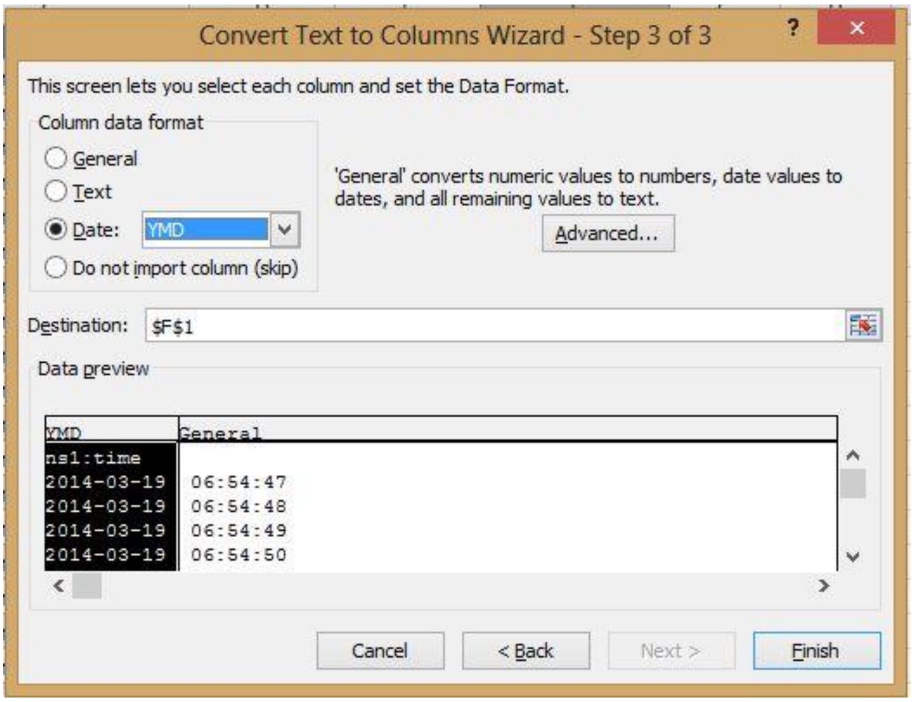


Figure 31 *Mark the column named "ns1:time" and check the box called "Date". The format YMD (Year Month Day) was chosen.*

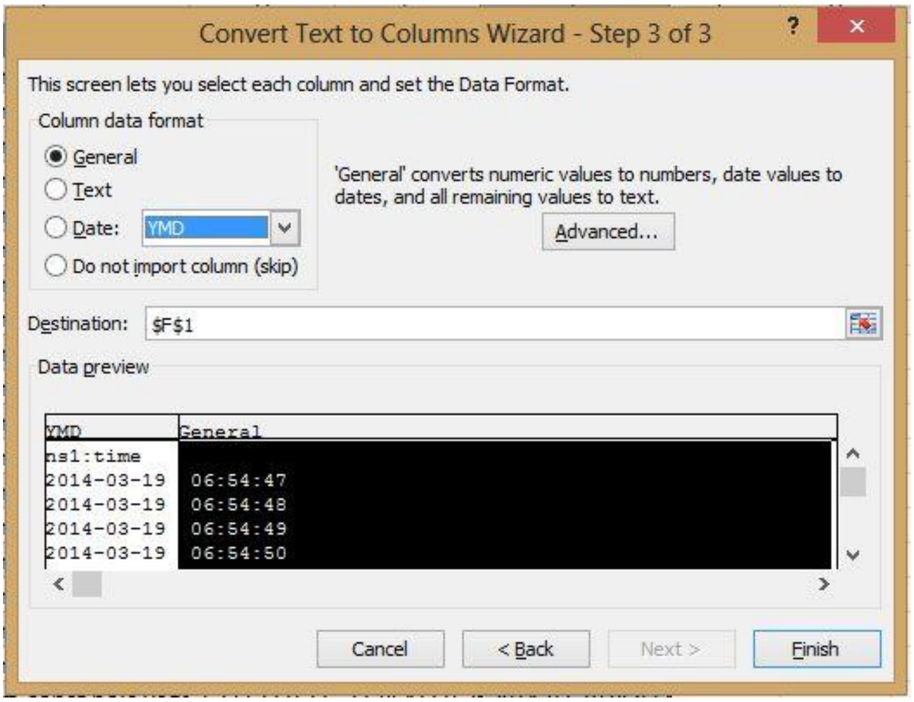
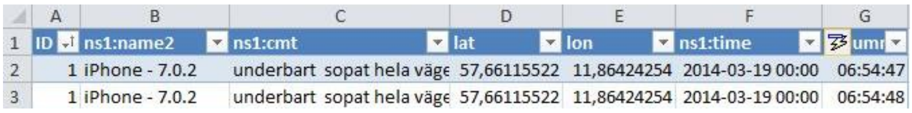


Figure 32 Mark the column named "General" and check the box called "General". Click on "Finish".

One column containing date and one column containing time had now been created, seen as column F and column G in Figure 33. However, the date in column F was followed by *00:00:00* which had to be removed. This was done by using the function *Find and Replace*, according to Figure 34 – Figure 38.



	A	B	C	D	E	F	G
1	ID	ns1:name2	ns1:cmt	lat	lon	ns1:time	umr
2	1	iPhone - 7.0.2	underbart sopat hela väge	57,66115522	11,86424254	2014-03-19 00:00	06:54:47
3	1	iPhone - 7.0.2	underbart sopat hela väge	57,66115522	11,86424254	2014-03-19 00:00	06:54:48

Figure 33 Column F contained date and "00:00:00" and column G contained time.

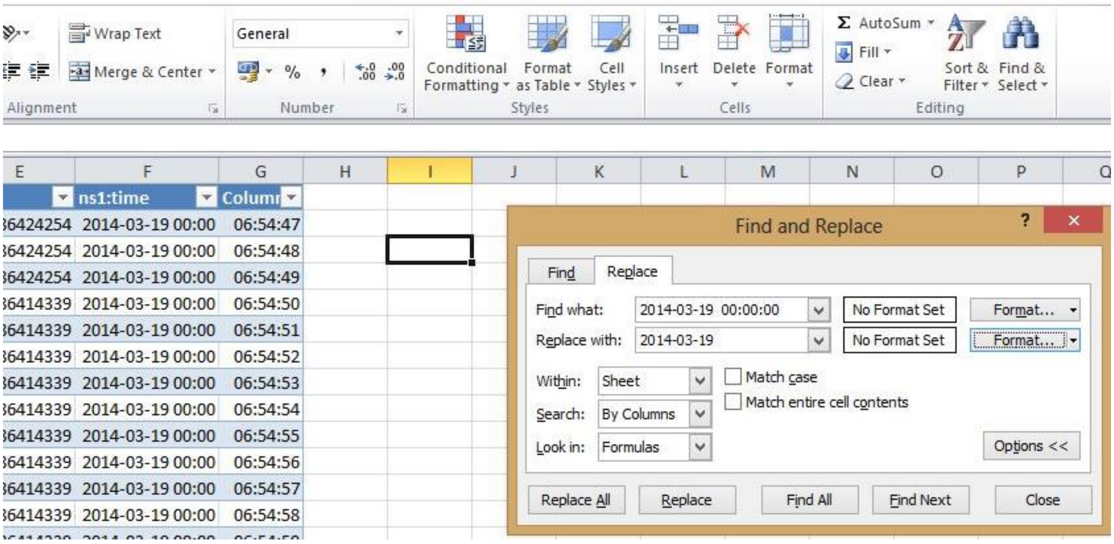


Figure 34 *Click on "Find & Select", under the tab “Start”, and then chose "Find and Replace". Type in what to find and what to replace with as in the Figure.*

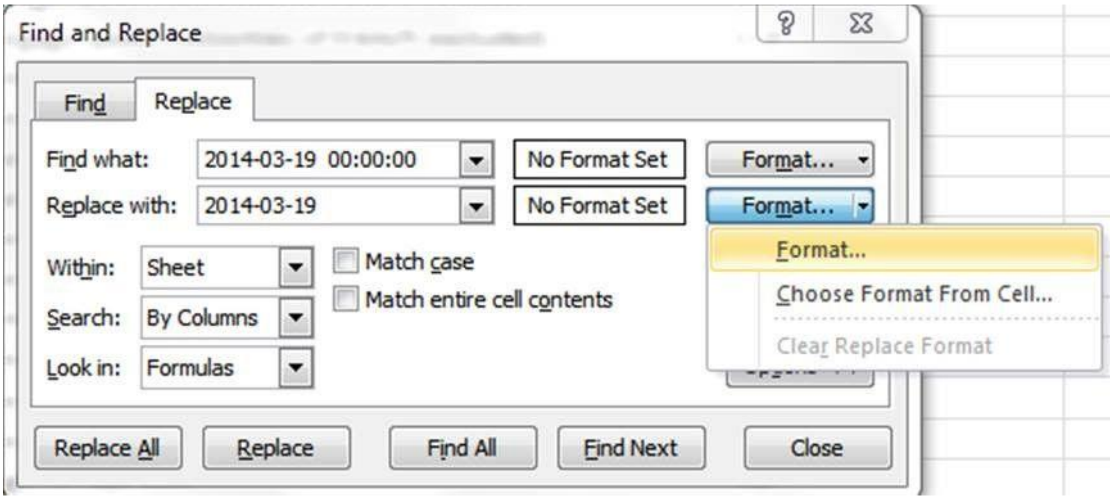


Figure 35 *Change the format of the cells which were to be replaced by clicking on “Format...”.*

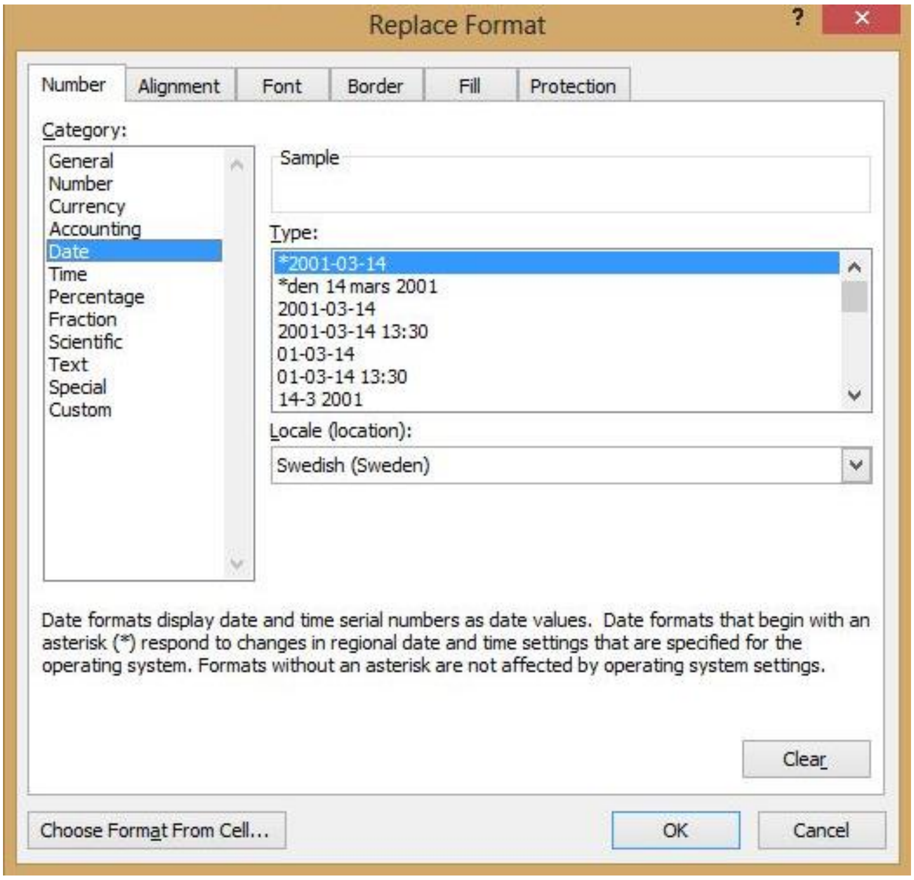


Figure 36 *Choose the following format of the date; "*2001-03-14" and click "OK".*

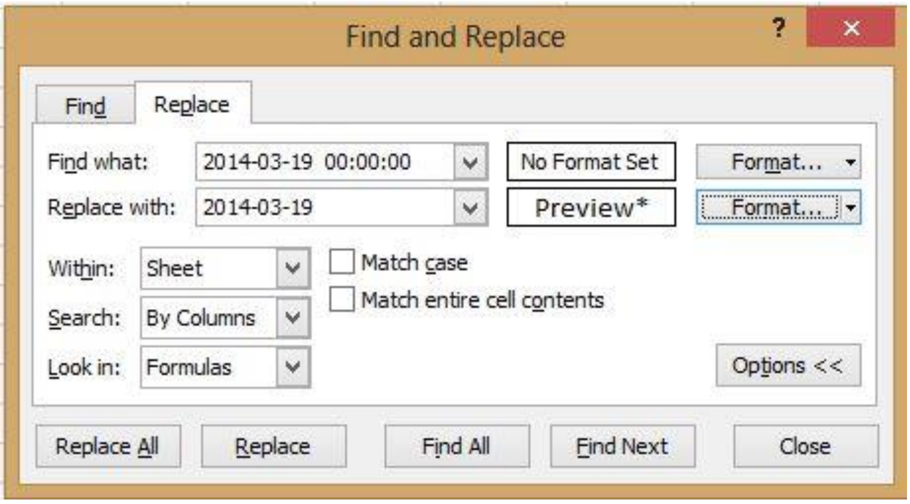


Figure 37 *Click on "Replace All" and do the same procedure for the date 2014-03-20.*

	A	B	C	D	E	F	G
1	ID	ns1:name2	ns1:cmt	lat	lon	ns1:time	Columr
2	1	iPhone - 7.0.2	underbart sopat hela väge	57,66115522	11,86424254	2014-03-19	06:54:47
3	1	iPhone - 7.0.2	underbart sopat hela väge	57,66115522	11,86424254	2014-03-19	06:54:48

Figure 38 Column F now contained only the date.

The headlines of the remaining columns were thereafter renamed, in order to clarify the content of each column, and three new columns, called *Distance*, *Time difference* and *Time*, were added. Now, the Excel sheet looked as Figure 39 shows.

	A	B	C	D	E	F	G	H	I	J
1	ID	Type of smartphone	Comment	Latitude	Longitude	Date	Time	Distance	Time difference	Velocity
2	1	iPhone - 7.0.2	underbart sopat hela	57,66115522	11,86424254	2014-03-19	06:54:47			
3	1	iPhone - 7.0.2	underbart sopat hela	57,66115522	11,86424254	2014-03-19	06:54:48			

Figure 39 Renaming of the columns and addition of the columns named "Distance", "Time difference" and "Velocity".

The next step was to calculate distance, time difference and velocity between each point. The distance between each point was calculated according to a distance formula, including the radius of the Earth, Pi and latitude and longitude coordinates. The distance formula can be seen in the formula field in Figure 40 below and is further explained in Appendix V. The time difference between each point was calculated according to Figure 41.

H3 fx =(ACOS(SIN(RADIANS(D2))*(SIN(RADIANS(D3)))+(COS(RADIANS(D2)))*(COS(RADIANS(D3)))*(COS(RADIANS(E2-E3)))))*6368000

	A	B	C	D	E	F	G	H	I	J	K	L
1	ID	Type of smartphone	Comment	Latitude	Longitude	Date	Time	Distance	Time difference	Velocity		
2	1	iPhone - 7.0.2	underbart sopat hela	57,66115522	11,86424254	2014-03-19	06:54:47					
3	1	iPhone - 7.0.2	underbart sopat hela	57,66115522	11,86424254	2014-03-19	06:54:48	0				
4	1	iPhone - 7.0.2	underbart sopat hela	57,66115522	11,86424254	2014-03-19	06:54:49	0				
5	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:54:50	7,0167729				
6	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:54:51	0				
7	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:54:52	0				

Figure 40 The distance formula is shown in the formula field on top of the figure.

SIN fx =[@Time]-G2

	A	B	C	D	E	F	G	H	I	J
1	ID	Type of smartphone	Comment	Latitude	Longitude	Date	Time	Distance	Time difference	Velocity
2	1	iPhone - 7.0.2	underbart sopat hela	57,66115522	11,86424254	2014-03-19	06:54:47			
3	1	iPhone - 7.0.2	underbart sopat hela	57,66115522	11,86424254	2014-03-19	06:54:48	0	=[@Time]-G2	
4	1	iPhone - 7.0.2	underbart sopat hela	57,66115522	11,86424254	2014-03-19	06:54:49	0	00:00:01	
5	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:54:50	7,0167729	00:00:01	
6	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:54:51	0	00:00:01	

Figure 41 The time difference between each point was calculated by subtract cell G3 from cell G2. The cell format in column I was giving the form "tt:mm:ss".

When the distance and time difference were received, the velocity could be calculated with the formula seen in Figure 42. In the formula, the distance was divided with 1000 in order to receive the velocity in the unit *km/h*. The column called *Time difference* had the format *tt:mm:ss* and had to be multiplied with 24 in order to receive the time in hours. This is due to that Excel defines 1 hour as 1/24-parts day and consequently 1 second as 1/24-parts hour. All necessary adjustments and calculations were now performed, according to Figure 43, and the Excel sheet was saved in the file format called *Text (tab delimited).*

SIN =(H3/1000)/(24*I3)

	A	B	C	D	E	F	G	H	I	J	K
1	ID	Type of smartphone	Comment	Latitude	Longitude	Date	Time	Distance	Time difference	Velocity	
2	1	iPhone - 7.0.2	underbart sopat hela	57,66115522	11,86424254	2014-03-19	06:54:47				
3	1	iPhone - 7.0.2	underbart sopat hela	57,66115522	11,86424254	2014-03-19	06:54:48	0	00:00:01	=(H3/1000)/(24*I3)	
4	1	iPhone - 7.0.2	underbart sopat hela	57,66115522	11,86424254	2014-03-19	06:54:49	0	00:00:01	0,00	
5	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:54:50	7,0167729	00:00:01	25,26	

Figure 42 The formula for calculation of the velocity is shown in the formula field.

	A	B	C	D	E	F	G	H	I	J
1	ID	Type of smartphone	Comment	Latitude	Longitude	Date	Time	Distance	Time difference	Velocity
2	1	iPhone - 7.0.2	underbart sopat hela	57,66115522	11,86424254	2014-03-19	06:54:47			
3	1	iPhone - 7.0.2	underbart sopat hela	57,66115522	11,86424254	2014-03-19	06:54:48	0	00:00:01	0,00
4	1	iPhone - 7.0.2	underbart sopat hela	57,66115522	11,86424254	2014-03-19	06:54:49	0	00:00:01	0,00
5	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:54:50	7,0167729	00:00:01	25,26
6	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:54:51	0	00:00:01	0,00
7	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:54:52	0	00:00:01	0,00
8	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:54:53	0	00:00:01	0,00
9	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:54:54	0	00:00:01	0,00
10	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:54:55	0	00:00:01	0,00
11	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:54:56	0	00:00:01	0,00
12	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:54:57	0	00:00:01	0,00
13	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:54:58	0	00:00:01	0,00
14	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:54:59	0	00:00:01	0,00
15	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:55:00	0	00:00:01	0,00
16	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:55:01	0	00:00:01	0,00
17	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:55:02	0	00:00:01	0,00
18	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:55:03	0	00:00:01	0,00
19	1	iPhone - 7.0.2	underbart sopat hela	57,66112098	11,86414339	2014-03-19	06:55:04	0	00:00:01	0,00
20	1	iPhone - 7.0.2	underbart sopat hela	57,66111511	11,86411162	2014-03-19	06:55:05	1,99721597	00:00:01	7,19
21	1	iPhone - 7.0.2	underbart sopat hela	57,66111163	11,8641226	2014-03-19	06:55:06	0,75912476	00:00:01	2,73
22	1	iPhone - 7.0.2	underbart sopat hela	57,66110979	11,86413752	2014-03-19	06:55:07	0,91015861	00:00:01	3,28
23	1	iPhone - 7.0.2	underbart sopat hela	57,66111716	11,86414691	2014-03-19	06:55:08	0,98613198	00:00:01	3,55
24	1	iPhone - 7.0.2	underbart sopat hela	57,661111	11,86413961	2014-03-19	06:55:09	0,81074559	00:00:01	2,92
25	1	iPhone - 7.0.2	underbart sopat hela	57,66111259	11,86409888	2014-03-19	06:55:10	2,42853193	00:00:01	8,74
26	1	iPhone - 7.0.2	underbart sopat hela	57,6611097	11,86406099	2014-03-19	06:55:11	2,27341705	00:00:01	8,18

Figure 43 This is what the completed Excel sheet looked like.

2. QGIS

The Excel file, which thus contained all the 72 number of cycle routes, were added to the program QGIS as a delimited text layer. This was done by clicking on *Layers* in the menu and then choosing *Add delimited text layer…*. The window, seen in Figure 44, was opened and the Excel file containing the cycle routes where chosen by clicking at the *Browse…* button. The entered settings are also shown in Figure 44.

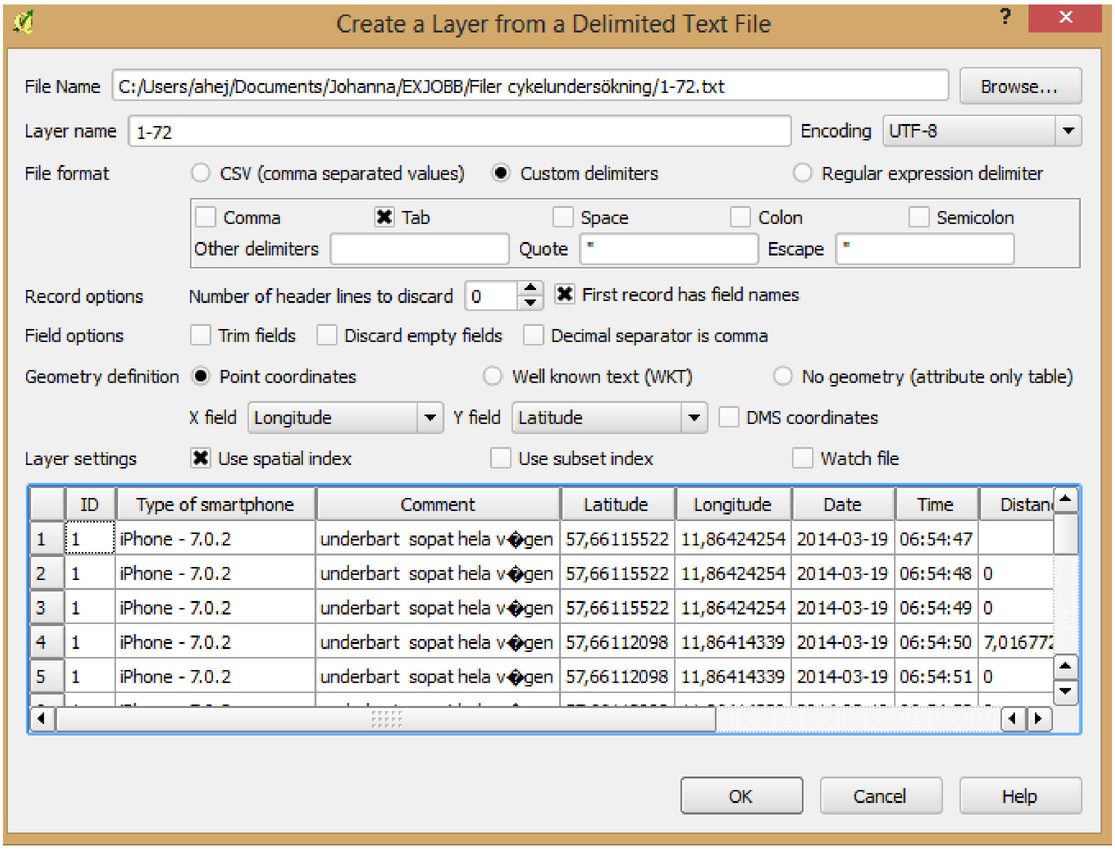


Figure 44 *Creation of a layer from a Delimited Text File. Choose the file containing the cycle routes by clicking on "Browse…". Enter the settings seen in this Figure and click "OK".*

The window seen in Figure 45 below was opened, where the reference system named *WGS 84 EPSG:4326* was chosen.

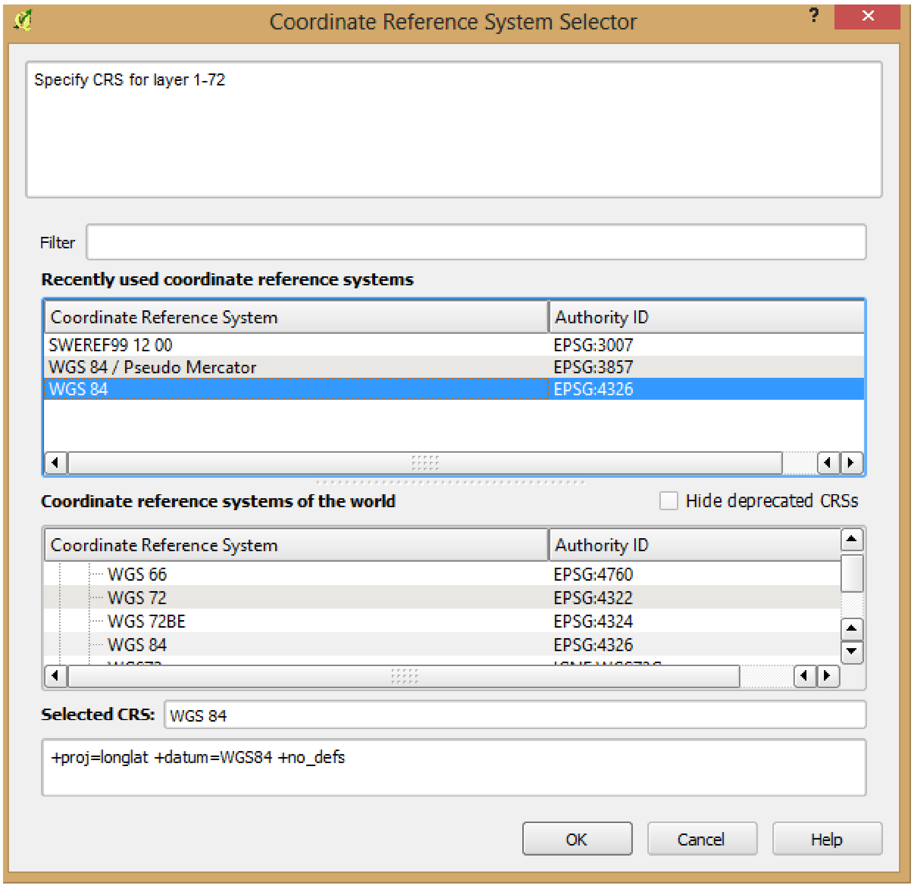


Figure 45 The coordinate reference system WGS 84 EPSG:4326 was chosen.

The cycle routes were thereafter visualized in the form of dots, which formed lines, according to Figure 46.

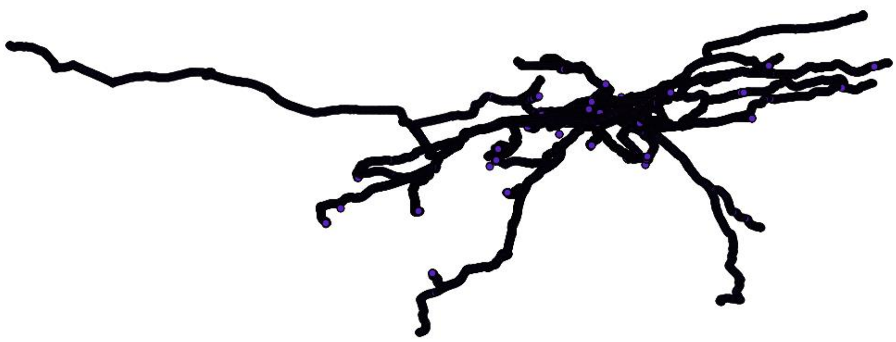


Figure 46 The cycle routes visualized in the map view in QGIS.

The next step was to add a map of Gothenburg, which was done by using the plugin called *Open Layers*. This plugin was installed according to Figure 47 – Figure 48 below. The other necessary plugin, called *Spatial Query*, was installed in the same way.

Figure 47 Choose "Plugins" from the menu and then go on "Manage and Install Plugins…".

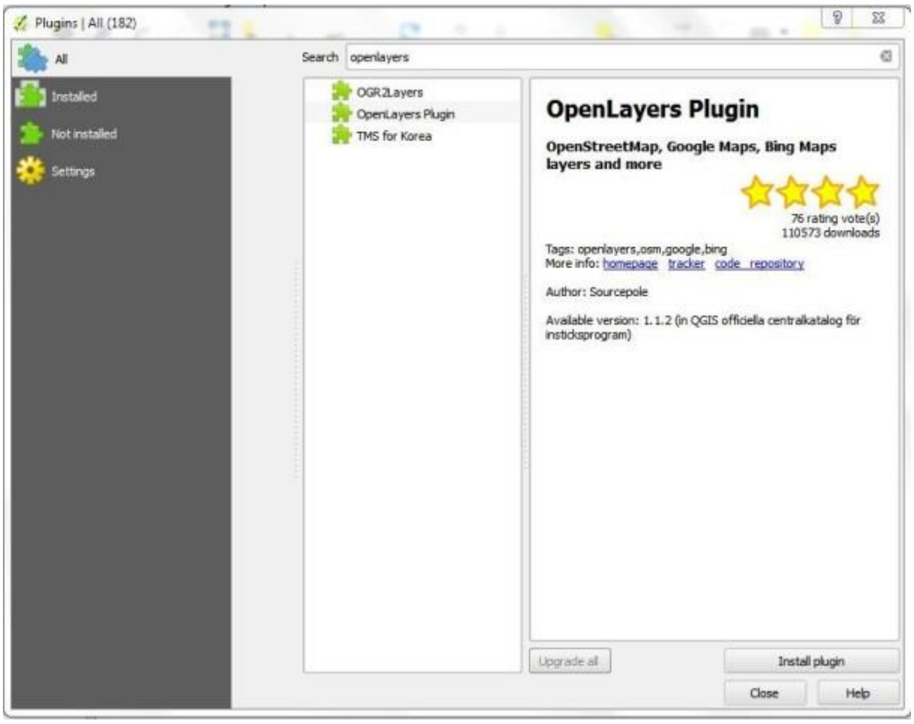


Figure 48 Search for the plugin that is to be installed and click on "Install plugin".

The map of Gothenburg was thereafter added as a layer according to Figure 49.

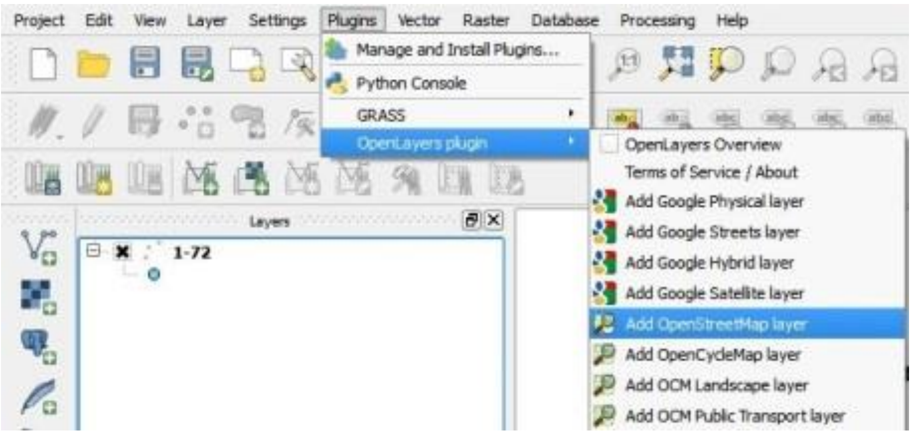


Figure 49 Choose "Plugins" from the menu, then go on "OpenLayers plugin" and choose one of the maps.

The map of Gothenburg and the cycle routes were now visualized, as can be seen in Figure 50 and Figure 51 below.

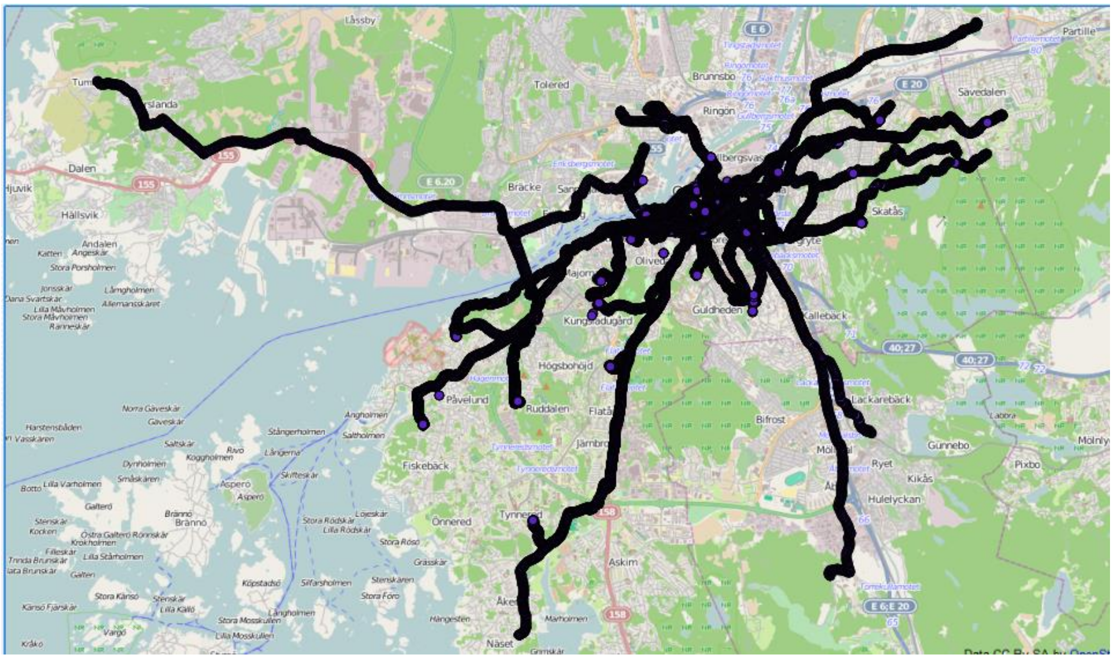


Figure 50 The map of Gothenburg and all 72 cycle routes.

Figure 51 A closer view of the cycle routes that interact with the stretch Nya Allén.

To enable editing of the cycle routes, e.g. make selections from its attribute table, it was necessary to change the layer's text file format into a shape file format. This was done according to Figure 52 – Figure 55 below.

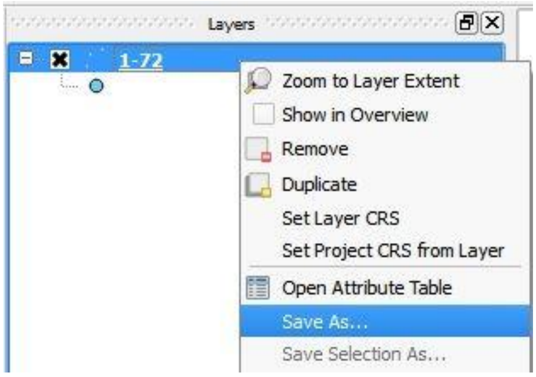


Figure 52 *Right click on the layer that contains the cycle routes, in case called "1-72", and choose "Save As…".*

Figure 53 *Choose the format "ESRI Shapefile", type in the name of the saved file and choose where the file shall be saved by clicking on "Browse". Control that the reference system is correct and click "OK".*

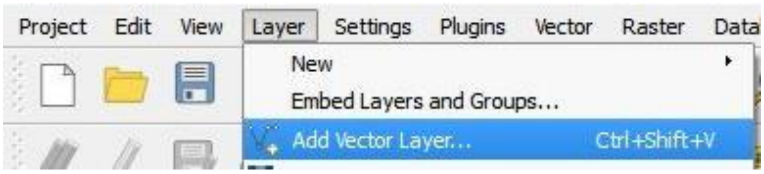


Figure 54 *Add the shape file as a vector layer by choosing "Layer" in the menu and then "Add Vector Layer…".*

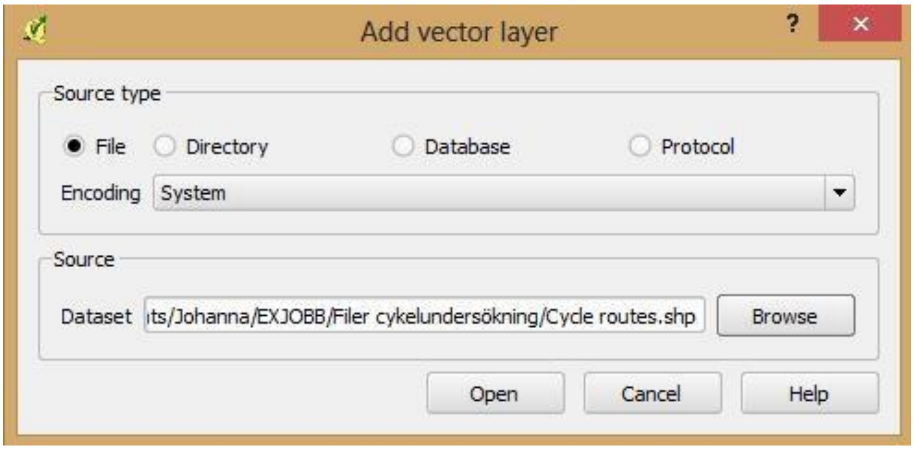


Figure 55 Click on “Browse” and choose the shape file named “Cycle routes”

The layer, called *Cycle routes*, was now added in the layer window and visualized in the map view, as shown in Figure 56.

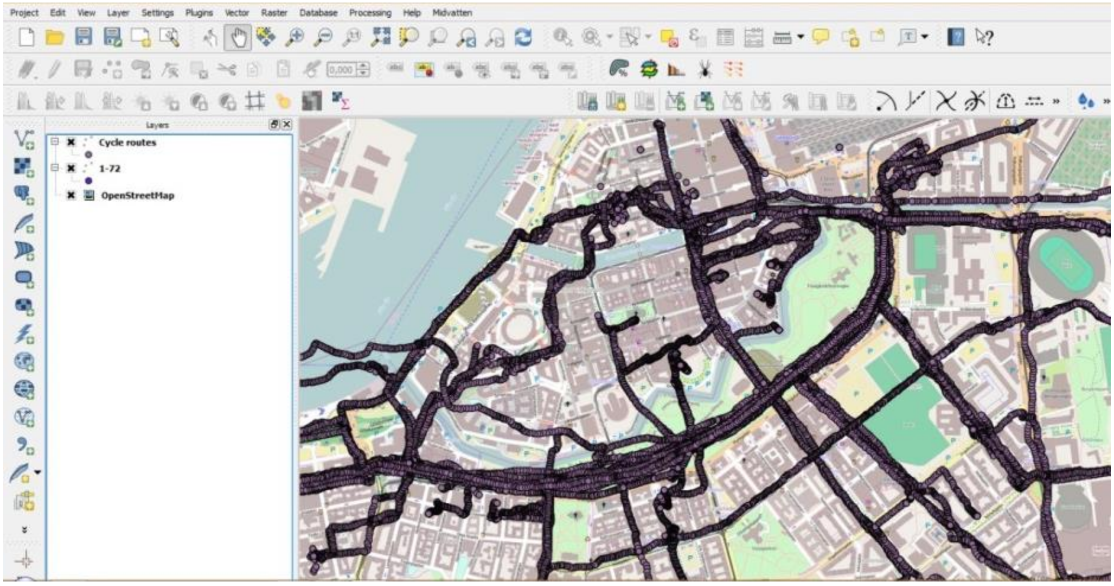


Figure 56 The vector layer named Cycle routes is added to both the layer window and to the map.

The cycle routes which went via the bicycle track Nya Allén were the points to be studied and it was therefore necessary to find a way to simply visualize these points on the map. The Traffic & Public Transport Authority has a shape file, named *Cykelbanor_shp_line.shp*, which contains all bicycle tracks in Gothenburg. The idea was to create a so called buffer zone around the bicycle track Nya Allén, which thus is one of the bicycle tracks included in the file *Cykelbanor_shp_line.shp*. The file was therefore added to the map as a vector layer, in the same way as Figure 55 above shows, and the bicycle tracks were shown as Figure 57 visualizes.

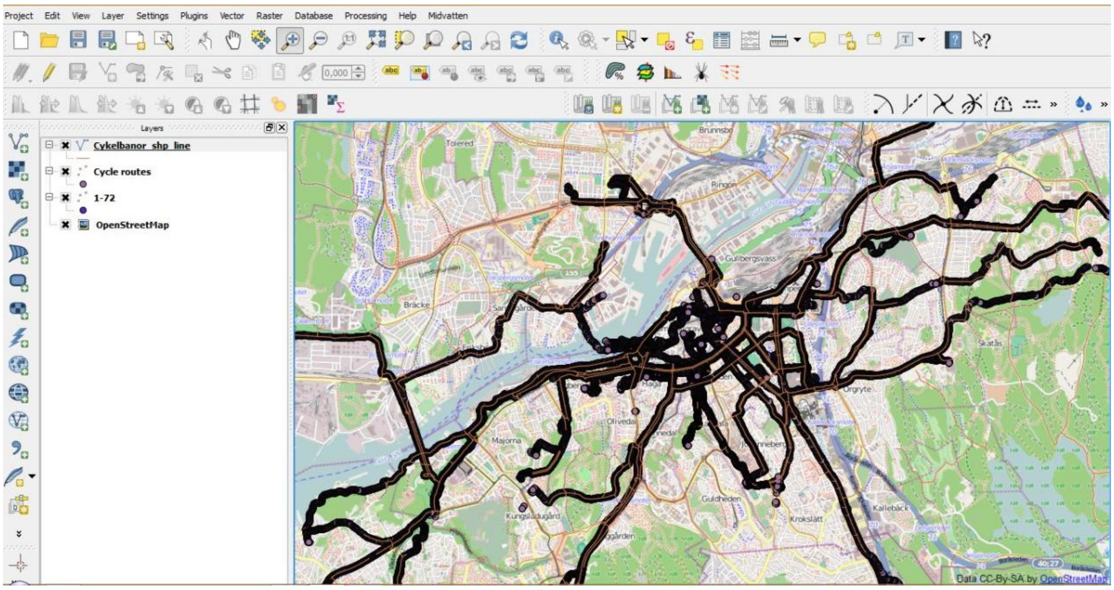


Figure 57 *The bicycle tracks are visualized in the map as lines, placed on top of the cycle routes, and the layer is named "Cykelbanor_shp_line".*

The creation of the buffer zone could now be started. The segments of the bicycle tracks that belonged to Nya Allén were selected by using the tool *Select Single Feature* as Figure 58 and Figure 59 show.

Figure 58 *The tool "Select Single Feature" is found in the toolbar.*

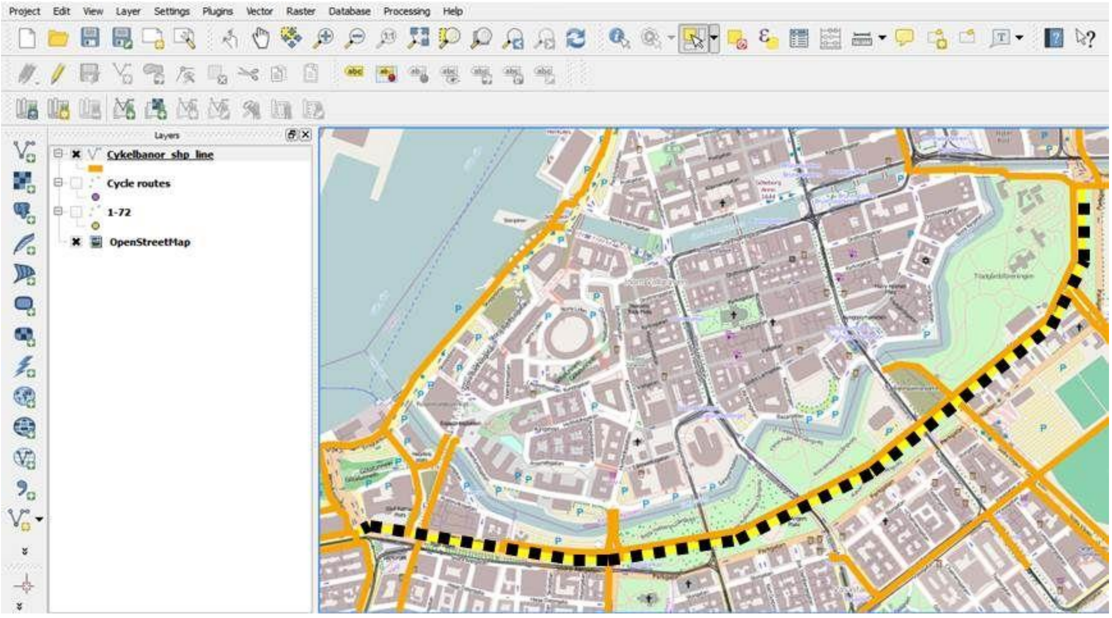


Figure 59 *Nya Allén was selected by clicking on the corresponding lines in the map view. The selected stretch can be seen as a dashed line.*

The buffer zone was thereafter created by using the tool called *Buffer(s)* and the procedure is shown in Figure 60 and Figure 61 below.

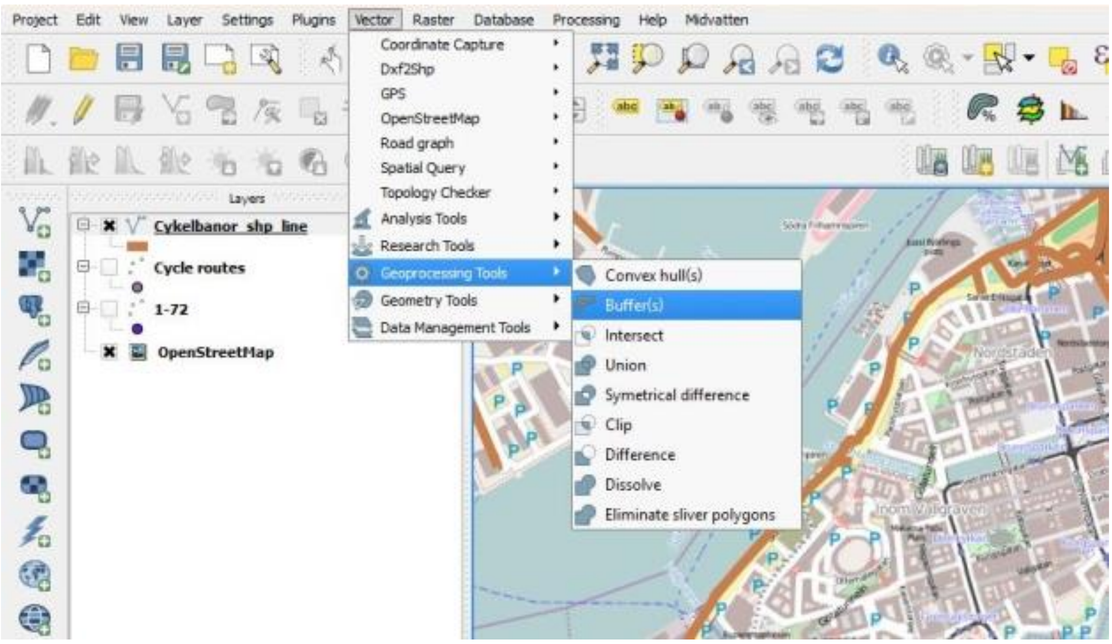


Figure 60 *Click on "Vector" in the menu, choose "Geoprocessing Tools" and thereafter "Buffer(s)".*

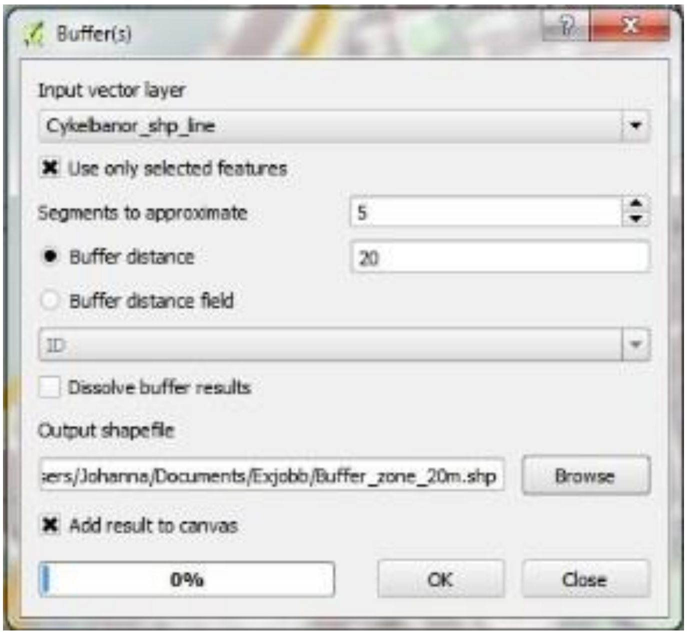


Figure 61 Type in the properties of the buffer zone. Check the boxes "Use only selected features" and "Add result to canvas" and click "OK".

The *Input vector layer* in Figure 61 is the layer that the buffer zone will be created around. Since the *Use only selected features* is checked, only the selected segments shown in Figure 59 will be included in the buffer zone. The buffer distance was determined to be 20 meters, which resulted in a total buffer zone width of 40 meter. The decision to have a 40 meters wide buffer zone was based on observations of the registered points along the stretch, where it was noticed that several points was located a few meters beside the bicycle track. The velocities connected to these points were still realistic, which indicated that only the coordinates had been improperly registered. By including these points in the buffer zone, the function was given a certain margin of error and a greater number of points could be analyzed. The created buffer zone formed a new layer and was visualized as a thicker area along the bicycle track Nya Allén, according to Figure 62 below.

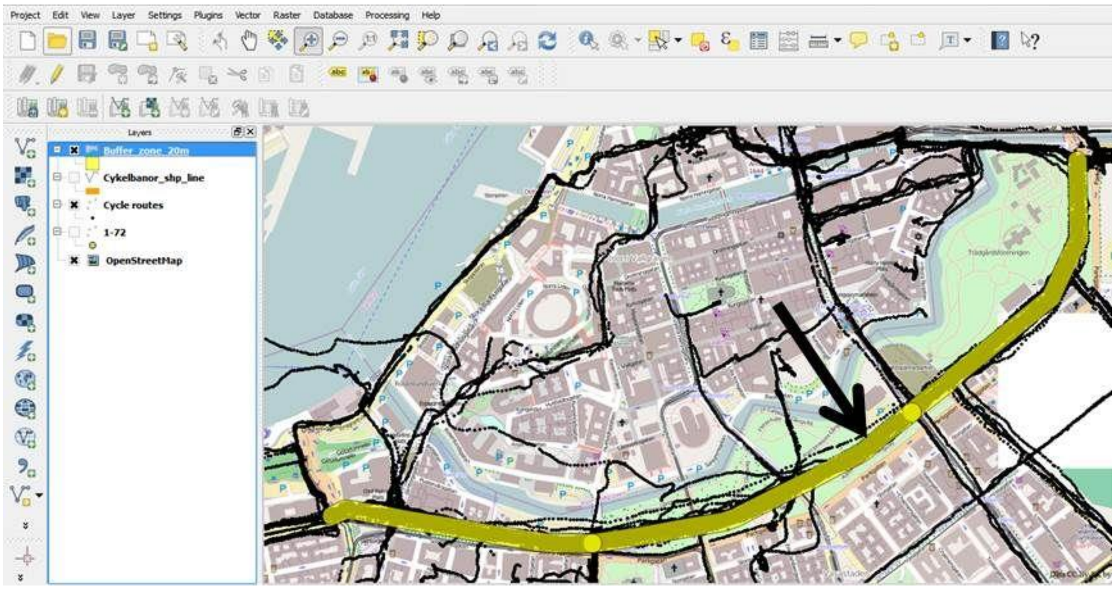


Figure 62 *The buffer zone forms a new layer in the layer window. The arrow points at the buffer zone, which is seen as a thicker area along Nya Allén.*

The next step was to sort out the points that coincided with the buffer zone and thus receive the points located along the stretch Nya Allén. This was done by using the plugin *Spatial Query* as Figure 63 – Figure 66 show.

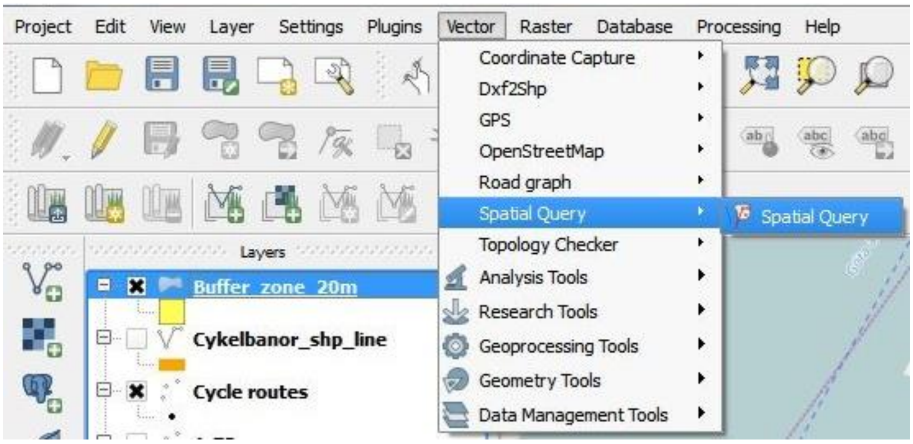


Figure 63 *"Spatial Query" is found under "Vector" in the menu.*

Figure 64 *These settings sort out the points from the layer "Cycle routes", which intersect with the created buffer zone "Buffer_zone_20m". Choose "Create new selection" and click on "Apply"*

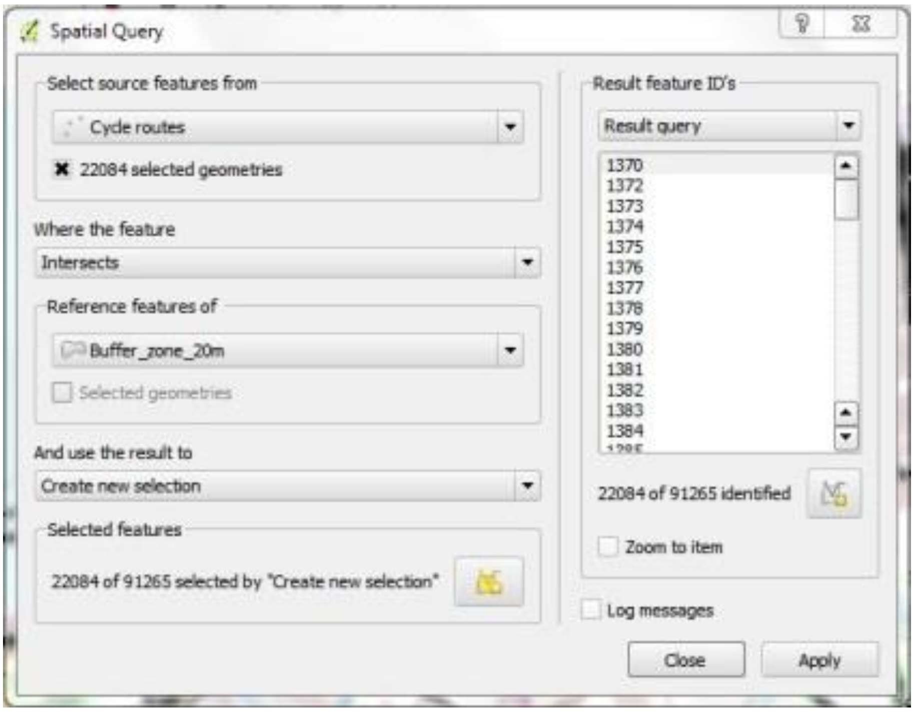


Figure 65 *The result of the query is shown, where 22084 points of 91265 points are found within the buffer zone. Click on "Apply".*

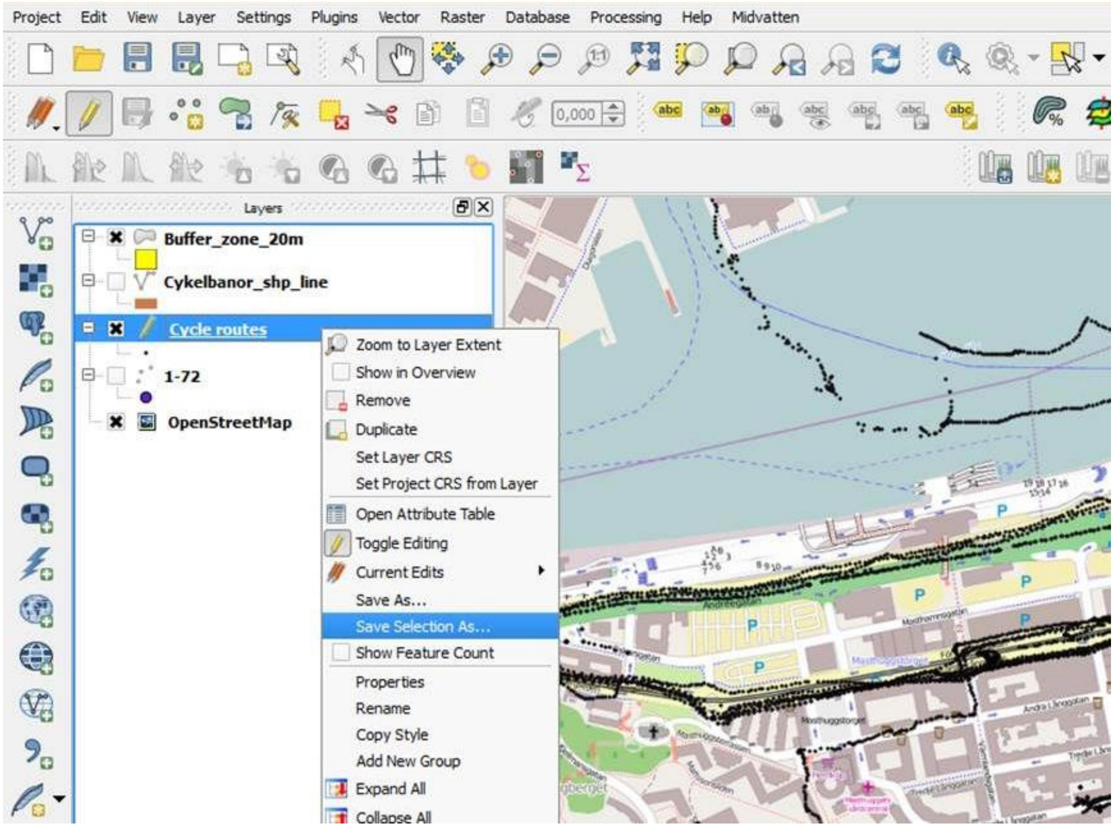


Figure 66 Save the selected points by right clicking on the layer "Cycle routes", choose "Save Selection As..." and save the selection as a shape file, as described earlier.

The selection was thereafter opened as a vector layer, in the same way as previously described. The selected points, corresponding to a number of 22084 points, were now shown as dots along the stretch Nya Allén, as can be seen in Figure 67 and Figure 68 below.

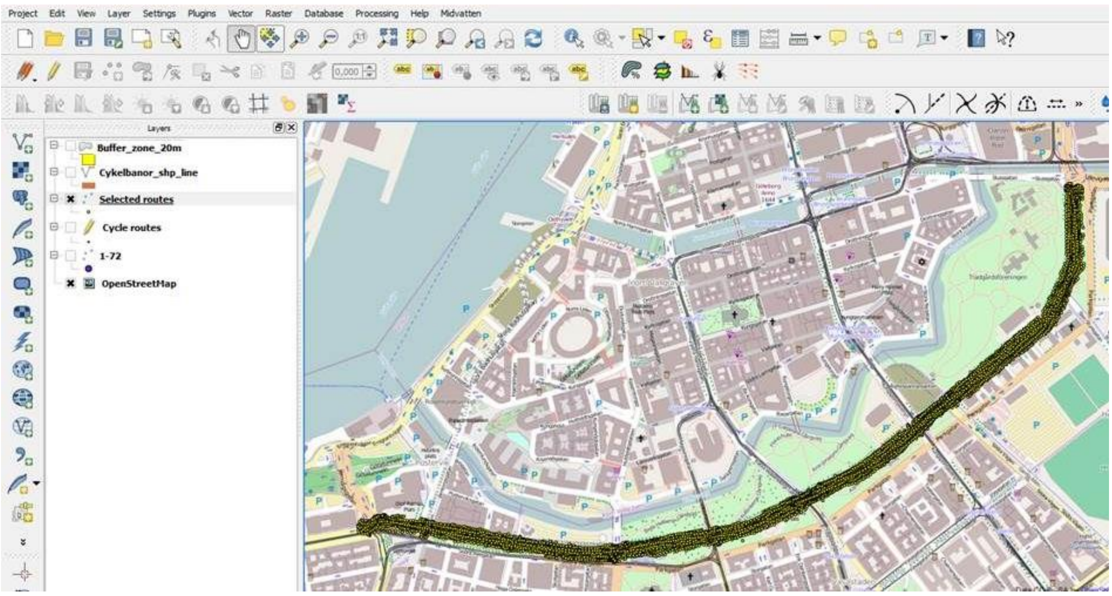


Figure 67 The saved selection named "Selected routes" was shown as a new layer in the layer window as well as dots in the map view.

Figure 68 *A closer view of the selected dots along Nya Allén.*

3. Excel

It was discovered that the way to express decimal numbers, differed between Excel and QGIS. To be able to perform calculations and make selections of the data, a decimal number must be separated by a comma in Excel but by a dot in QGIS. The Excel file that was opened in QGIS thus contained decimal numbers separated by commas. The attribute table of the layer *Selected routes* hence had to be reopened in Excel, in order to switch all commas into dots. This procedure was done according to Figure 69 – Figure 70.

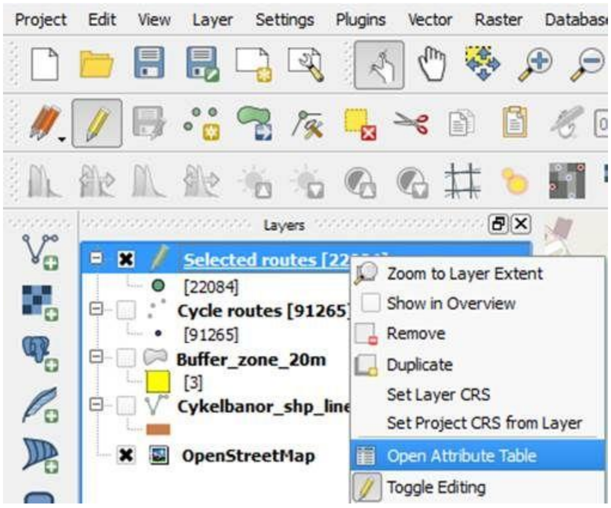


Figure 69 *Open the attribute table by right clicking on the layer "Selected routes" and then choose "Open Attribute table".*

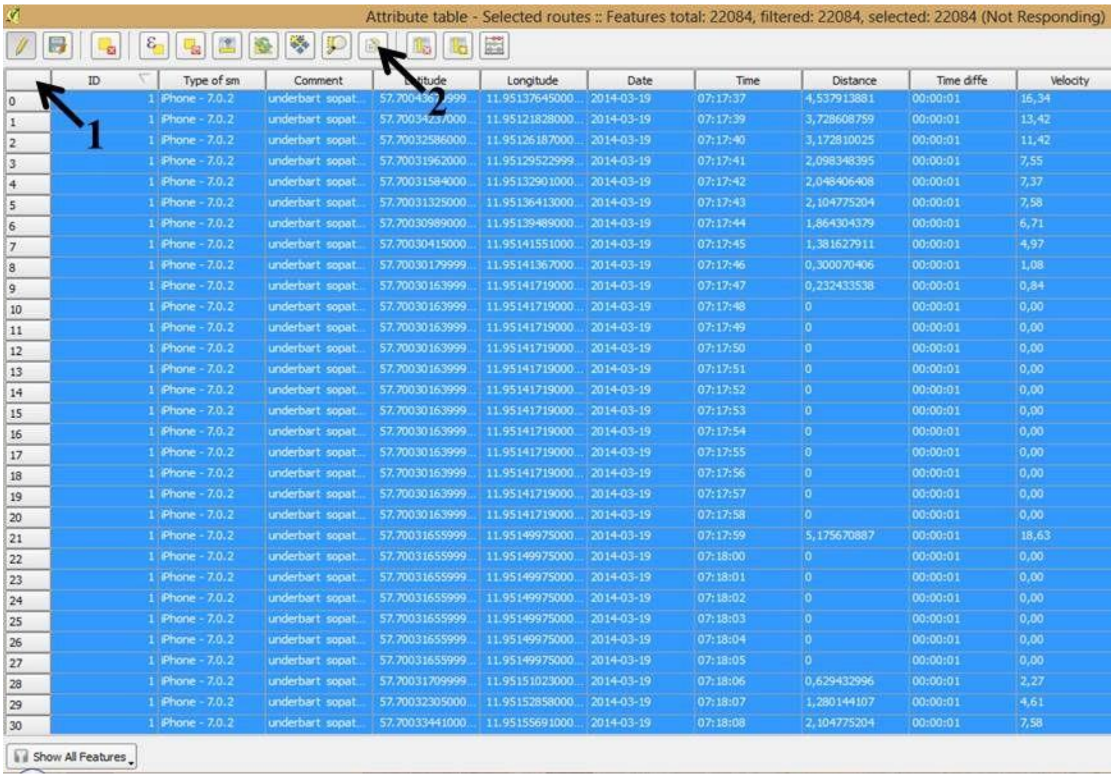


Figure 70 1: Mark the attribute table by clicking in the upper left corner.

2: Copy the attribute table by clicking on the button that the arrow points at.

A new empty document in Excel was thereafter opened, in which the copied attribute table was pasted. The procedure of switching commas into dots was made by using the function *Find and Replace*, according to Figure 71.

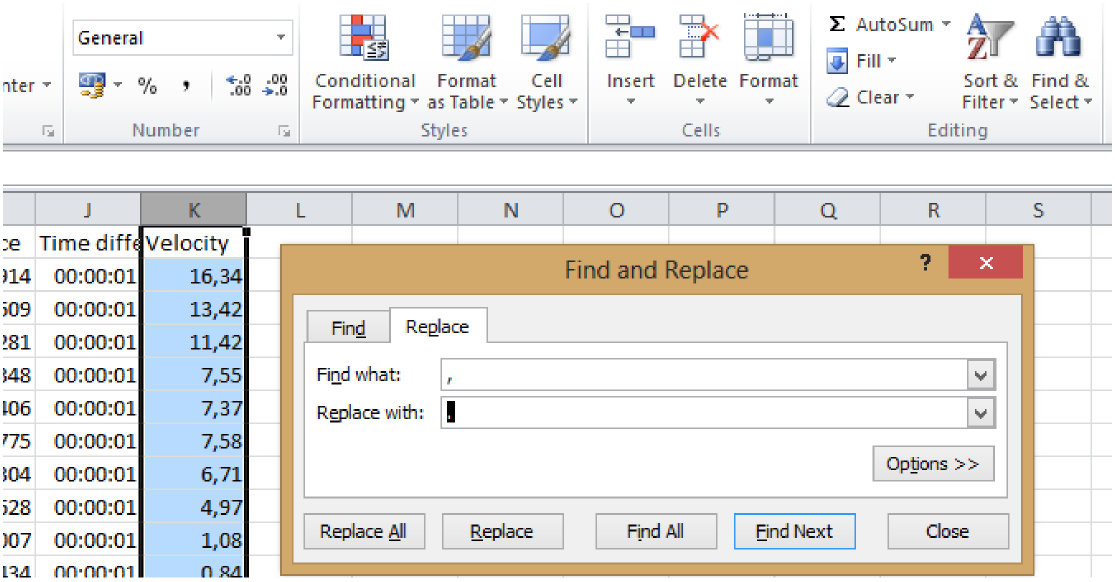


Figure 71 *Mark the column that contain the velocities and use the function "Find and Replace" in order to switch all commas into dots. Finish the replacement by clicking on "Replace all".*

The document was again saved in the file format *Text (tab delimited)* and was named *Commas to dots*. Thereafter, the file was opened in QGIS in the same way as already shown in Figure 44 and Figure 45.

4. QGIS

It was noticed that several of the registered points contained unrealistic data, such as velocities of 100 km/h or even higher for instance. These inaccuracies were therefore removed from the layer *Commas to dots* by using the function called *Query Builder*, which was opened according to Figure 72 and Figure 73.

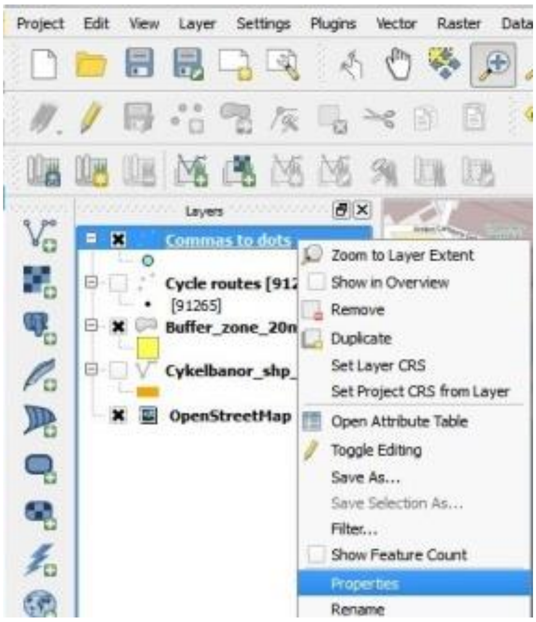


Figure 72 Right click on the layer and choose "Properties".

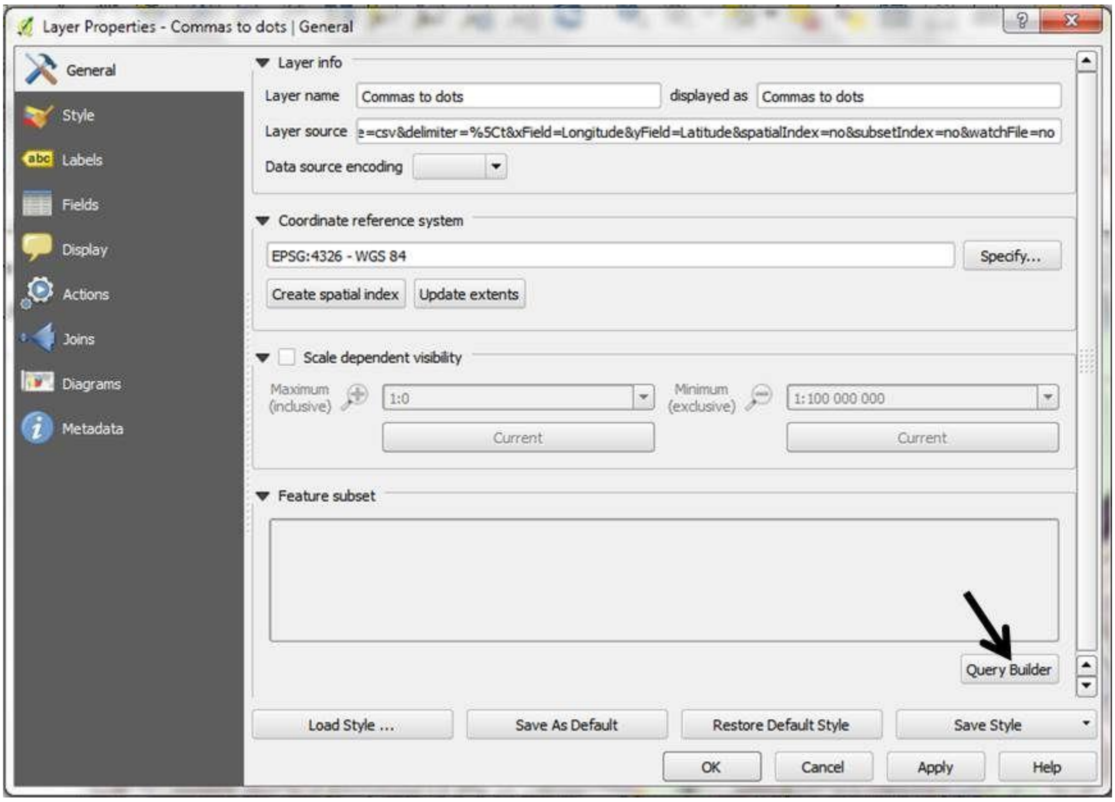


Figure 73 Click on "Query builder", found in the lower right corner.

Based on assessments of the conditions of the selected stretch and consultation with the Traffic & Public Transport Authority, it was decided to filter all velocities within the interval 0-45km/h. As mentioned in section 3.2.2, the function *Min cykeltur* was programmed to register a new point each second. However, the received data showed that time difference between the registered points often was longer than 1 second. It was thus decided to also filter the time difference, where time differences within 1-60 seconds were chosen. This interval was based on observations of the data, which indicated that points with a time difference of up to 60 seconds still contained realistic data. Figure 74 – Figure 77 show the procedure of how these criteria were entered into the *Query builder*.

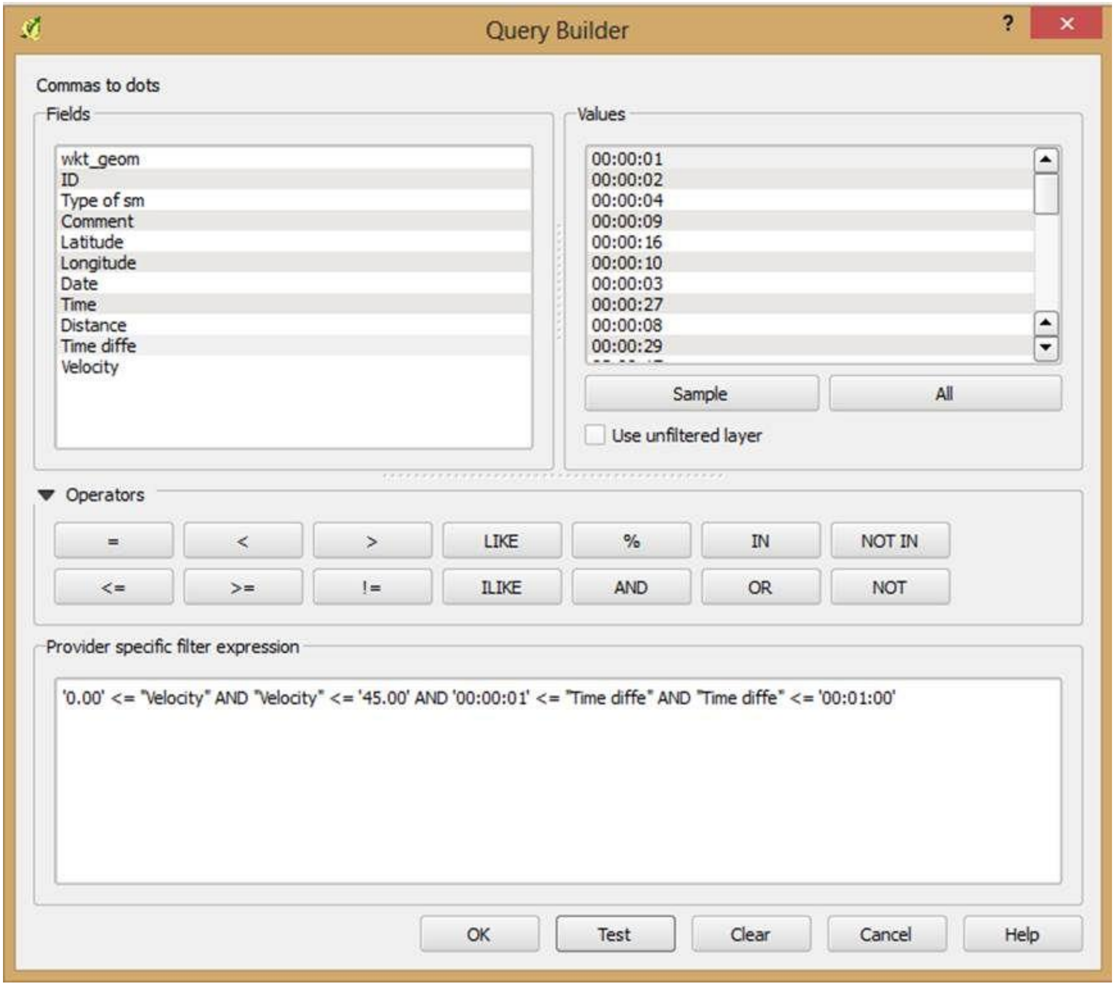


Figure 74 *Enter the criteria in the field called "Provider specific filter expression" and click on "OK". These criteria thus sort out points with velocities of 0-45 km/h and time differences of 1-60 seconds.*

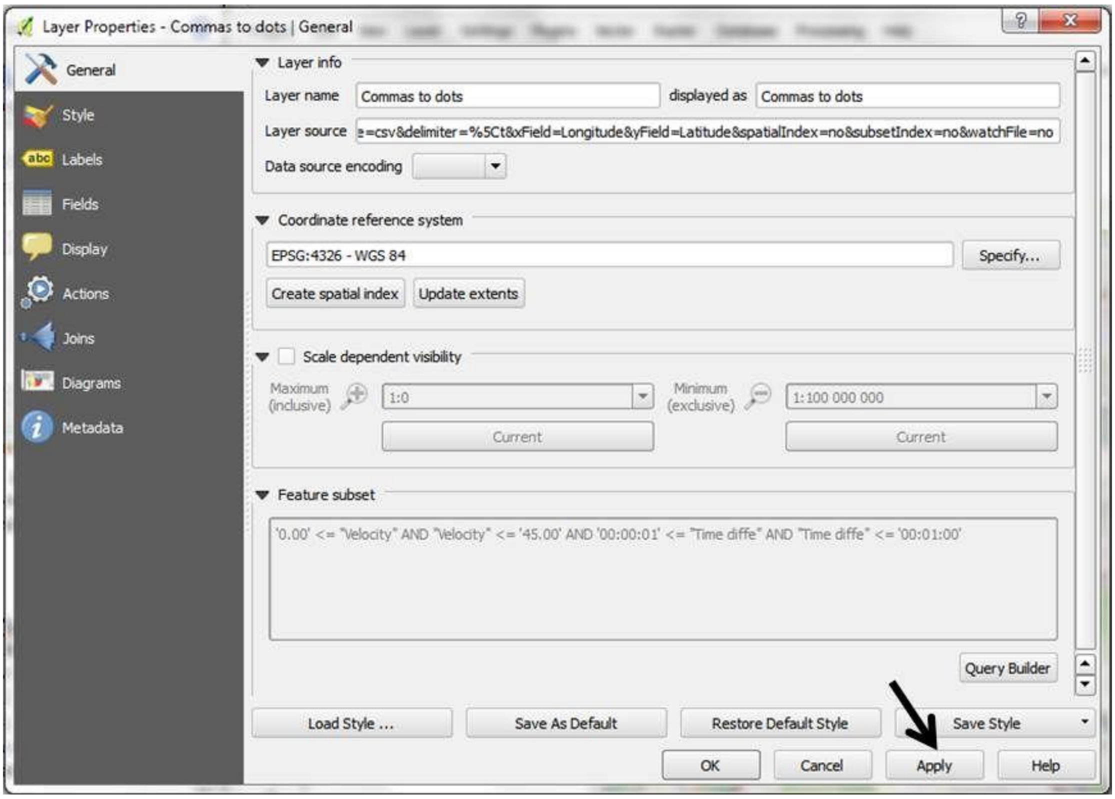


Figure 75 *The entered criteria can be seen in the field called "Feature subset". Click on "Apply" and then "OK".*

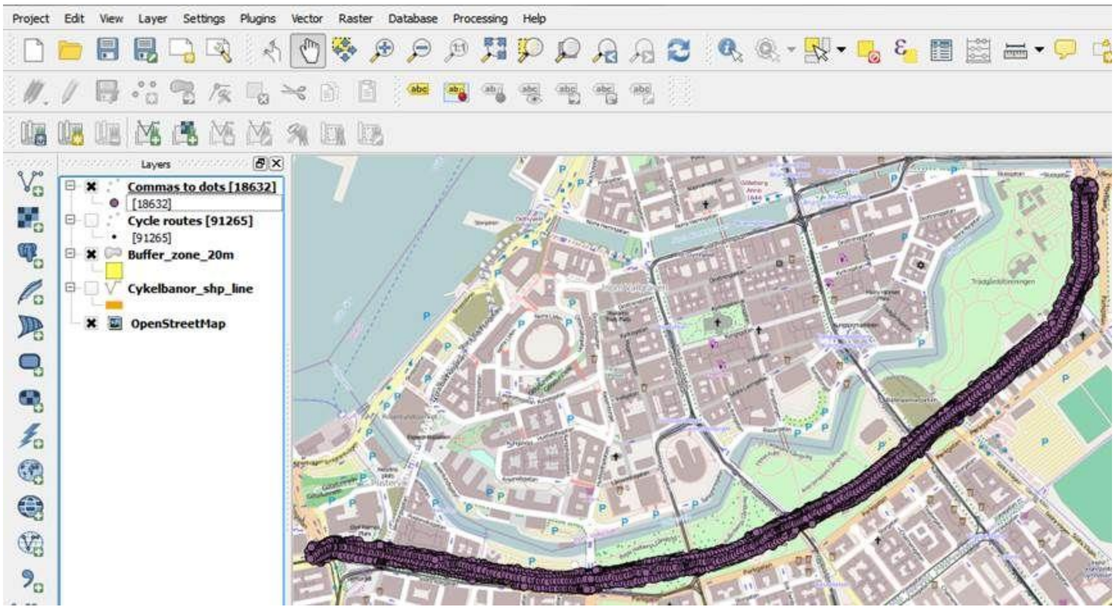


Figure 76 *The layer "Commas to dots" now contained 18632 points, which meant that 3461 points contained inaccuracies and were removed.*

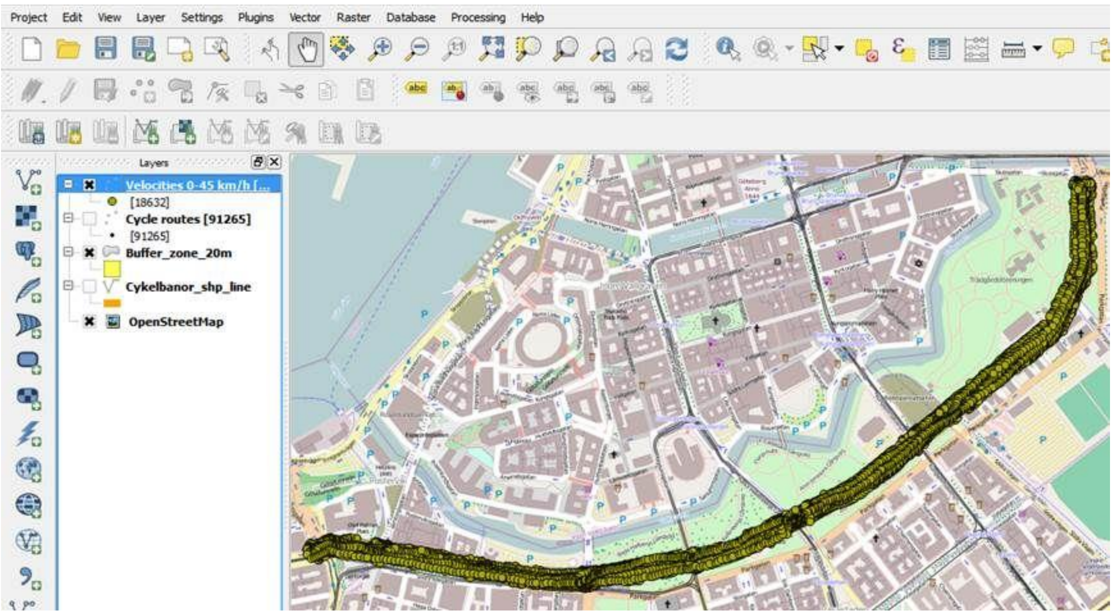


Figure 77 At last, the layer was renamed as "Velocities 0-45 km/h".

The next step was to create several layers with velocities within different intervals, in order to receive the velocity distribution for the stretch. This was done according to the same principle as already is described in Figure 74 – Figure 77 above, i.e. to define criteria in the *Query builder* in order to sort out velocities within a specific interval. The procedure of sorting out velocities greater than 0 km/h and smaller or equal to 5 km/h is shown in Figure 78 – Figure 80.

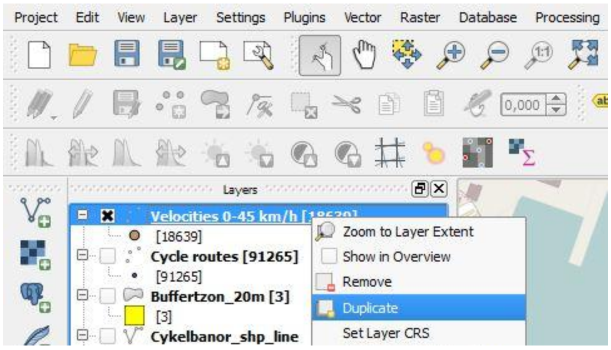


Figure 78 Duplicate the layer "Velocities 0-45 km/h" by right clicking on the layer and choose "Duplicate".

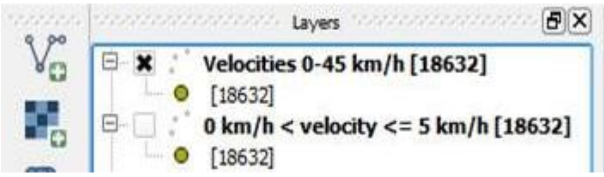


Figure 79 The duplicated layer was thereafter renamed as "0 km/h < velocity <= 5 km/h" and its "Query builder" was opened.

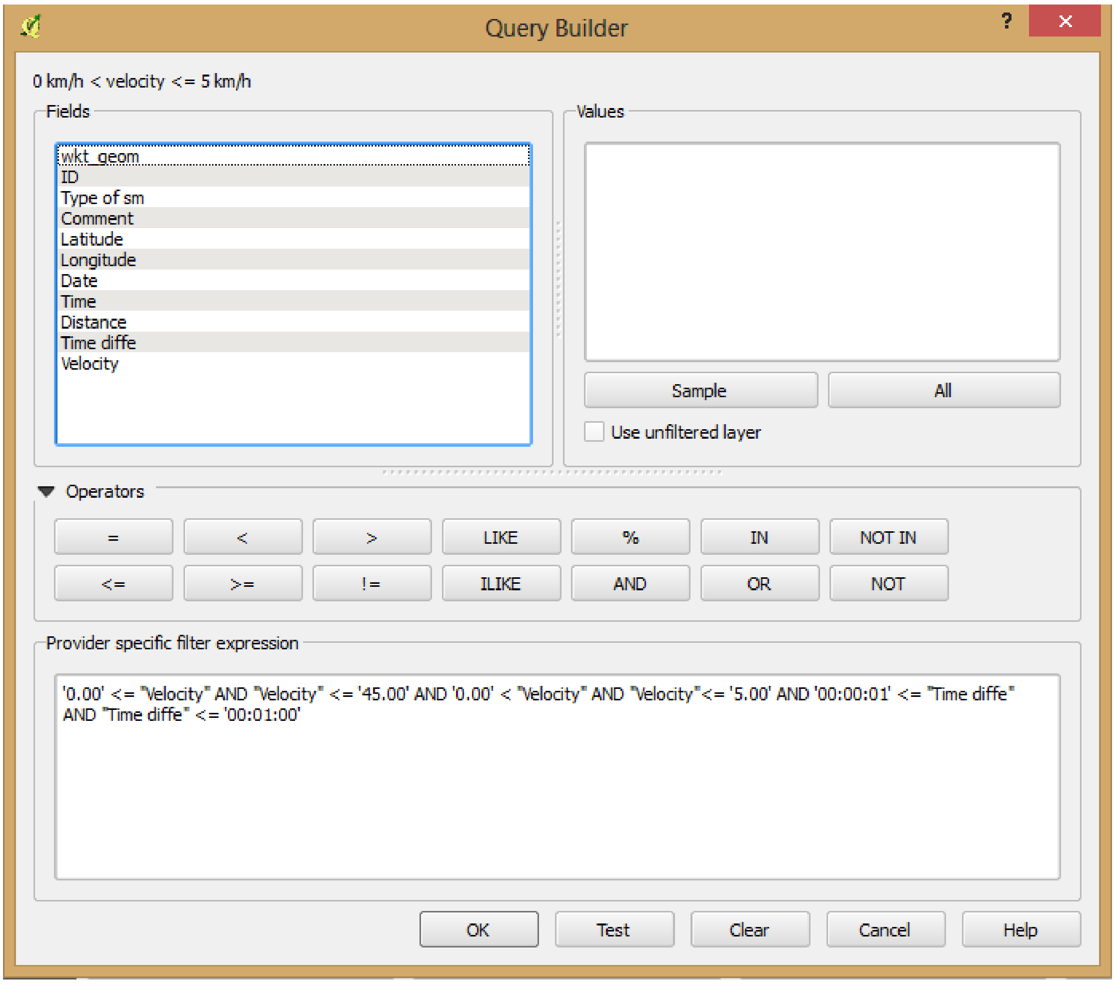


Figure 80 Enter the criteria seen in the field "Provider specific filter expression" and click "OK".

The procedure shown in Figure 78 – Figure 80 was repeated for 10 different velocity intervals, which obviously had different criteria. The velocity intervals were added as layers in the layer window, as Figure 81 shows. Each layer is visualized by dots along the stretch, as can be seen in Chapter 5 in Figure 15 and Figure 17 – Figure 25.

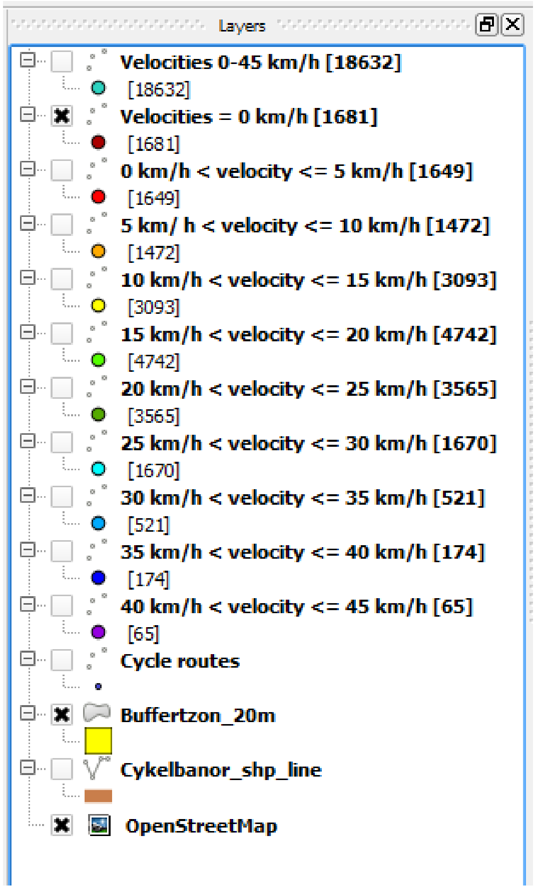


Figure 81 The velocity distribution is received by the 10 different velocity intervals and layers.

5. Excel

The attribute table of the layer *Velocities 0-45 km/h* was pasted into a new Excel document, as described in Figure 69 and Figure 70. Some adjustments of the table were carried out, which can be seen in Figure 82 – Figure 84.

	A	B	C	D	E	F	G	H	I	J	K	L
1	wkt_geon	wkt_geon	ID	Type of sm	Comment	Latitude	Longitude	Date	Time	Distance	Time diffe	Velocity
2	POINT(11.	POINT(11.	1	iPhone - 7.(	underbart	57.70043671	11.95137645	2014-03-19	07:17:37	4,537914	00:00:01	16.34
3	POINT(11.	POINT(11.	1	iPhone - 7.(	underbart	57.70034237	11.95121828	2014-03-19	07:17:39	3,728609	00:00:01	13.42

Figure 82 Column A and B contained irrelevant data and were therefore deleted.

	A	B	C	D	E	F	G	H	I	J
1	ID	Type of smartphone	Comment	Latitude	Longitude	Date	Time	Distance	Time difference	Velocity
2	1	iPhone - 7.0.2	underbart	57.70043671	11.95137645	2014-03-19	07:17:37	4,537913881	00:00:01	16.34
3	1	iPhone - 7.0.2	underbart	57.70034237	11.95121828	2014-03-19	07:17:39	3,728608759	00:00:01	13.42

Figure 83 The headings were adjusted.

	A	B	C	D	E	F	G	H	I	J
1	ID	Type of smartphone	Comment	Latitude	Longitude	Date	Time	Distance	Time difference	Velocity
2	1	iPhone - 7.0.2	underbart	57,7004367	11,9513765	2014-03-19	07:17:37	4,537913881	00:00:01	16,34
3	1	iPhone - 7.0.2	underbart	57,7003424	11,9512183	2014-03-19	07:17:39	3,728608759	00:00:01	13,42

Figure 84 The dots in column D, E and J were replaced by commas, by using the function "Find and Replace".

Furthermore, the following calculations were carried out:

- average velocity (including/excluding velocities equal to 0 km/h)
- number of
  - stops
  - cyclists
  - smartphones
- velocity distribution
- how many percent of the time that the cyclists stands still

The process and used expression of each calculation is described in Figure 85 – Figure 96 below.

fx =SUM(M2:M18633)/18632

M	W	X
Velocity		
16,3	Average speed (velocities of 0 km/h included)	15,5

Figure 85 Column M contained the registered velocities for all points along the stretch Nya Allén. The formula for calculation of average velocity, where velocities of 0 km/h are included, is seen in the formula field.

fx =SUMIF(M2:M18633;">0";M2:M18633)/(COUNTIF(M2:M18633;">0"))

M	W	X
Velocity		
16,3	Average speed (velocities of 0 km/h included)	15,5
13,4	Avergage speed (velocities of 0 km/h excluded)	17,0

Figure 86 The formula for calculation of average velocity, where velocities of 0 km/h are excluded, is seen in the formula field.

X4 fx =SUM(IF(FREQUENCY(A2:A18640;A2:A18640)>0;1))

	A	W	X	Y
1	ID			
2	1	Average speed (velocities of 0 km/h included)	15,5	
3	1	Avergage speed (velocities of 0 km/h excluded)	17,0	
4	1	Number of cycle routes	67	

Figure 87 The formula calculates the sum of unique ID numbers, i.e. the number of cycle routes.

X5	f_x	=SUM(IF(FREQUENCY(MATCH(B2:B18633;B2:B18633;0);MATCH(B2:B18633;B2:B18633;0))>0;1))			
	A	B	W	X	Y
1	ID	Type of smartphone			
2	1	iPhone - 7.0.2	Average speed (velocities of 0 km/h included)	15,5	
3	1	iPhone - 7.0.2	Avergage speed (velocities of 0 km/h excluded)	17,0	
4	1	iPhone - 7.0.2	Number of cycle routes	67	
5	1	iPhone - 7.0.2	Number of different smartphones	17	

Figure 88 The formula calculates the number of different types of smartphones by summing all unique sentences from column B.

X6	f_x	=SUM(P2:P18633)		
	O	P	W	X
1		Time of velocity = 0 km/h		
2	0,0	00:00:00	Average speed (velocities of 0 km/h included)	15,5
3	0,0	00:00:00	Avergage speed (velocities of 0 km/h excluded)	17,0
4	0,0	00:00:00	Number of cycle routes	67
5	0,0	00:00:00	Number of different smartphones	17
6	0,0	00:00:00	Total time of stops	00:29:04

Figure 89 Column P contained the times (of each point) when the velocity is equal to zero. The total time of stops for all registered points were calculated by taking the sum of the column called Time of velocity = 0 km/h.

	f_x	=SUM(I2:I18633)	
	I	W	X
	Time difference		
1	00:00:01	Average speed (velocities of 0 km/h included)	15,5
9	00:00:01	Avergage speed (velocities of 0 km/h excluded)	17,0
5	00:00:01	Number of cycle routes	67
5	00:00:01	Number of different smartphones	17
8	00:00:01	Total time of stops	00:29:04
4	00:00:01	Total time	05:40:30

Figure 90 By summarizing all time differences, included in column I, the total time for all cycle routes, together, was calculated.

X8	f_x =X6/X7	
	W	X
1		
2	Average speed (velocities of 0 km/h included)	15,5
3	Avergage speed (velocities of 0 km/h excluded)	17,0
4	Number of cycle routes	67
5	Number of different smartphones	17
6	Total time of stops	00:29:04
7	Total time	05:40:30
8	Average percentage of "standstill time"	9%

Figure 91 The average percentage of "standstill time", i.e. the time when the cyclists stands still, was calculated according to the formula in the formula field. The result shows how much of the spent time, on the stretch Nya Allén, where the cyclists' velocity was equal to zero.

The total number of stops along the stretch, for all cycle routes, was calculated in three steps according to Figure 92 – Figure 94.

f_x =IF(M2=0;1;0)

M	N
Velocity	Number of points = 0 km/h
16,3	0,0
13,4	0,0

Figure 92 The formula returns "0" if the velocity is not equal to zero and "1" if the velocity is equal to zero. If column N is summarized, it results in the number of points with a velocity equal to zero.

O2 f_x =IF(AND(N3=1;N2=0);1;0)

	N	O	Y
1	Number of points = 0 km/h	Number of stops	
2	0,0	0,0	
3	0,0	0,0	

Figure 93 The formula, which is explained in the paragraph below, returns the number of stops for all cycle routes all together.

In the formula in Figure 93, the criteria is true if cell N3 is equal to 1 and cell N2 is equal to 0. This means that every time the velocity changes, from a velocity equal to zero into a velocity greater than zero, the criteria is true and the formula returns a number one. Each number one in column O thus corresponds to one stop. If column O is summarized, as Figure 94 shows, the total number of stops for all cycle routes will be given.

X9 f_x =SUM(O2:O18633)

O	W	X
Number of stops		
0,0	Average speed (velocities of 0 km/h included)	15,5
0,0	Avergage speed (velocities of 0 km/h excluded)	17,0
0,0	Number of cycle routes	67
0,0	Number of different smartphones	17
0,0	Total time of stops	00:29:04
0,0	Total time	05:40:30
0,0	Average percentage of "standstill time"	9%
0,0	Number of stops	312

Figure 94 The number of stops is calculated by summarizing the column O.

X10 f_x =X6/X9

	W	X
1		
2	Average speed (velocities of 0 km/h included)	15,5
3	Avergage speed (velocities of 0 km/h excluded)	17,0
4	Number of cycle routes	67
5	Number of different smartphones	17
6	Total time of stops	00:29:04
7	Total time	05:40:30
8	Average percentage of "standstill time"	9%
9	Number of stops	312
10	Average length of stop	00:00:06

Figure 95 The formula calculates the average length of each stop, in seconds.

X11 f_x =X9/X4

	W	X
1		
2	Average speed (velocities of 0 km/h included)	15,5
3	Avergage speed (velocities of 0 km/h excluded)	17,0
4	Number of cycle routes	67
5	Number of different smartphones	17
6	Total time of stops	00:29:04
7	Total time	05:40:30
8	Average percentage of "standstill time"	9%
9	Number of stops	312
10	Average length of stop	00:00:06
11	Average number of stops per cycle route	4,7

Figure 96 The formula calculates the average number of stops per cycle route.

The velocity distribution, which already had been produced in QGIS, was also calculated in Excel. In Figure 97, the different velocity intervals can be seen and also the formula for calculation of the number of points with a velocity equal to zero. For the other velocity intervals, the formula for calculation of the number of points is similar. Only the formula for the interval $0 < velocity \leq 5$ is therefore shown, as an example, in Figure 98.

f_x =COUNTIFS(M2:M18633;"0")

M	AB	AC	AD
Velocity		Velocity distribution [km/h]	Number of points
16,3		0	1681
13,4		0 < velocity ≤ 5	1649
11,4		5 < velocity ≤ 10	1472
7,6		10 < velocity ≤ 15	3093
7,4		15 < velocity ≤ 20	4742
7,6		20 < velocity ≤ 25	3565
6,7		25 < velocity ≤ 30	1670
5,0		30 < velocity ≤ 35	521
1,1		35 < velocity ≤ 40	174
0,8		40 < velocity ≤ 45	65

Figure 97 The formula counts the number of cells, in column M, which contains a velocity equal to zero.

f_x =COUNTIFS(M2:M18633;">0";M2:M18633;"<5")+COUNTIF(M2:M18633;"5")

M	Y	AC	AD
Velocity		Velocity distribution [km/h]	Number of points
16,3		0	1681
13,4		0 < velocity ≤ 5	1649
11,4		5 < velocity ≤ 10	1472
7,6		10 < velocity ≤ 15	3093
7,4		15 < velocity ≤ 20	4742
7,6		20 < velocity ≤ 25	3565
6,7		25 < velocity ≤ 30	1670
5,0		30 < velocity ≤ 35	521
1,1		35 < velocity ≤ 40	174
0,8		40 < velocity ≤ 45	65

Figure 98 *The formula counts the number of cells, in column M, which contains velocities included in the interval "0 < velocity ≤ 5". For the other intervals; simply change the numbers in the formula, so that the interval of interest is covered.*

The different velocity distributions were further visualized in a pie chart diagram, according to Figure 99 below.

AC	AD
Velocity distribution [km/h]	Number of points
0	1681
0 < velocity ≤ 5	1649
5 < velocity ≤ 10	1472
10 < velocity ≤ 15	3093
15 < velocity ≤ 20	4742
20 < velocity ≤ 25	3565
25 < velocity ≤ 30	1670
30 < velocity ≤ 35	521
35 < velocity ≤ 40	174
40 < velocity ≤ 45	65

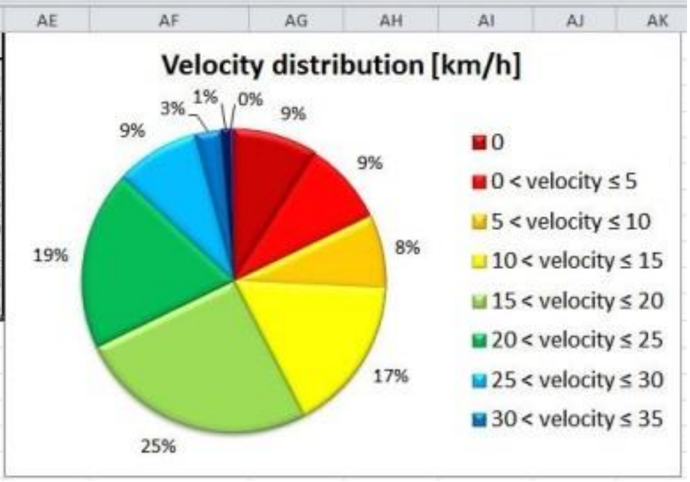


Figure 99 *The table showing the velocity distribution, column AB and AC, were the basis for the creation of the pie chart shown in this Figure.*

In addition to the already mentioned analyzed parameters, further calculations and filtering of the data could also be performed. In conjunction with the investigation along Nya Allén, the cyclists were asked to state their age and gender in the comment field of the function *Min cykeltur*. These comments are thus the content of column C, named *Comment* in Figure 100, and could be used to analyze possible connections between velocity, gender and age. This could be done by using the tool called *Custom AutoFilter* according to Figure 100 and Figure 101.

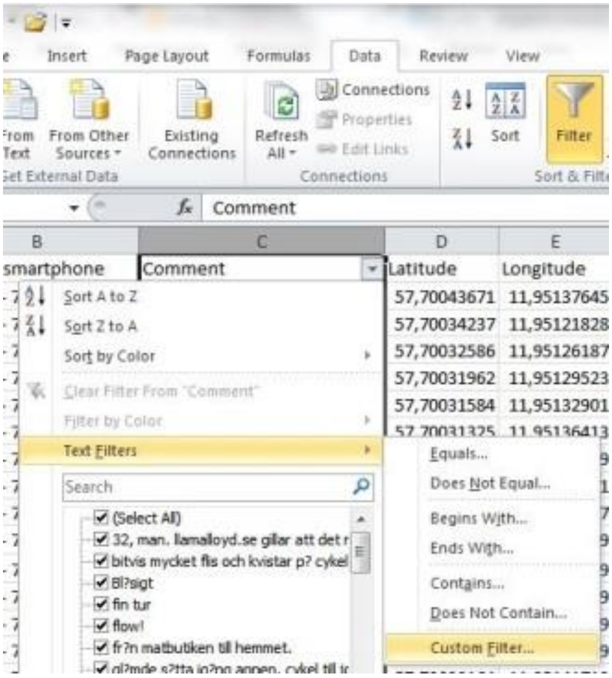


Figure 100 *Mark column C and click on "Filter", found under the tab "Data" in the menu. The tool "Custom AutoFilter is then found according to the Figure.*

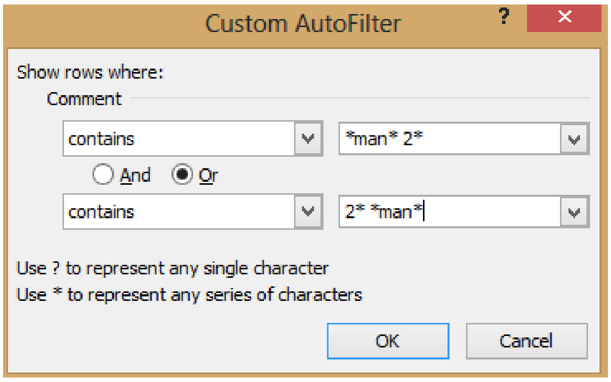


Figure 101 *This expression sorts out men between 20-29 years. The same principle could be used for the women and all range of ages.*

However, most of the cyclists who participated in the investigation missed to state their age and gender. Due to the lack of this information, an analysis regarding possible connections between velocity and gender and age were not carried out in this MSc thesis.

Appendix II – The open source software QGIS

QGIS is a so called open source software, which means that the program can be freely used, changed and shared by anyone (Open Source Initiative). QGIS is licensed under the GNU General Public License, which is a free license for software that aims to insure that the software remains free for all users (Free Software Foundation, 2014). In QGIS, it is possible to visualize, manage, edit, and analyze data (QGIS Development Team, 2014). The program also supports many types of vector, raster and database formats and runs on e.g. Linux, Mac OSX, Windows and Android. Most of the functionalities of QGIS are provided by core features and plugins, which are automatically part of the program when downloading it. In addition to the core plugins, external plugins can easily be installed by using the *Plugin manager*. The basics about QGIS are easy to learn, thanks to the wealth of tutorials, guides and documentation available on the internet. Besides, additional support can be obtained from the international support community consisting of enthusiastic users, developers and supporters.

Appendix III – Information sheet about the investigation along Nya Allén

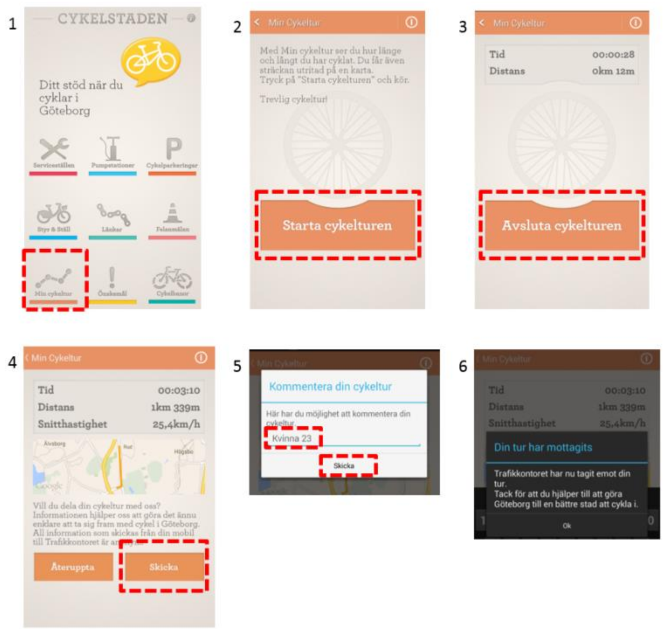
A translated version of the information sheet, which was given to the cyclists on the two days of the investigation, is shown in this Appendix.

Would you like to contribute to a better bicycle infrastructure in Gothenburg?

We are searching for cyclists who would like to contribute to an improved bicycle planning in Gothenburg by participate in an investigation on Wednesday 19 and Thursday 20 March. The Traffic & Public Transport Authority’s app *Cykelstaden* includes the function *Min cykeltur*, which enable you as a cyclist to log your cycle route. Furthermore, you may choose to anonymously share the data with the Traffic & Public Transport Authority. In that way, you help the Traffic & Public Transport Authority to gain knowledge about how cyclists move and thus contribute to the development of the bicycle infrastructure in Gothenburg.

This is how it works:

- Download the app *Cykelstaden* in your smartphone.
- You as a cyclist use the function *Min cykeltur* in order to log your cycle route.
- Cycle the bicycle track along the stretch Nya Allén.
- When your cycle route is completed; click on *send* and state your gender and age.
- Finally, share the data with the Traffic & Public Transport Authority by once again click on *send*.

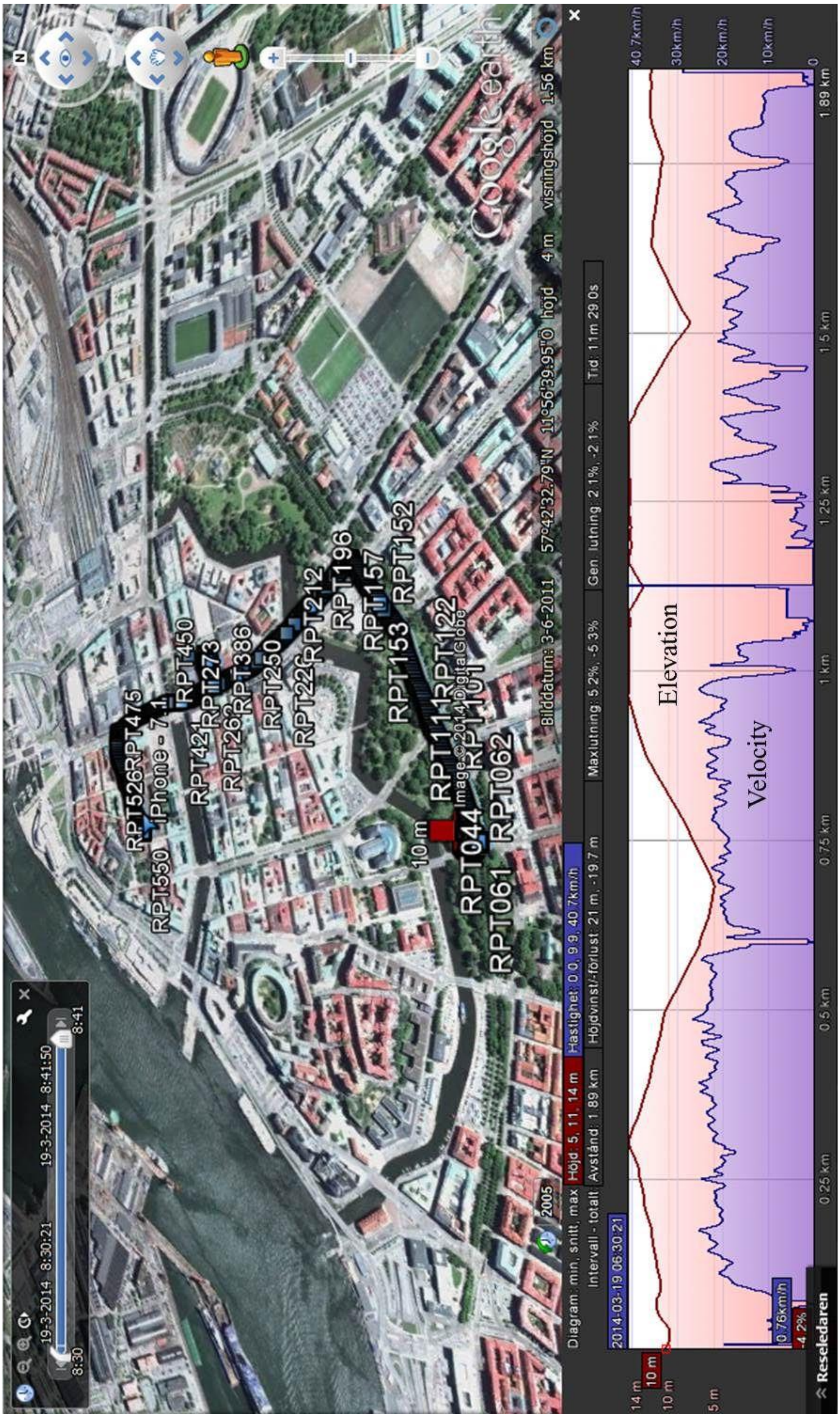


Would you like to help? – Contact us via email:

- johanna.aalto@trafikkontoret.goteborg.se
- johanna.nystrom@trafikkontoret.goteborg.se

You are welcome to participate in the investigation without sending us a notation, but you will then not receive any feedback via email at the end of the evaluation.

Appendix IV – A cycle route visualized in Google Earth



Appendix V – The distance formula

The distance formula[4], which was used when calculating the distances between two points in Excel, is presented below. The formula is based on latitude and longitude coordinates and on the radius of the Earth. In the formula, the latitude and longitude coordinates are called *Lat1* and *Lat2* respectively *Long1* and *Long2* and the radius of earth is called R_{earth}.

$$Distance = \frac{\cos^{-1}((\sin Lat1 \cdot \sin Lat\ 2) + (\cos Lat1 \cdot \cos Lat2 \cdot \cos Long2 - Long1)) \cdot \pi \cdot R_{earth}}{180}$$

$$R_{earth} = 6378000\ m$$

$$Point\ 1 = (Lat1\ ; Long1)$$

$$Point\ 2 = (Lat2\ ; Long2)$$

[4] The distance formula was given by Lennart Falk, Senior lecturer in Mathematical sciences/Mathematics.