Pedestrian Microsimulation

A comparative study between the software programs Vissim and Viswalk

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

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Göteborg, Sweden 2013

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Examensarbete / Institutionen för bygg- och miljöteknik,
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Cover:
The figure shows a 3D-view of a signalized crossing including pedestrians and vehicular traffic (PTV Group, 2013d).

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ABSTRACT

Global and national targets to reduce climate change impact are of great importance when planning future infrastructure in the city of Gothenburg. One goal set by the City of Gothenburg Transportation Administration (Göteborgs Stad Trafikkontoret) is to increase the pedestrian share of traffic. Traffic simulations are an established method when analyzing vehicle flows, where Vissim is one of the most widely used microsimulation software programs. The company that developed Vissim, Planung Transport und Verkehr AG (PTV), has in recent years developed an additional software program known as Viswalk, which is specifically aimed at pedestrian simulations. The purpose of this study was to investigate the need for pedestrian simulations at the City of Gothenburg Transportation Administration and also to find what added value Viswalk can bring to them, compared to pedestrian simulation in Vissim. This was done by performing interviews at the City of Gothenburg Transportation Administration and by performing four case studies in Vissim and Viswalk. The case studies aimed at investigating how well the simulation programs reflect reality and comparing pedestrian behavior in the two programs when interacting with each other and when interacting with vehicles. The interviews showed that there was a great interest for pedestrian simulations at the City of Gothenburg Transportation Administration, which indicated a potential need. The study also showed that there are several areas of applications where the software programs Vissim and Viswalk could be used to satisfy those needs. Furthermore, the case studies showed that Viswalk can provide an added value to pedestrian simulations in some situations. This is especially apparent in scenarios that are complex and handles large volumes of pedestrians. Another important aspect is that the model setup in Viswalk is less time demanding in such scenarios and that the visual outcome is reflecting reality more accurately.

Keywords: Pedestrian simulation, Vissim, Viswalk, Calibration, Traffic analysis

Mikrosimulering av fotgängare
En jämförande studie mellan simuleringsprogrammen Vissim och Viswalk
Examensarbete inom Infrastructure and Environmental Engineering
CECILIA FRIIS
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Väg och trafik
Chalmers tekniska högskola

SAMMANFATTNING

Globala och nationella målsättningar för att minska klimatpåverkan är av stor vikt vid planerandet av framtida infrastruktur i Göteborg. Ett mål som har fastställts av Göteborgs Stad Trafikkontoret är att öka andelen resor som sker till fots. En etablerad metod för att analysera fordonstrafik är trafiksimuleringar. Ett av de mest använda mikrosimuleringsprogrammen är Vissim, utvecklat av Planung Transport und Verkehr AG (PTV). Företaget har under senare år även utvecklat simuleringsprogrammet Viswalk som är särskilt inriktat på att simulera fotgängare. Den här studien syftade till att undersöka behovet av fotgängarsimuleringar på Trafikkontoret och även till att undersöka vilket mervärde Viswalk kan ge jämfört med simulering i Vissim. Metoden för att genomföra detta var att intervjua tjänstemän på Trafikkontoret samt genom att utföra fyra fallstudier i Vissim och Viswalk. Fallstudierna syftade till att undersöka hur väl simuleringsprogrammen återspeglar verkligheten samt till att jämföra fotgängarnas beteende i de två programmen, med hänsyn såväl till interaktion med fordonstrafik som till fotgängarna sinsemellan. Intervjuerna visade på ett stort intresse av fotgängarsimuleringar på Trafikkontoret, vilket i sin tur tyder på ett potentiellt behov av detta. Studien visade även på att det finns flera möjliga användningsområden där Vissim och Viswalk kan tillgodose ett sådant behov. Vidare visade fallstudierna att fotgängarsimulering i Viswalk kan tillföra ett mervärde i vissa situationer. Detta är särskilt tydligt i scenarier som är komplexa och inkluderar stora volymer av fotgängare. En annan viktig aspekt är att modellbyggande i Viswalk är mindre tidskrävande i sådana scenarier och att det visuella resultatet avspeglar verkligheten mer korrekt.

Nyckelord: Fotgängarsimulering, Vissim, Viswalk, Kalibrering, Trafikanalys

Contents

Preface

This study is a result of a Master Thesis at the Department of Civil and Environmental Engineering, Chalmers University of Technology. The thesis has been financed by the City of Gothenburg Urban Transport Administration. During the work with this thesis, support has been provided by the supervisors Johan Jerling at the Strategic Planning department and Joachim Karlgren & Julia Emqvist at Trivector AB.

The thesis has been carried out by the authors Cecilia Friis and Lina Svensson between December 2012 and June 2013 in collaboration with the examiner Gunnar Lannér, University Lecturer at the Road and Traffic Research Group at Chalmers University of Technology.

We would like to thank all of the interviewed officials at the City of Gothenburg Urban Transport Administration for their valuable input. A special thanks to our supervisors Johan, Joachim & Julia. Your support and guidance have been highly appreciated. We would also like to express our appreciation to Gunnar for undertaking the role as our examiner.

Finally, we would also like to thank Søren Frost at Cowi AB for your advice regarding the simulation models, AV-service at Chalmers for providing necessary equipment and our opponents Alexander Senning & Mats Sundberg for valuable feedback.

Gothenburg June 2013

Cecilia Friis & Lina Svensson

1 Introduction

According to global and national targets of reducing climate change impact, the total traffic work around the world must be decreased. In line with this, the city of Gothenburg has set up clear goals and comprehensive infrastructure investments, not least through great measures in the public transport sector. One important step in the pursuit of these goals is to encourage more people to travel by foot (Göteborgs Stad, 2013a, p. 21). Increasing the pedestrian group's share of traffic will contribute to an optimization of the entire traffic system. Besides reducing the environmental impact, increasing the pedestrian share also has many advantages for public health reasons. Considering this, it is of great importance to start managing pedestrians as a separate traffic group.

Most trips begin and end with a walk, to and from the primary mode of transport. This makes pedestrians the largest traffic group, even if walking is not always the primary mode of travel for the trip (Galiza, Kim, Ferreira, & Laufer, 2010, p. 3). Therefore, pedestrian simulation tools are useful in order to fully understand all components of travel. In terms of vehicle flow analyzes, traffic simulations have been a widely used method in different traffic situations. In recent years, more advanced techniques and technology have also made it possible to simulate pedestrians in a more realistic manner (Bönisch & Kretz, 2009, pp. 1-2). Since pedestrians, like vehicles, have an impact on traffic flow, it is of great interest to incorporate this group into the simulations in order to see how they interact with vehicles. It lies in the interest of the City of Gothenburg Urban Transport Administration (Göteborgs Stad Trafikkontoret) to evaluate how such an analysis can be useful for them.

Today, the microsimulation software Vissim is used for vehicle simulations at the Urban Transport Administration. This report is aimed at finding what added value the new microsimulation software Viswalk, developed by the same company and specifically aimed at pedestrian simulations, would give to them. This is done by investigating the need for a pedestrian simulation tool at the Urban Transport Administration and by performing case studies.

1.1 Background

In February of 2013, the City of Gothenburg Urban Transport Administration released a referral of a new traffic strategy with long-term goals for the city of Gothenburg. Historically, the car has often been prioritized during traffic planning in the city. In the new traffic strategy, however, a reprioritization of the different traffic groups is a consistent topic. In heavily visited public transport zones, the city street spaces shall in addition to public transport from now on primarily be planned with respect to pedestrians and secondary to bicyclists. The referral also states that 35 % of the residents' trips shall be made on foot or by bicycle, compared to 30 % today (Göteborgs Stad, 2013a, p. 35). That poses many local challenges for the Urban Transport Administration. People shall be encouraged to reside within the city and choose to walk or take the bicycle instead of taking the car at the same time as the traffic accidents and the health impact caused by traffic should be reduced. At present, there is a lack of knowledge regarding pedestrian behavior and pedestrian flows in Gothenburg. Therefore, the referral also specifies that there is a need of increasing the competence and the resources related to pedestrian behavior in the city (Göteborgs Stad, 2013a, p. 38).

There are several ways of analyzing pedestrian patterns where, among others, a microsimulation can be one useful tool. This type of software exists in different forms with varying features and capacities. At the City of Gothenburg Urban Transport Administration, the microsimulation software Vissim has previously been used in the context of analyzing car traffic. The Vissim software is somewhat restricted regarding pedestrian simulations. However, the new software program Viswalk allows for more complex pedestrian simulations. Discussions about whether this extra feature would be worth investing in and what added value it would provide compared to original pedestrian simulation in Vissim, has been brought up at the Urban Transport Administration.

1.2 Purpose

The purpose of this study is to compare pedestrian simulations in Viswalk to original pedestrian simulations in Vissim. Focus is also on finding possible useful benefits of performing pedestrian simulations at the City of Gothenburg Urban Transport Administration. In addition, the report will aim to work as guidance for possible future work regarding pedestrian simulations in Vissim and/or Viswalk at the City of Gothenburg Urban Transport Administration.

1.3 Research questions

- Is there a need for using pedestrian simulations at the City of Gothenburg Urban Transport Administration?
- What added value would Viswalk bring to the City of Gothenburg Urban Transport Administration in comparison to the original pedestrian function in Vissim?

1.4 Limitations

Since this study is conducted on behalf of the City of Gothenburg Urban Transport Administration, the evaluation of Viswalk and the original pedestrian module in Vissim will focus on aspects that are relevant from a traffic perspective. This study should not be seen as a thorough comparison between the two software programs, more so as a comparison in certain situations. Indoor simulations with Viswalk are not evaluated. Furthermore, the comparison between Vissim and Viswalk is made from a pedestrian perspective. Vissim has many other uses that are not mentioned in this report.

In the use of the Vissim software, there are possibilities to use some of the functions that are available in Viswalk. However, this accessibility is limited to simulations of maximum 30 pedestrians inside the model at the same time. The comparison between Vissim and Viswalk in this report will only apply to the comparison between Viswalk and the original Vissim version that treats more than 30 pedestrians, i.e. where the pedestrians are modeled as a vehicle type. The Viswalk software has no capacity limits when it comes to number of pedestrians.

For the calibration models that are a part of this study, a limited area is studied and then modeled. Factors outside of this area that may be affecting the models are not taken into account. Furthermore, only afternoon scenarios are evaluated. In addition to this, focus on this report is not to go into great detail regarding the setup of the specific simulation models that are being evaluated in this study. However, alterations to the model and adjustments to pre-set parameters that are made during the calibration process are presented in the report.

It should also be mentioned that the content of this study is dependent on the time available, which is limited to 20 weeks. More time would lead to a more in-depth study of pedestrian behavior and pedestrian interaction with vehicles in particular. It would also allow for better follow-ups of real scenarios, in order to establish how well reality can be reflected in each software program.

2 Method

The process of conducting this thesis can be divided into five major parts. The first part was a literature study and orientation in Vissim and Viswalk with the purpose of obtaining adequate knowledge in the area. The second part consisted of planning and performing interviews with officials at the City of Gothenburg Urban Transport Administration in order to examine their need for a pedestrian simulation tool. Part three consisted of a data collection, which was used in part four when a case study was performed by calibration and simulation in Vissim and Viswalk. In addition to the calibration case study, three smaller case studies were performed with the main purpose of comparing the two software programs. Thereafter, as the fifth and final part of this thesis, Viswalk was analyzed and evaluated by taking the research questions into consideration. During the entire process of conducting this thesis, report writing was also done. The method process is illustrated in Figure 2.1.

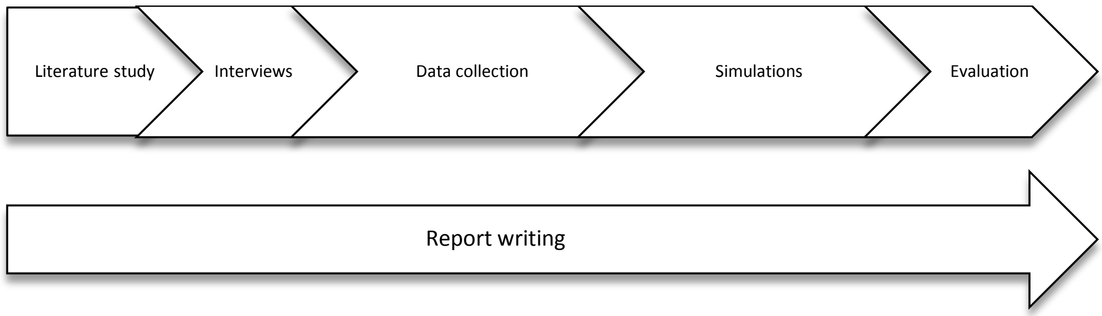


Figure 2.1 The figure shows the process of conducting this thesis.

2.1 Literature study and orientation in Vissim and Viswalk

In order to obtain knowledge in the area of pedestrian analyzes and simulations as well as in both of the simulation programs, a literature study was a natural first part of the process. Focus was on literature regarding pedestrian analyzes, including pedestrian volume studies and measurements, as well as prior studies and information about the software programs. At the initial stage of the process, effort was also put into getting experience from the software programs. This was done by following tutorials and setting up simpler models in the program. To some extent, the literature study continued throughout the major part of writing this thesis.

2.2 Interviews at the City of Gothenburg Urban Transport Administration

When sufficient knowledge in and about Viswalk was gained, the next step was to conduct interviews with officials at the City of Gothenburg Urban Transport Administration. This was done in order to gain more understanding in their work and what possible needs they may have of a pedestrian simulation tool. The interviewed officials were chosen based on their role at the Urban Transport Administration. Some additional interviews were also performed based on ideas from the interviewed officials. Officials from each department were interviewed in order to cover all possible aspects. In total, eleven officials have been interviewed, including:

- two officials within the *Strategic Planning* department
- five officials within the *Traffic* department

- three officials within the *Mobility Management and ITS/Analysis* department
- one official within the *Road and Track* department

It should be noted that the interviews have been carried out in Swedish and thereafter translated into English by the authors.

The questions asked to the employees where somewhat different depending on what position they had or in what department they worked. However, some of the general questions that were asked during the interviews are listed below:

- What do you work with and what are your responsibilities at the City of Gothenburg Urban Transport Administration?
- How familiar are you with Vissim/Viswalk?
- To what extent do you work with pedestrians or interaction between pedestrians and other traffic?
- Do you see any use of pedestrian simulations in your work? If yes, in what situations?
- Do you see any problems in using simulation tools like Vissim and Viswalk? (e.g., time consuming, requires a lot of detailed data, etc.)

2.3 Data collection for calibration

Data for the first case study, the calibration model, was gathered by filming a location in the University of Gothenburg campus located in the neighborhood of Haga (Gothenburg), see location in Figure 5.1. Filming took place during three different occasions; morning, lunch and afternoon. This was done in order to observe pedestrian behavior and their movement patterns at different hours. It was found that the afternoon hours generated the largest interaction between pedestrians and vehicles. Therefore, the afternoon rush hours were filmed on two additional occasions between 3.30-5.30 pm and then studied at five minute intervals. The maximum 15-minute pedestrian flow was then multiplied by four to get the maximum hour.

Apart from the number of pedestrians passing the area, their route choices and behavior were also observed. Speed was estimated by measuring the travel times of the pedestrians as they walked along a known distance. Based on the filming results, the pedestrians have been divided into the following categories;

- Individuals
- Groups
- Runners

The different group definitions are based on the pedestrians' velocities. To determine the different categories' velocities, pedestrians from each category were clocked in order to get the mean value. The number and velocities of motor vehicles and bicyclists passing were also studied. Thereafter, the results were used to create normal distribution curves for each traffic group to base the model input on.

2.4 Simulation in Vissim and Viswalk

The simulation process consists of two parts: one model calibration of a present scenario and three smaller non site-specific case studies of different scenarios.

The calibration model was built in both Vissim and Viswalk in order to be able to compare the two. The models were calibrated in order to reflect real life pedestrian and traffic behavior as true as possible by adjusting different possible parameters.

The three smaller case studies were chosen in order to get a better view of how Vissim and Viswalk differ from each other. Two of the scenarios were aimed at comparing pedestrian behavior and pedestrian interaction on a more detailed level. A third scenario was aimed at evaluating the interaction between pedestrians and vehicles in each software program.

2.5 Evaluation of simulations

Evaluations of the simulations were performed continuously. Both the results in terms of visualization and output of the models were taken into consideration and used as a basis for answering the research questions.

3 Pedestrian simulation in Vissim and Viswalk

The simulation programs Vissim and Viswalk are developed by the German company Planung Transport und Verkehr AG (PTV). PTV has developed several products in the traffic planning and traffic engineering field that are widely used around the world (PTV Group, 2013a). Vissim and Viswalk are *microsimulation* tools, which mean that vehicles and pedestrians are simulated as individual objects within a larger system (Laufer, 2008, p. 2). As pedestrians are not as predictable when moving as vehicles moving in traffic, they are more complex to simulate. The Viswalk software is developed as an addition to Vissim, with the purpose of simulating and analyzing pedestrian flows in a more realistic manner than what is possible by only using Vissim. The Viswalk tool can be used both within the Vissim software and separately, as an external software. Within Vissim, Viswalk can be used to simulate both pure pedestrian flows and pedestrian interaction with vehicles. When Viswalk is used separately, it is not possible to simulate vehicular traffic.

3.1 Areas of application

In terms of areas of application for Vissim and Viswalk, the possibilities are about the same. What distinguishes the two software programs, however, is rather the model setup, the possibility to adjust pedestrian parameters and hence also the outcomes of the models. This is mainly due to the fact that the pedestrian functions in Viswalk allow the pedestrians to move more realistically than in Vissim.

In both of the simulation tools, a model can be built up to study any scenario where the main goal is to ensure a smooth flow of pedestrians, *indoors* as well as *outdoors*. In terms of indoor pedestrian simulations, Viswalk is the main choice for such simulations, especially when the pedestrian volume is large.

What can be simulated in both Vissim and in Viswalk (in combination with Vissim) is also the *interaction* between pedestrians and other traffic and hence how the vehicular traffic is influenced by the pedestrians (PTV Group, 2011). Such a simulation may help to improve current infrastructure in cities where the pedestrian volumes are significantly large. On a more detailed level, it can be helpful when it comes to planning the location of new pedestrian crossings or the width of a sidewalk.

Furthermore, pedestrians in Vissim and Viswalk can be simulated in terms of *waiting scenarios*, making *route choices* and boarding and alighting *public transport* (PTV Group, 2013b). This makes the software programs useful when making timetables for public transport, since dwell times can be accurately estimated and taken into consideration to allow for a more reliable public transport system. Another application for public transport may be to determine the optimal location of a bus/tram stop, or how the waiting pedestrians at a bus stop affect other traffic such as bicycle tracks, foot paths or vehicular traffic.

When designing new buildings, both software programs can be used to *analyze capacity* and *optimize the use of space*. However, by simulating a planned scenario in Viswalk, more detailed analyzes can be made, for instance to avoid bottlenecks and disturbing obstacles in the building constructions. In terms of safety, an important area of application for Viswalk is also the possibility to perform *evacuation analyzes*. By doing this, safe escape routes can be found for buildings, arenas, tunnels and other facilities.

A large construction building, such as a central station, is another scenario where large pedestrian flows can be expected. By using Viswalk, simulations can be run in order to analyze the passengers' routes of choice in the building, which depend on the architecture of the building, how pedestrian routes are organized, where elevators and escalators are located, etc. One example where Viswalk has been used for this type of purpose is at the planning of the Central Station of Amsterdam, The Netherlands. The station is currently undergoing construction in order to accommodate more visitors as both the bus- and train terminals are increasing in size (PTV Group, 2012). Before constructions started, Viswalk was first brought into the process in order to simulate the current scenario at the station. This gave an output of statistical data in terms of level of service, which is Section 3.4.4, at stairways, pedestrian routes and platform. This made it possible to see where the station was the most sensitive to construction activities. It also allowed for visualization of the consequences on the pedestrian flow if certain trains were to be rerouted to other platforms during the construction process, for example. By taking this under consideration, the often time-consuming process of re-construction and renovation of buildings can be carried out in a way that does not disturb the function of the building more than necessary.

A summarized list of the possibilities regarding areas of application in Vissim and Viswalk can be seen in Table 3.1.

Table 3.1 The table presents a summary of possible areas of application for Vissim and Viswalk.

	Possible in Vissim	Possible in Viswalk	Comments
Pedestrians walking on sidewalks	X	X	In Vissim simulated as vehicles on links. In Viswalk moving freely on links or areas.
Pedestrians walking on areas (open spaces)		X	
Pedestrians walking on construction elements (ramps, escalators)		X	
Pedestrians walking on different storeys		X	
Pedestrian interacting with vehicular traffic	X	X	In Viswalk only possible in combination with Vissim.
Pedestrians on unsignalized crosswalks	X	X	More complicated model setup in Vissim since the pedestrians are not able to meet each other on the same link.
Pedestrians on signalized crosswalks	X	X	More complicated model setup in Vissim since the pedestrians are not able to meet each other on the same link.
Pure large pedestrian volumes		X	Only Viswalk can deal with large volumes of pedestrians, such as in evacuation situations, airports and central stations.
Public Transport	X	X	Construction elements (areas as platform edges or waiting areas included) only possible in Viswalk.
Pedestrians meeting on the same link		X	Possible when the option "use as pedestrian area" in Viswalk is checked, see Section 3.2.1.2 for more information.
Dwell Time	X	X	Provided in both software programs, but in Vissim only for public transport. In Viswalk, queuing, waiting, etc. can be simulated.

3.2 Model setup

The two software programs differ somewhat when it comes to how to set up a model or a system. With information received from the Vissim 5.40 User Manual (PTV Planung Transport Verkehr AG, 2012), this section will present similarities and differences in the main model setup in Vissim and Viswalk.

3.2.1 Building the models

The main difference between the two software programs is that pedestrians in Vissim are simulated as vehicles while pedestrians in Viswalk are able to move more freely. Although they are both managed in the same desktop, there is a certain pedestrian icon for Viswalk offering more model opportunities. The Vissim desktop can be seen in Figure 3.1. The red circle marks the pedestrian icon which activates Viswalk. Described below are some basic differences in model setup between Vissim and Viswalk.

Figure 3.1 The figure shows the Vissim desktop (PTV Planung Transport Verkehr AG, 2012, p. 36).

3.2.1.1 Vissim

To enable pedestrians or vehicles to walk or drive in a Vissim model, *links* have to be placed out on the worksheet. Pedestrian or vehicle inputs can thereafter be set at the start of the link, see Figure 3.2a. In the case of pedestrian simulations, the input will represent the chosen amount of pedestrians that will be sent out on the link per hour. A link in Vissim only allows for pedestrians walking in one direction. Once a pedestrian has entered a link, it will continue to follow that link as long as no other command is made. If there is a desire to make the pedestrian change from one link to another, a *connector* has to be placed in between the two links in order to bind them together, see Figure 3.2a. Connectors can connect an endless amount of links and are required to allow pedestrians to change link in Vissim. Furthermore, to make pedestrians choose a certain direction when they reach a connector, different routes have to be set, as can be seen in Figure 3.2b. When a set of route choices has been set up for a model, the amount of pedestrians that shall walk the different routes is determined by giving a percentage of pedestrians for each route.

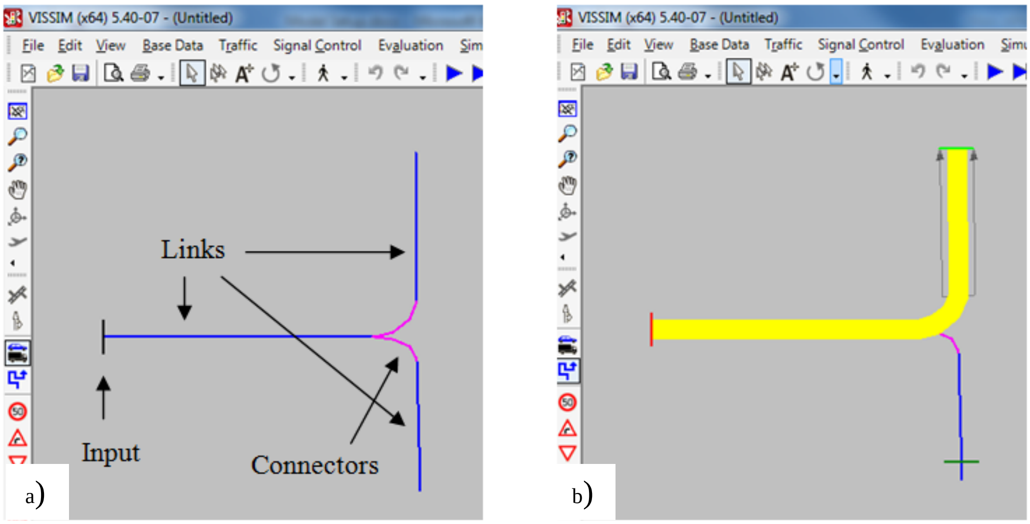


Figure 3.2 a) The basic set up of a model in Vissim. b) The figure shows how a routing decision is placed.

3.2.1.2 Viswalk

In addition to walking on links, as in original pedestrian simulations in Vissim, pedestrians in Viswalk are also able to walk on *areas*, see Figure 3.3a. By walking on areas, pedestrians are allowed to walk more freely and more realistically. Instead of walking in rows on a predetermined route, pedestrians are able to make sudden turns, walking around each other and changing directions. Pedestrians are also able to walk in different directions in one designated area. Links are still necessary in scenarios where interaction between pedestrians and other vehicles is wanted. However, in Viswalk links can be *used as areas*, which means that the *Social Force Model* behavior, which is described further in Section 3.3.2, that is used on areas also can be applied to the links. In turn, this allows for pedestrians to walk in more than one direction on the link. This provides a simulation with all the benefits of realistic pedestrian behavior even in interaction with vehicles.

The pedestrian input in Viswalk is set in a certain area and route choices are set in a similar way as in Vissim, but with a start and an end area, see Figures 3.3a and 3.3b. To connect the links to the areas, they simply have to overlap, meaning no connectors are necessary in Viswalk. Another function that is available only in Viswalk is the pedestrians' possibility to walk on construction elements such as ramps and escalators. It is also possible to build up a model in several layers, something that can be of important use when it comes to airports or central stations.

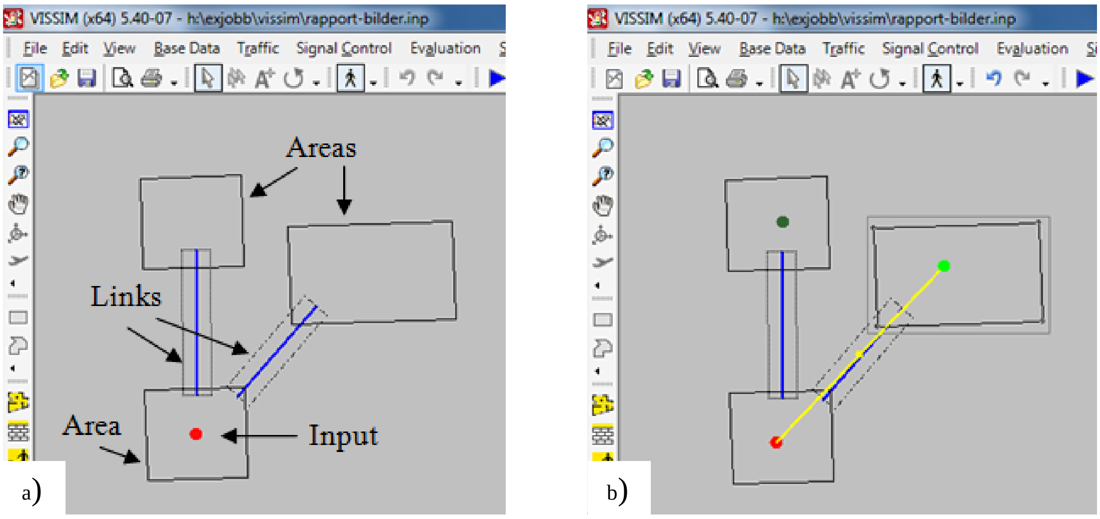


Figure 3.3 a) The figure shows three areas in Viswalk, connected by two links. The dot in the bottom area represents the pedestrian input in Viswalk. b) Shows a route choice between two areas.

3.2.2 Conflict zones

In all situations where there is a conflict between vehicle or pedestrian flows, for instance at an unsignalized pedestrian crossing, at a crossroad or between vehicles on the same link, the different flows have to be given certain rules of who should receive priority and who should give way. In Vissim and Viswalk, this is regulated either by the *priority rule* tool or the *conflict area* tool (PTV Planung Transport Verkehr AG, 2012, pp. 283-302).

The priority rule can be seen in Figure 3.4, where a red stop line is placed on the link that serves for the vehicles that should give way for the crossing road. A green conflict marker connected to the red stop line is thereafter placed on the main road, offering several optional conditions that must be fulfilled before the vehicles on the minor road are allowed to cross the red line. A stop line can have an endless amount of conflict markers connected to it and they all offer several setting options involving the two main conditions;

- minimum headway (distance) and
- minimum gap time

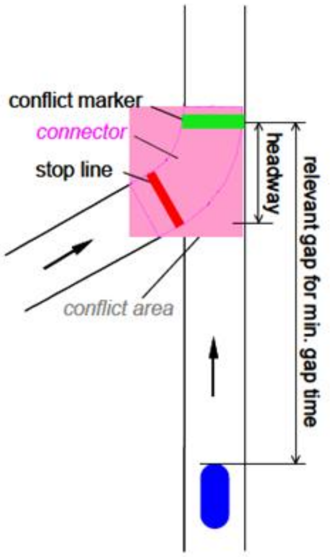


Figure 3.4 The figure shows the setup of a priority rule with a red stop line and a green conflict marker (PTV Planung Transport Verkehr AG, 2012, p. 289).

One alternative to the priority rules is the conflict area tool, which is a more simple way of dealing with conflict zones. It can be used wherever two links or connectors overlap and the user defines which lane should be given priority (green fields in Figure 3.5) and which should give way (red fields). Some further options such as front and rear gap time, safety distance factor and additional stop distance can then be adjusted for each conflict area. According to the PTV Group (2012, p. 283), the conflict areas are the primary recommended tool to use in conflict zones, since it is the most user-friendly one. However, there are still several situations where this tool is not sufficient to solve the simulation problem in a desirable manner. In these situations, the priority rules are a better choice.

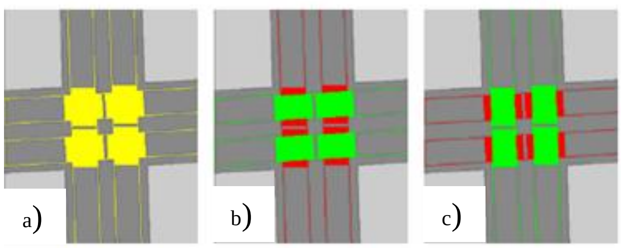


Figure 3.5 a) Passive conflict area b) Conflict areas with right of way in left/right direction c) Conflict areas with right of way in top/bottom direction (PTV Planung Transport Verkehr AG, 2012, p. 296).

3.3 Pedestrian behavior settings

In addition to general pedestrian inputs, it is also possible to affect pedestrian behavior by adjusting specific parameters. Pedestrian movement in Vissim and Viswalk are based on two different behavior models, *the Wiedemann model* and *the Social Force model* respectively. Due to a difference in model setup regarding pedestrian behavior, the possibilities of adjusting parameters differs in the two software programs.

3.3.1 Vissim

Since pedestrians in Vissim are modeled in the same way as vehicles, they are restricted to move along predetermined routes. This model is based on the Wiedemann model, which is a car following model describing vehicles' positions and velocities, that takes both physiological and psychological aspects into account (PTV Planung Transport Verkehr AG, 2012, p. 136). The vehicle following model provides a somewhat unrealistic pedestrian behavior as they are moving far more rational than in reality.

3.3.1.1 Parameters

Being based on the Wiedemann vehicle following model, the adjustable pedestrian parameters in Vissim are the same as those for vehicles. Information regarding parameters is obtained from the Vissim 5.40 User Manual (PTV Planung Transport Verkehr AG, 2012, pp. 137-141). Only those parameters that are considered to be relevant for pedestrian simulations and for this study are presented in this chapter.

Look ahead distance – Defines the distance forward within which a pedestrian can see and react to other pedestrians and vehicles.

Observed vehicles – Determines how well pedestrians can predict and react to other pedestrians and vehicles.

Look back distance – Defines the distance backward within which a pedestrian can see and react to other pedestrians and vehicles.

Temporary lack of attention – Determines the inattentiveness towards other pedestrians or vehicles.

Smooth close-up behavior – Allows for an even deceleration in pedestrians when approaching a pedestrian or vehicle that is decelerating.

Standstill distance for static objects – Distance between a pedestrian and a static object in front of him or her.

Model parameters – Depend on which model is chosen. Typical model parameters include the standstill distance between pedestrians, headway as well as acceleration and deceleration parameters.

Lateral parameters **–** Defines the lateral position of pedestrians within one lane and their possibility to pass each other.

3.3.2 Viswalk

Viswalk is developed in order to allow for simulations with a realistic behavior in pedestrians as well as the possibility to simulate complex situations. This can be done both in interaction with traffic (in combination with Vissim) and without (PTV Group, 2011).

Pedestrian behavior in Viswalk is based on what is known as the Social Force Model. This model takes the somewhat irrational behavior of pedestrians into account. According to Helbing and Molnár (1995), the motion of pedestrians can be considered as a result of human beings being subjected to forces. These forces consist of several internal motivations that together allows for the individual to move in a certain way or direction. The force, F, that causes pedestrians to decelerate or accelerate consists of four terms:

$$F = F_{driving} + F_{social} + F_{wall} + F_{noise} \tag{3.1}$$

$F_{driving}$: Driving force in the desired direction

F_{social}: Forces between pedestrians

F_{wall}: Forces from walls

F_{noise}: A random force term that is implemented in order to prevent deadlocks at bottlenecks

Most likely, the most significant motivation for a pedestrian to move is his or her desire to reach a certain destination as soon and as comfortable as possible. However, there are some factors that influence the pedestrian's path and speed towards reaching the destination. Keeping the distance to obstacles, buildings or objects, and not to forget other pedestrians, is one important factor. Another is possible attractive effects of the motion, such as seeing a friend or a window display, which can make the pedestrian slow down momentarily or even stop or take a detour. All these factors are essential in the Social Force Model. A visualization of the model can be seen in Figure 3.6.

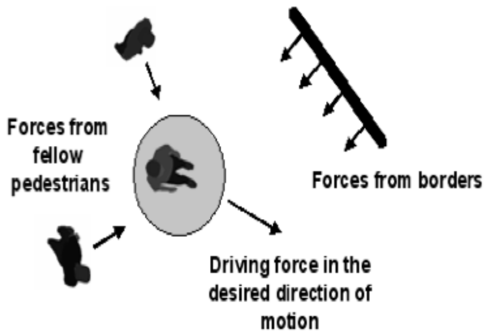


Figure 3.6 The figure visualizes important attributes of the Social Force Model (Laufer, 2008, p. 3).

Due to the internal motivations and forces, pedestrians are automatically forming self-organizing lanes of people walking in the same direction when encountering an opposing flow (Laufer, 2008, p. 3). A visualization of this can be seen in Figure 3.7. At narrow passages, the walking direction will change in oscillatory patterns. As a result of this, Viswalk allows for a realistic modeling of the pedestrian walking behavior.

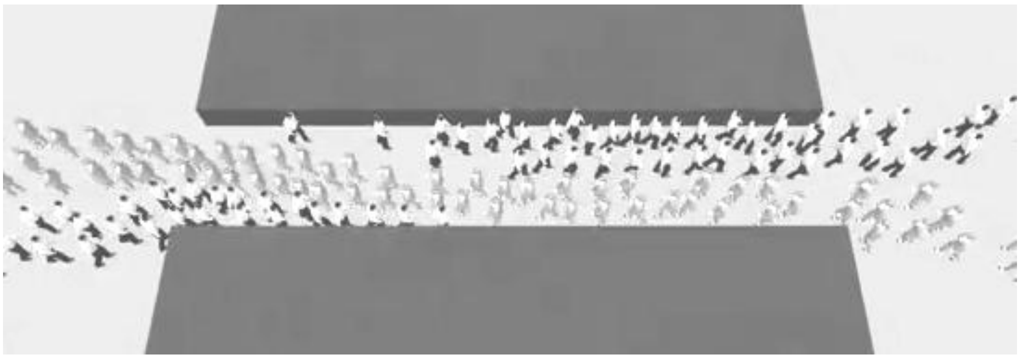


Figure 3.7 The figure shows self-organized lanes of pedestrians in a narrow passage. Black/white pedestrians are walking in one direction and grey pedestrians in the other (PTV Group, 2010).

3.3.2.1 Parameters

There are many parameters that can be adjusted in Viswalk. Which parameters to adjust and how to adjust them depend on what is being simulated. Information regarding parameters is obtained from the Vissim 5.40 User Manual provided by PTV Planung Transport Verkehr AG (2012, pp. 489-494) or from example files that are included in the software program if no other sources are given. If nothing else is mentioned, the parameters listed below are to be adjusted in the parameter file.

Dynamic potential – The default setting for Viswalk makes the pedestrians choose the shortest path possible. This is known as *static potential*, as the distance to the destination does not change during the simulation run. However, there are situations when the quickest path to reach a destination is not necessarily the shortest path. For many travelers, it is more appealing to reach the destination as quickly as possible, rather than walking the absolute shortest path. The intention of *dynamic potential* is to make pedestrians choose the path with the estimated minimal remaining travel time to the destination (Kretz, Grosse, Hengst, Kautzsch, Pohlmann, & Vortisch, 2011, p. 734). By enabling the dynamic potential, the pedestrian reevaluates the path throughout the walk, always looking for the shortest trip from the current point. Within the dynamic potential, there are several parameters which can be adjusted. The Dynamic potential can be adjusted through the routing tool.

Never walk back – Determines whether pedestrians are to stop or not when the difference between the calculated velocity and the desired direction is more than 90°.

Use cache – Complex and thus time-consuming calculations can be limited by adjusting this parameter when running several simulations on a model. Calculations from the first simulation are valid for all simulations if the geometry of the model is consistent.

Tau (τ) – Tau can be interpreted as the reaction time of the pedestrians. Together with the desired velocity and the current velocity, tau determines the driving force, $F_{driving}$. By decreasing tau, the acceleration and driving force increases. As a consequence, the time of throughput can be reduced by decreasing tau in narrow passages. When a large group of pedestrians are passing a bottleneck, the pedestrians that are approaching the bottleneck entrance slow down due to the social forces. By decreasing tau, the driving force will be stronger relative to the social force. As a consequence, the density at the entrance of the bottleneck will increase, which allows for a better flow through the bottleneck.

Grid size – Defines how pedestrians influence each other. It determines a maximum distance at which a pedestrian may have influence on another pedestrian. The grid consists of squares with adjustable size. A certain pedestrian will only be affected by another pedestrian if that pedestrian is situated in one of the eight surrounding adjacent squares. A too small value can lead to pedestrians evading too late when meeting or passing, due to not being able to discover each other in time.

React to n – Determines the maximum number of pedestrians that are taken into consideration when calculating the social force, F_{social}. The actual number of pedestrians taken into consideration may be smaller than this number if the influence conditions of the grid size parameter are not fulfilled.

Lambda mean – Intends to take into account that people and events behind a pedestrian do not influence its movement as much as people and events ahead of the pedestrian do. Lambda affects the social force, F_{social}.

A soc isotropic and B soc isotropic – Together with lambda mean, these two parameters governs the direction-dependent force between pedestrians.

VD – Takes the relative velocities of pedestrians into account and contributes to the social force, $\mathrm{F}_{\mathrm{social}}$. By increasing VD, opposing pedestrians will evade earlier when passing or meeting.

A soc mean and B soc mean – Govern the strength and range of the speed-dependent social force between two pedestrians.

Noise – Determines the strength of the random force term, F_{noise}. The random force term is added to the force after all other forces have been calculated only if a pedestrian is slower than his or her desired speed for a certain time.

Routing – There are several parameters within the routing that can be adjusted. These affect both calculation times and exactness of calculations. They can also add extra distance to narrow pathways compared to wide ones in order to achieve more realistic route choices in pedestrians when there is a choice between the two. This is only possible when static potential is used; i.e. pedestrians are walking the shortest path possible to reach their destination.

Queue order and queue straightness – Determine the shape of queues. Increasing the parameters will result in an increasingly orderly queue.

Side preference – Determines side preferences of pedestrians, whether they prefer passing each other to the left or to the right. Random behavior is set as default.

3.4 Evaluation possibilities

There are numerous evaluation possibilities in Vissim and Viswalk. In this chapter, those evaluation possibilities that are considered to be the most relevant for this study will be presented. Output files can be obtained either as raw data or compiled data.

3.4.1 Travel times

Measuring *travel times* along a certain distance is a well established method in the context of traffic evaluations. In Vissim and Viswalk, the evaluation setup is quite similar. In the first mentioned program, start and stop measure lines are placed on the link, while start and stop points are placed on areas in Viswalk. The method can be applied on both vehicular traffic and pedestrian flows.

The gathered output after a simulation run provides average travel times per time interval, which can be divided into several shorter time intervals over the simulation.

3.4.2 Queue lengths

Another often used evaluation method is the *queue length* measurement. This evaluation type offers an output of average queue length per interval. The length of the queue is measured upstream a link, starting at a position where a *queue counter*-line is placed on the link. Since this type of measurement is depending on the queue counter, it is mainly used for traffic bounded to links, i.e. vehicular traffic and pedestrians in Vissim. However, it can preferably be used in models where pedestrians in Viswalk interact with other traffic, e.g. studies of how pedestrians impact on vehicular queue lengths in unsignalized crossings. In Vissim and Viswalk, the user can define a speed under which vehicles are considered to be queuing.

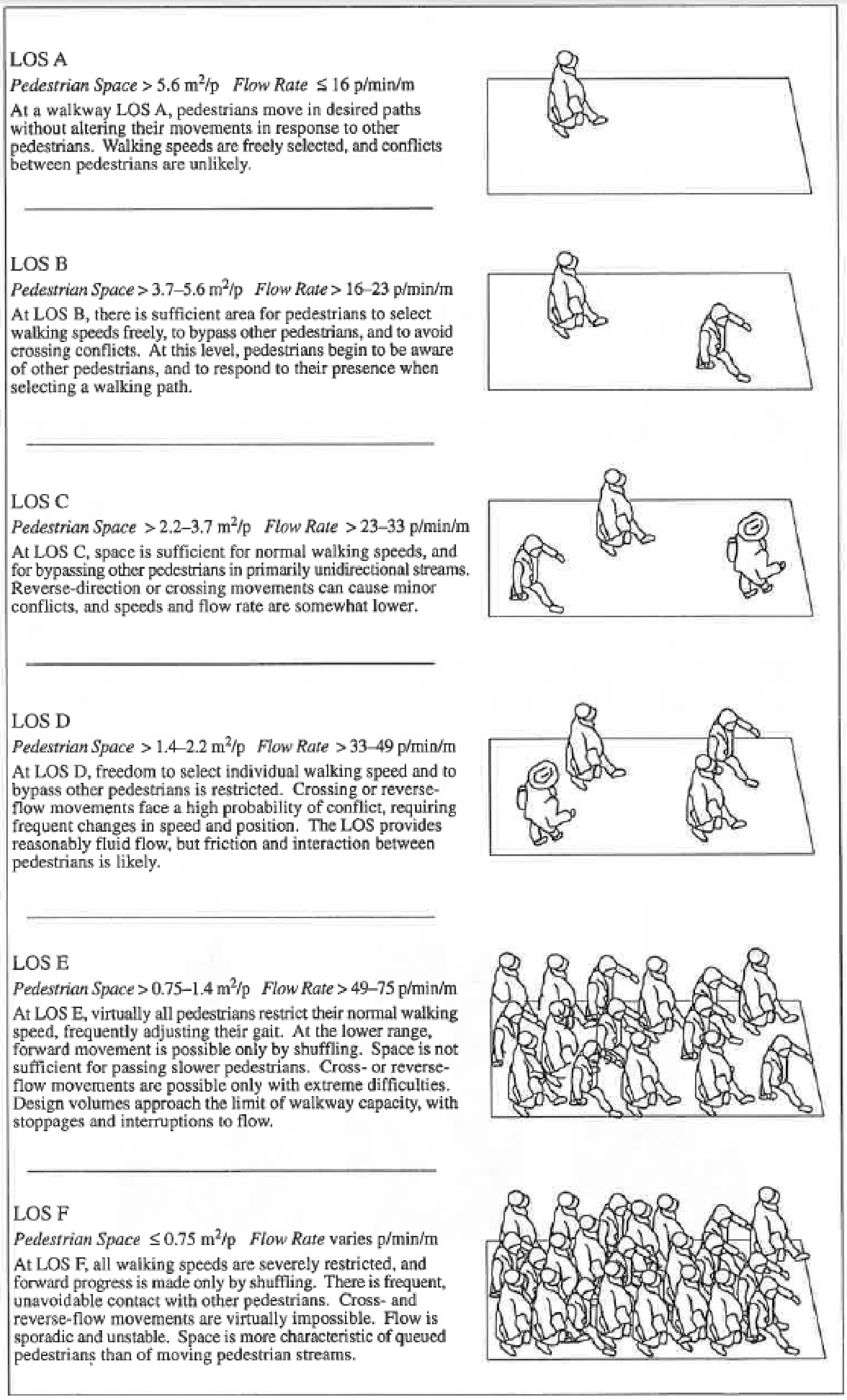
3.4.3 Density levels

The *density* of a certain link or area can also be obtained. This can give an indication on how crowded a certain spot is. The density is given as number of pedestrians per kilometer in both Vissim and Viswalk. The average density can be obtained for shorter or longer time intervals.

3.4.4 Level of service (LOS)

The concept of *level of service* is a standard widely used by traffic engineers to classify different elements of infrastructure. It measures the quality of different facilities such as highways, intersections, pedestrian walkways, stairways and queuing areas in terms of density and travelling comfort and is “based on service measures such as speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience” according to Burden (2006 ch.2 p.9).

In Viswalk, LOS is obtained as vehicles per square meter. There are several LOS standards that somewhat differ both in terms of level breakpoints and what the levels are based on. In Figure 3.8, one of the most commonly used standards (HCM) can be seen. The LOS thresholds in this standard have been determined “on the basis of the walking speed, pedestrian spacing, and the probabilities of conflict at various traffic concentrations" according to PTV Planung Transport Verkehr AG (2012 p.478).



LOS A

Pedestrian Space > 5.6 m²/p *Flow Rate* ≤ 16 p/min/m

At a walkway LOS A, pedestrians move in desired paths without altering their movements in response to other pedestrians. Walking speeds are freely selected, and conflicts between pedestrians are unlikely.

LOS B

Pedestrian Space > 3.7–5.6 m²/p *Flow Rate* > 16–23 p/min/m

At LOS B, there is sufficient area for pedestrians to select walking speeds freely, to bypass other pedestrians, and to avoid crossing conflicts. At this level, pedestrians begin to be aware of other pedestrians, and to respond to their presence when selecting a walking path.

LOS C

Pedestrian Space > 2.2–3.7 m²/p *Flow Rate* > 23–33 p/min/m

At LOS C, space is sufficient for normal walking speeds, and for bypassing other pedestrians in primarily unidirectional streams. Reverse-direction or crossing movements can cause minor conflicts, and speeds and flow rate are somewhat lower.

LOS D

Pedestrian Space > 1.4–2.2 m²/p *Flow Rate* > 33–49 p/min/m

At LOS D, freedom to select individual walking speed and to bypass other pedestrians is restricted. Crossing or reverse-flow movements face a high probability of conflict, requiring frequent changes in speed and position. The LOS provides reasonably fluid flow, but friction and interaction between pedestrians is likely.

LOS E

Pedestrian Space > 0.75–1.4 m²/p *Flow Rate* > 49–75 p/min/m

At LOS E, virtually all pedestrians restrict their normal walking speed, frequently adjusting their gait. At the lower range, forward movement is possible only by shuffling. Space is not sufficient for passing slower pedestrians. Cross- or reverse-flow movements are possible only with extreme difficulties. Design volumes approach the limit of walkway capacity, with stoppages and interruptions to flow.

LOS F

Pedestrian Space ≤ 0.75 m²/p *Flow Rate* varies p/min/m

At LOS F, all walking speeds are severely restricted, and forward progress is made only by shuffling. There is frequent, unavoidable contact with other pedestrians. Cross- and reverse-flow movements are virtually impossible. Flow is sporadic and unstable. Space is more characteristic of queued pedestrians than of moving pedestrian streams.

Figure 3.8 A description of the different levels of service for pedestrians in the HCM standard (Transportation Research Board, 2000, ch.11 p.9).

The Vissim software does not provide any LOS output possibilities. Nevertheless, the density output can be used instead of the LOS to measure a corresponding accessibility and comfort of a walking or waiting area.

3.4.5 Visual evaluation

The most obvious form of *visual evaluation* is by watching the simulation as it runs in 2D and 3D mode. By doing this, it is easy to quickly discover problem areas of a model. This is useful when trying different traffic solutions for certain scenarios in both Vissim and Viswalk. Visual evaluation is also an important part during the calibration process of a model.

In addition to watching the simulation, visual evaluation may also be obtained in terms of LOS. There are two different types of LOS outputs in Viswalk. The first one provides data gathered in a file, which can then be used to create different diagrams. The second one is gained by watching the model during the simulation in LOS mode. This visual method makes different colors in different fields in the model represent the levels of service, see Figure 3.9. Thus, it can be seen if, where and when hot spots will occur in the modeled scenario.

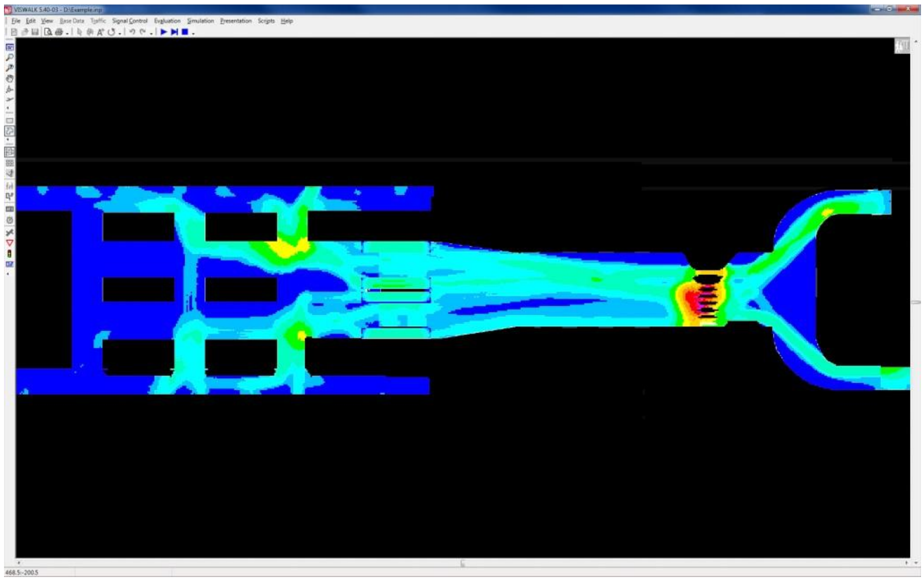


Figure 3.9 A visualization of LOS in the Amsterdam Central Station case which was described in Section 3.1 (PTV Group, 2013c).

4 Inventory of the need for pedestrian simulations at the City of Gothenburg Urban Transport Administration

The City of Gothenburg Urban Transport Administration consists of, with the exception of head organization and central functions, four departments which all have different responsibilities. Their common goal is to offer everyone efficient, safe and sustainable mobility in the city of Gothenburg. The departments can be seen in Figure 4.1.

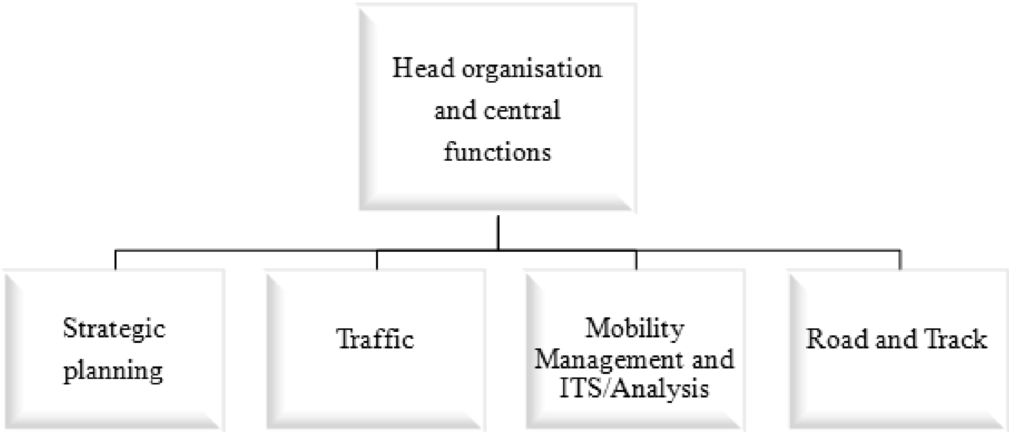


Figure 4.1 A simplified organization map for the City of Gothenburg Urban Transport Administration.

Strategic Planning is responsible for long-term operational and financial planning, including investment and operating plans. Their work includes traffic forecasts and developing visions and goals for the Urban Transport Administration. The department also has overall responsibility for questions regarding public transport, environment and traffic safety.

The *Traffic* department plans the design and usage of streets. They work with proposals for new traffic solutions in urban development as well as short-term traffic measures, for example during events and road construction.

Mobility Management and ITS/Analysis develops new methods and services for road users in Gothenburg. The department is also responsible for traffic education and environmental programs.

Road and Track is managing traffic facilities. This includes operation, maintenance and building new roads and tracks. The department is also responsible for permits regarding usage of public land and construction in the street.

Officials from each department have been interviewed and the results from the interviews are presented in this chapter.

4.1 The pedestrian situation today and in the past

The common opinion among the interviewed officials from each department is that pedestrians are an insufficiently studied traffic group at the City of Gothenburg Urban Transport Administration. Little is known about pedestrian behavior and pedestrian movement within Gothenburg.

Today, a lot of the pedestrian planning at City of Gothenburg Urban Transport Administration is performed based on experience. This is the case when large events are taking place within the city, where capacity and movement patterns are known from experience, a method that today is working satisfactory according to an official within the *Traffic* department. Apart from planning based on experience, there has also been a tradition in Gothenburg to prioritize vehicles over pedestrians. First priority has been to make sure vehicles will have sufficient space and then the pedestrians would have to settle with what is left. A contributing factor to this is that there are no guidelines regarding how much room a certain amount of people that are moving around a specific area need. The fact that pedestrian data is more difficult to gather than vehicle data also contributes to pedestrian planning being more complex.

One common opinion among the officials is that pedestrians should be studied more in the future and that guidelines regarding pedestrians are needed. It is a group that is becoming increasingly important in the densification of the city and is now seen as one of the highest priority groups. According to the new traffic strategy, there is a long-term goal to create a better society for pedestrians. Thus, there is an interest in studying pedestrian flows and more specifically pedestrian movement in Gothenburg in order to better understand where and how they move. This would benefit all sorts of traffic planning from both a capacity and traffic safety perspective.

4.2 Useful areas of application at the City of Gothenburg Urban Transport Administration

All interviewed officials could see a great interest in simulating pedestrians. Those who did not see a specific area of use in their own daily work could see benefits for the Urban Transport Administration as a whole. The different ideas that came up are divided into categories under which they are exemplified further.

4.2.1 Capacity planning

Officials within all departments immediately brought up the many construction projects that are taking place in Gothenburg in the next decades to come. Due to new structures, there will be a change in the pedestrian pattern of the city. There is a concern regarding how pedestrians will be able to move around in the city and how they might affect other traffic. Pedestrian simulation could be an efficient tool in order to predict a future scenario and thereby make necessary adjustments so that a potentially unsustainable situation can be avoided. One official within the *Traffic* department found it especially interesting to look at the areas around the upcoming stations in the West Link Project. Tens of thousands of people will appear every day from underground, making the train stations Korsvägen, Haga and the Central Station into very vulnerable areas. Simulations could be performed in order to analyze whether these areas are ready for such an increase of visitors or if measures need to be taken, such as increasing the size of the areas available for pedestrians. There is also interest in analyzing how quickly people will disappear from an entrance when large groups emerge at the same time. Such simulations are also useful when determining where entrances to the underground train stations should be placed in order to avoid disturbing other traffic.

Other uses for pedestrian simulation in Viswalk is to, in the early stage of a new project, analyze the space that is needed for a square or a street in order to take care of the expected number of pedestrians that visit the area. A simulation could be a helpful tool when determining dimensions.

4.2.2 Justification of projects and measures

Due to a lack of existing tools, it is today difficult to justify new projects. It could for example be a crowded street where the interaction between vehicles and pedestrians is not optimal. A mutual suggestion from officials in the *Traffic* department was to let microsimulations serve as a visual aid in order to justify such projects, as new locations for crossings or wider sidewalks can easily be simulated and evaluated.

A very important aspect for the Urban Transport Administration to consider, which was brought up by an official in the *Strategic Planning* department, is traffic safety, as one of their main goals is to offer safe mobility in Gothenburg. In this area, microsimulation could be a useful tool in order to more fully understand pedestrian patterns in central Gothenburg and from there work on solutions which would better meet the actual needs of pedestrians and therefore create more traffic safety. One official within the *Road and Track* department brought up another aspect of traffic safety; as they are working in the later stages of road projects, the need they could see for using a simulation tool such as Viswalk is to use it as a visual tool to point out conflicts between road construction workers and traffic during constructions. The tool could visualize the possible need of a signalized crossing when workers frequently need to cross a road and the traffic flow is at such a level that it could be of danger to the workers.

4.2.3 Redirection of traffic and pedestrian flows

A common opinion among the officials is that an even more pressing issue than planning for pedestrian space after the completion of the huge construction projects that are to be taking place in Gothenburg is the issue of where and how pedestrians and other traffic will be able to move within the city during the processes. Today, there is no established method at the Urban Transport Administration for handling large pedestrian flows during such circumstances. Several officials claimed that this needs to be studied further in order for the city to be fully prepared and ready to handle a significant change in the pedestrian flow during construction. A consequence of a poorly planned construction process could encourage more people to walk than what is expected, due to this being the most flexible and easily maneuverable way to go somewhere, and this could worsen the situation even further. Microsimulations could be used in order to find the optimal redirection routes for both vehicles and pedestrians.

4.2.4 Follow-up of projects

One official within the *Strategic Planning* department could see benefits from using Viswalk when following up projects. Being a goal oriented organization, measures taken by the Urban Transport Administration should be followed up in order to see if the right decisions have been made and if the outcome of the measures has been as expected. Simulations can be used in order to evaluate if the expected goals have been fulfilled.

4.2.5 Simulate attractive force of places, objects and environment

Several officials expressed an interest in the possibility to simulate attractive forces of the surroundings. This would be interesting in order to see where pedestrians are moving and how they are affected by their surroundings, for example what added value a wide street surrounded by trees would have in comparison to a narrow alley.

4.2.6 Summarized results from the Interviews

Summarized from the interviews presented in this chapter, the most significant and consistently statements are listed below:

- No current established method for handling large pedestrian flows
- Great interest in pedestrian simulations in the areas of
    - capacity planning
    - justification of projects and measures
    - redirection of traffic and pedestrian flows
    - follow-up of projects
    - simulating attractive forces of places, objects and environment
- More knowledge in pedestrian behavior is requested
- Insecurities regarding input data
- Wish for default parameter values and data specific for Gothenburg
- More guidelines regarding pedestrian evaluations are needed

5 Case Studies

In order to be able to evaluate the two software programs, four different case studies were performed:

- Case study 1 – Calibration
- Case study 2 – Pedestrian flow in one direction
- Case study 3 – Pedestrian flow in two directions
- Case study 4 – Pedestrian interaction with vehicles

Case study 1 was performed in order to study how well models in each program can be adjusted to reflect a real scenario. The purpose of Case study 2 was to evaluate how pedestrians act in relation to each other when moving in larger groups in the respective software programs. Case study 3 further evaluated pedestrian behavior by studying opposite flows. In Case study 4, pedestrian interaction with vehicular traffic was the focus.

5.1 Case Study 1 - Calibration

In order to evaluate pedestrian simulation in Vissim and Viswalk, models were set up in each software program and calibrated in order to reflect a real scenario as true as possible. Site observations from the chosen location are presented in Section 5.1.1, before the calibration processes of the Vissim and Viswalk models are presented in more detail in Section 5.1.2.

5.1.1 Site observations – Handels

During filming of a pedestrian scenario, several observations were made. Observations such as flow, velocities and routes are used as input in the calibration models.

The location that has been studied can be seen in Figure 5.1. Main focus was on the street Vasagatan with the limitations of Sprängkullsgatan to the west, Kurs- och tidningsbiblioteket (KTB) to the north, Haga kyrkogata to the east and the University of Gothenburg (GU) to the south.

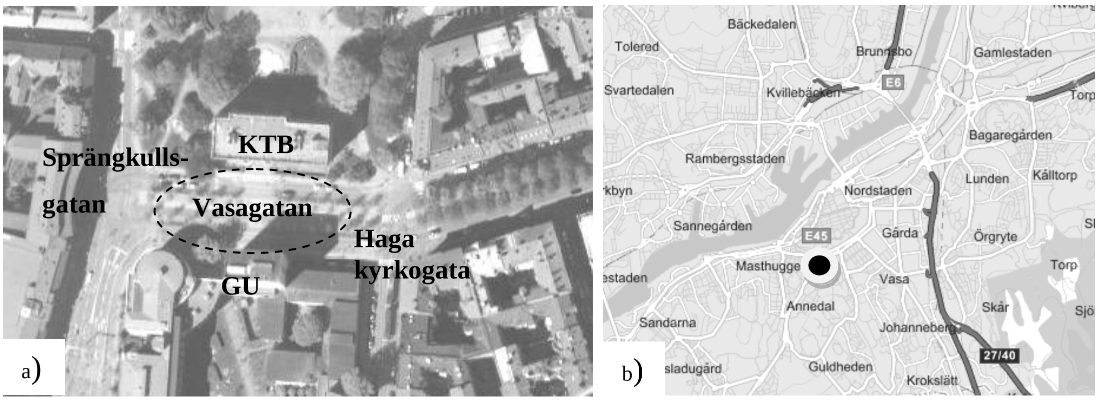


Figure 5.1 a) The map shows the location of interest for this report. Focus has been on the pedestrian crossing at Vasagatan, between KTB and GU (Eniro, 2013) b) The dot marks the location of Vasagatan in Gothenburg (Eniro, 2013).

Located between KTB and GU, there is a 16 meters wide pedestrian crossing. From north to south it crosses a sidewalk, a 50 kilometer per hour one-way road with western direction, the main pedestrian and bicycle path with designated areas for pedestrians and bicyclists in each direction, a 50 kilometer per hour one-way road with eastern direction and a sidewalk along the GU building. The main bicycle and pedestrian path is delimited by trees and bicycle parking on each side.

A significant characteristic of the site is that it is situated in the middle of a university area which is largely influenced by the campus life. The area is also influenced by the widely used pedestrian and bicycle path starting in the area and going east towards the city center.

Weather conditions during measuring

Data collection took place in March of 2013. In Table 5.1, the weather conditions during the gathering of data are presented. It was observed that people were stopping and standing still more during the last two measuring occasions when the sun was shining.

Table 5.1 The weather conditions during the gathering of data.

Date and time	Day of the week	Weather	Temperature
March 4 **3.30-5.30 pm**	Monday	Cloudy	-3˚C
March 13 **3.30-5.30 pm**	Wednesday	Sunny	-3˚C
March 14 **3.30-5.30 pm**	Thursday	Sunny	0˚C

Pedestrian flow

Pedestrian flows were measured in nine different locations. The locations can be seen in Figure 5.2. The amount of people originating from and arriving to each location was counted and is used as input for the calibration models.

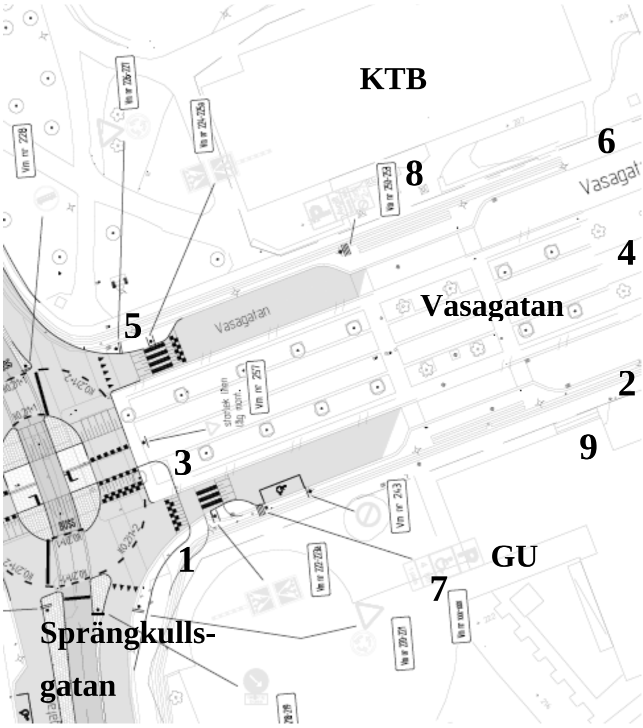


Figure 5.2 The origins and destinations of pedestrians on the calibration site.

The maximum quarter for each day can be seen in Table 5.2. Since the majority of the pedestrians in the area are students originating from the University of Gothenburg building, the maximum quarter during the afternoon took place at around 16.00 due to the school day being over at that time.

Table 5.2 The maximum quarter of pedestrian flows at Vasagatan.

Date	Maximum quarter
March 4	3.50-4.05 pm
March 13	4.00-4.15 pm
March 14	3.55-4.10 pm

The total number of pedestrians originating from each area is presented in Table 5.3. In the simulation model input, the average value of pedestrians has been used.

Table 5.3 The number of pedestrians originating from each area during the maximum quarter.

Area	March 4	March 13	March 14	Average
1	22	21	16	**20**
2	31	54	26	**37**
3	36	22	37	**32**
4	28	25	33	**29**
5	10	17	25	**17**
6	20	24	43	**29**
7	91	75	75	**80**
8	17	28	32	**26**
9	53	145	88	**95**

Bicycle flow

The number of bicycles on Vasagatan during the maximum quarter for pedestrians is presented for each direction in Table 5.4. In the simulation models, the average value of bicycles has been used.

Table 5.4 The number of bicycles during the maximum quarter for pedestrians.

	March 4	March 13	March 14	Average
Eastern direction	24	20	23	**22**
Western direction	39	31	25	**32**

Vehicle flow

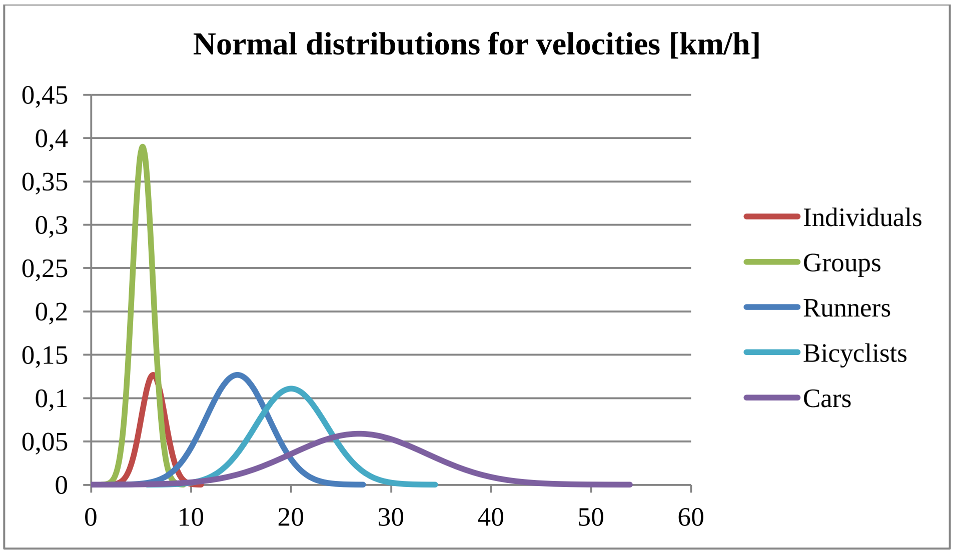
The number of cars on Vasagatan during the maximum quarter for pedestrians is presented for each direction in Table 5.5. In the simulation models, the average value of cars has been used.

Table 5.5 The number of cars during the maximum quarter for pedestrians.

	March 4	March 13	March 14	Average
Eastern direction	47	84	46	**59**
Western direction	51	75	50	**60**

Traffic velocities

The velocity input in the simulation models were based on the results of the normal distribution curves shown in Graph 5.1. Measured velocities for all groups can be found in Appendix I.



Graph 5.1 The normal distributions of each velocity group.

The relatively low driving speeds among the car group was most likely partially due to the fact that the distance of concern is rather short and located between one roundabout and one intersection. Additionally, the pedestrian crossing in between is elevated just to get the drivers to keep down the driving speed.

Pedestrian routes

The route choices of the pedestrians moving in the location were studied. The average routing choices from the measured occasions are presented in Table 5.6. Numbers 1-9 refer to the locations in Figure 5.2 presented in Section 5.1.1.3.1.

Table 5.6 An origin-destination matrix over the pedestrian flow distribution. All numbers are in percent.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	-	30	0	10	0	0	60	0	0
2	46	-	6	0	12	0	8	2	26
3	0	4	-	73	0	9	0	14	0
4	17	0	58	-	8	0	8	7	2
5	0	0	0	20	-	31	9	29	11
6	0	0	25	0	43	-	10	22	0
7	39	20	8	11	11	3	-	8	0
8	0	2	43	14	7	16	18	-	0
9	6	61	7	2	16	3	3	2	-

A more thorough table of the route choices can be seen in Appendix II.

Observed behavior in pedestrians

The pedestrian behavior at the chosen location has been studied. Many observations have been made, however all have not been taken into account in the simulations due to lack of time and limitations in the program. Nevertheless, all observations are presented in this chapter.

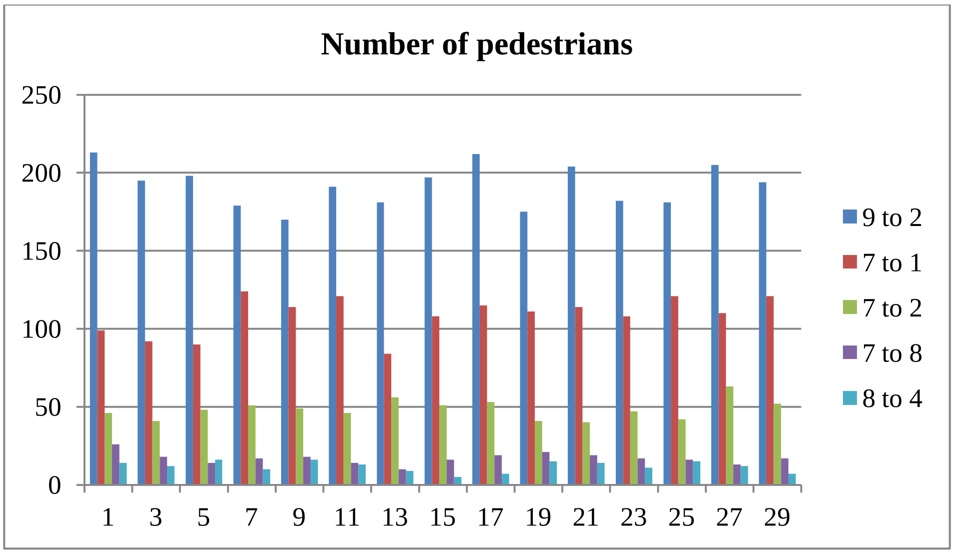
The most prominent observations during the filming are listed below:

- During the morning hour, pedestrians walked more individually and with a more targeted walking style. In the lunch and afternoon hours the pedestrians showed a more irrational walking behavior.
- About 20 % of the pedestrians walked in groups of two or more. This was especially apparent during lunch hours and when students left the GU and KTB buildings. See Figure 5.3b.
- Pedestrians who walked in groups were generally moving slower than those who walked individually.
- Pedestrians walked slower when they walked over the pedestrian crossing compared to when they walked along a sidewalk.
- During sunny days many pedestrians tended to reside in the area, especially along the sidewalk outside the KTB building, which is not shaded and where several park benches are placed. See Figure 5.3a. While many pedestrians resided on the sidewalk, they also partially limited the accessibility for those who went along it.
- Some pedestrians walked slowly and stopped occasionally, often as they looked at their phones or walked with a kid.
- Some pedestrians walked with strollers, especially in the afternoon on the main pedestrian path. Many of these walked in groups side by side.
- Generally, pedestrians accelerated slowly when they left a building, especially those who walked in groups.
- During the afternoon peak hour, many pedestrians stopped and even stood still in groups outside the buildings while they said goodbye to friends and fellow students, before they went their separate ways. See Figure 5.3c.

Figure 5.3 a) The figure shows the studied crossing at one of the filming sessions. It illustrates some pedestrians residing in the area and some who are walking in groups. b) Pedestrians walking in groups over the crossing. c) Pedestrians saying goodbye before walking their separate ways.

5.1.2 Calibration

The models were calibrated visually and by running simulations. Visual calibration was performed by watching the simulation and making necessary adjustments in order to achieve an as natural behavior as possible of pedestrians and vehicles. When simulations were performed in Vissim and Viswalk, they were based on a specific random number. The random numbers produced values that deviated somewhat from the inputs that had been given to the models. In order to be able to assure that the deviations were within a reasonable range, 15 simulations with different random numbers were run. Before these simulations gave satisfactory results, i.e. before the models were able to perform a simulation that could fulfill the required inputs, the models were calibrated by adjusting parameters and making other necessary adjustments to the setup of the models. Graph 5.2 shows deviating values during 15 simulation runs in Vissim.



Graph 5.2 The 15 simulation runs generated different results for the five measured routes. All differences are within a reasonable range from the observed results, which were, from top to bottom, 185, 100, 54, 20 and 12.

The output from the simulations were considered to be satisfactory when the *GEH-value*, a statistical measurement, was <5.0 for 85 % of all modeled traffic volumes (Trafikkontoret Stockholm Stad, 2005, pp. 11-12).

$$\text{GEH} = \sqrt{\frac{(E-V)^2}{\frac{(E+V)}{2}}} \tag{5.1}$$

E = the estimated traffic volume from simulation model

V = the observed traffic volume

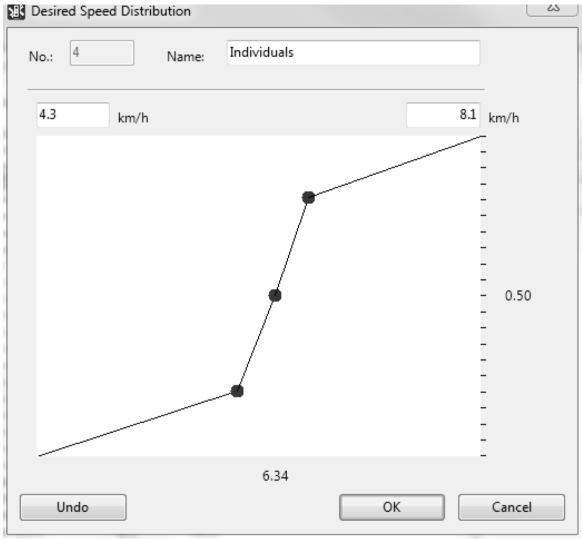
In this chapter, the calibration processes of the Vissim and Viswalk models are presented. It should be noted that more time and particularly more knowledge in the program would most likely lead to improvements in the calibration processes.

5.1.2.1 General adjustments for Vissim and Viswalk

General observations that apply for both the Vissim and Viswalk models are presented in this chapter. Thereafter, more specific comments for each software program are presented.

Adjustment of velocities

The velocities were adjusted in order to better reflect reality. Velocities were inserted into Vissim and Viswalk by setting a maximum and minimum for each traffic group. It is not possible to insert normal distributions directly into the program; however, an S-shaped distribution that will define the likelihood of the occurrence of each velocity can be created. Figure 5.4 shows an example of an S-shaped velocity distribution from one of the traffic groups.



5.4 An S-shaped velocity distribution curve for the individual pedestrian traffic group created in Viswalk.

In order to reduce the sensitivity of the S-shaped distributions, 30th and 70th percentiles were used in order to eliminate extreme deviations from the normal distributions. The different velocity intervals for each group are presented in Table 5.7.

Table 5.7 The table presents the velocity intervals that have been used as input in the simulation programs.

Velocity group	**30th percentile [km/h]**	**70th percentile [km/h]**
Individuals	4.3	8.1
Groups	3.5	6.8
Runners	9.6	19.7
Bicycles	14.2	25.8
Vehicles	16.0	37.6

Additionally, the vehicle velocity over the pedestrian crossing and in connection to the crossing outside of the modeled network was found necessary to reduce in order to better reflect reality. Thus, reduced speed areas with a maximum speed of 30 kilometer per hour were inserted.

In real life, people are walking in groups

During filming, it was observed that many pedestrians were walking in groups. There is no built-in function for this in the program. In order to achieve a more realistic simulation, a 3D-model of a woman with a child, *mom+kid*, was used in order to represent pedestrians walking in groups of two. The pedestrian input was corrected accordingly. The mom+kid can be seen in Figure 5.5 in Section 5.1.2.2.

Unrealistic behavior in vehicles in the model

In the initial model, one link was used in order to represent the pedestrian crossing in Haga. Due to the crossing being 16 meters wide, the vehicles were not able to creep forward if there was a pedestrian crossing further ahead. In order to get a more realistic behavior from approaching vehicles, the link was split into four narrower ones. By dividing the link into four, the vehicles were allowed to slowly cross each link that was free of pedestrians even though there were pedestrians further up ahead. In the same crossing, conflict areas were used in the initial model to give pedestrians right of way. As this also prevented the vehicles to drive over the crossing if pedestrians were anywhere on or near the crossing, priority rules were used instead. This allowed for a more realistic flow in the crossing.

Multiple route choices

It was observed that a large share of the pedestrians in the main pathway did not walk along the designated pedestrian area. Out of those originating from east in the main pathway and intending to cross the pedestrian crossing either towards GU or continuing south on Sprängkullsgatan, it was observed that 62 % were taking a short-cut over the bicycle path. In order to more realistically model those who walked diagonally over the bicycle path, an optional route was placed in Viswalk which directed 62 % to take the short-cut. In Vissim, the short-cuts were simulated by adding diagonal links. However, the pedestrian pattern of this solution did not reflect reality as well as the solution in Viswalk did.

Deviating calibration values

The modeled traffic volumes were measured for all traffic groups: pedestrians, bicyclists and motor vehicles, in order to check the accuracy of the traffic amounts in the model. During the calibration process, significantly deviating values were found. After some adjustments to the model, all groups had GEH-values below 5.0, thus the model was considered to be valid. All GEH-values can be found in Appendix III. The result from the simulation can be seen in Graph 5.2.

5.1.2.2 Vissim

A screenshot from the calibration model in Vissim can be seen in Figure 5.5. Due to Vissim not being primarily a pedestrian simulation tool, it was experienced that it was more difficult to achieve a natural behavior in Vissim compared to Viswalk. Most effort was put into creating a model that was able to simulate the situation capacity-wise, despite the relatively low flow of pedestrians in the scenario.

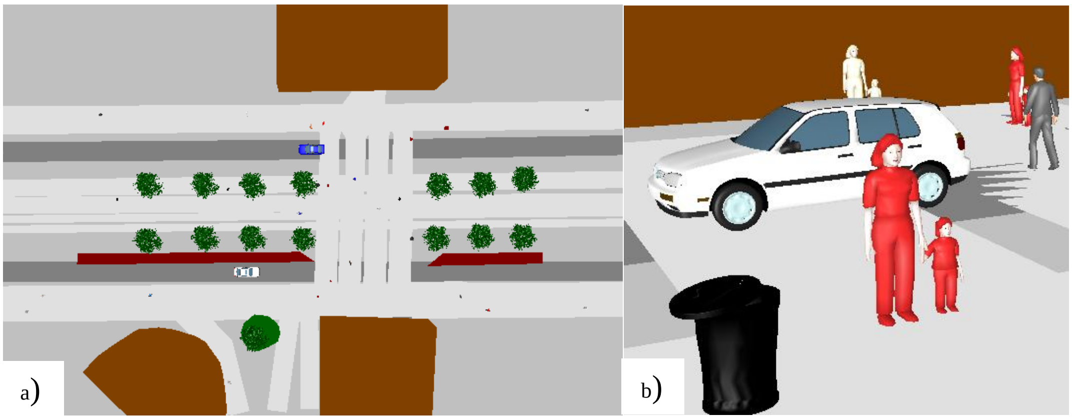


Figure 5.5 a) Calibration model seen from above in Vissim. b) A 3D-model of a Mom+kid, representing a group.

Low capacity on links and connectors

The main issue with the Vissim model was the limited capacity on the links. This was mainly indicated by the fact that the pedestrians could not pass each other, which consequently contributed to a queue of pedestrians that walked behind a slower walking one. In order to give the pedestrians the possibility to walk up side by side, the first measure was to widen the links. It was also found that the default width of the pedestrians was set to 1.5 meters. According to a standard set by Trafikverket (2004, p. 33), the Swedish Transport Administration, this parameter was then changed to 0.70 meters instead.

After these settings were changed, some of the pedestrians seemed to walk up side by side. But still, no pedestrians seemed to automatically change course to be able to pass another one ahead. To enable for this, some settings were changed in the *Driving behavior.* In the tab *Lateral,* the box named *"Keep lateral distance to vehicles on next lane(s)"* was checked and the minimum lateral distance was then changed from one meter to 0.30 meters. Thereafter, the pedestrians were able to change course and accordingly pass each other or walk up side by side, with the exception when a mom+kid was walking ahead of a faster walking pedestrian that wanted to pass. In that case the sidewalk in Vissim was too narrow to make it possible for the pedestrian behind to pass. This could possibly represent the real case if there was a group of three to four students walking side by side outside the school buildings, which were frequently seen during the filming sessions. However, if the mom+kid would represent two people walking side by side, it should be more reasonable that a pedestrian behind would be able to pass them. This means that using the mom+kid figure to represent people walking in groups sometimes has a realistic impact when it comes to making the model look more realistic.

In order to examine the capacity limits due to this restriction, a case that approximately represented a more visited area of the city was simulated by increasing the pedestrian input. During the simulation, some limitations in the model were found. One observation that occurred frequently was that a cluster of pedestrians were formed on the links behind a slow-walking pedestrian, see Figure 5.6. This happened due to the narrow links that limited the pedestrians to pass the slower-walking pedestrian ahead, as was noticed to a minor extent in the original model. What was more apparent in this case, however, was that the cluster of pedestrians also contributed to a misleading picture of a more problematic scenario than really was the case.

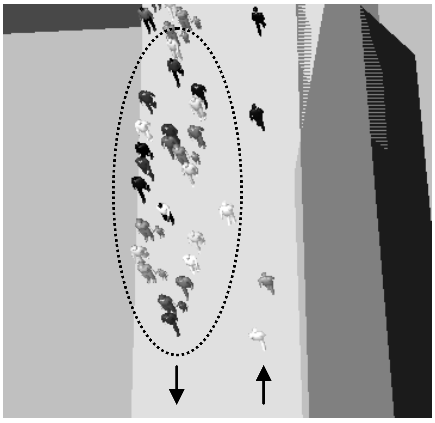


Figure 5.6 The figure shows a cluster of pedestrians in Vissim walking down the link, hindered to pass the slow-walking pedestrian in the front.

Another problem that was noticed was how Vissim dealt with the conflict between the pedestrian flows. If neither priority rules nor conflict areas were applied to the conflict zones, the pedestrians walked right through each other. To make the conflict look more realistic, the conflict area-tool was used. However, although many parameters for the conflict areas were adjusted, the pedestrians stopped up in an unnatural way at the conflict zones. The priority rule-tool was then applied instead. By using priority rules, the conflict could be simulated more realistically. But since this tool is very time consuming, it is not considered reasonable to use priority rules to solve the problem either. Briefly, this shows that Vissim has significant issues when it comes to dealing with larger amounts of pedestrians.

Limited capacity when changing links

Although the pedestrians were able to move more freely on the links after the altered settings mentioned above, they were still limited when it came to changing links or connectors. This was particularly evident on the links coming out from the buildings (i.e. where a pedestrian input was set at the start of the link) or over the crossings where the pedestrian flow was denser. The main reason for this problem was because the pedestrians got somewhat disturbed in their movement pattern each time they had to enter a connector or a new link or when they were in a conflict with another link. No measures were found to successfully solve this problem.

Unrealistic movement in the model

Another issue in Vissim that became very apparent during the simulation of Case study 1 was the unrealistic and rational movement of the pedestrians that strictly followed the direction of the links placed out. This got particularly clear over the wide crossing that was split up in four links, two links in each direction. Obviously, it is not likely that pedestrians would walk lined up in two rows to cross a 16 meters wide crossing and that was neither the case during filming. In terms of output quality, this would also generate longer travel times than what is realistic. The problem could of course be mitigated by splitting up the crossing in even more links. But unfortunately this requires a lot of time and energy, not least because of all the new routes that has to be set after such a reform. It was therefore determined that no further measures should be done regarding this issue.

5.1.2.3 Viswalk

A screenshot from the calibration model in Viswalk can be seen in Figure 5.7.

Many parameters can be adjusted in Viswalk in order to calibrate a model to reflect reality as true as possible. Due to limitations in time, estimations are made regarding which ones would benefit the model the most while still not being overly time consuming. Due to the more realistic behavior of pedestrians in Viswalk and the fact that they were not restricted to walking on links, capacity was not an issue in the Viswalk model of this scenario. Due to the refined possibilities regarding parameter setup and model setup in Viswalk compared to Vissim, more time was spent on achieving a more natural visualization of the scenario.

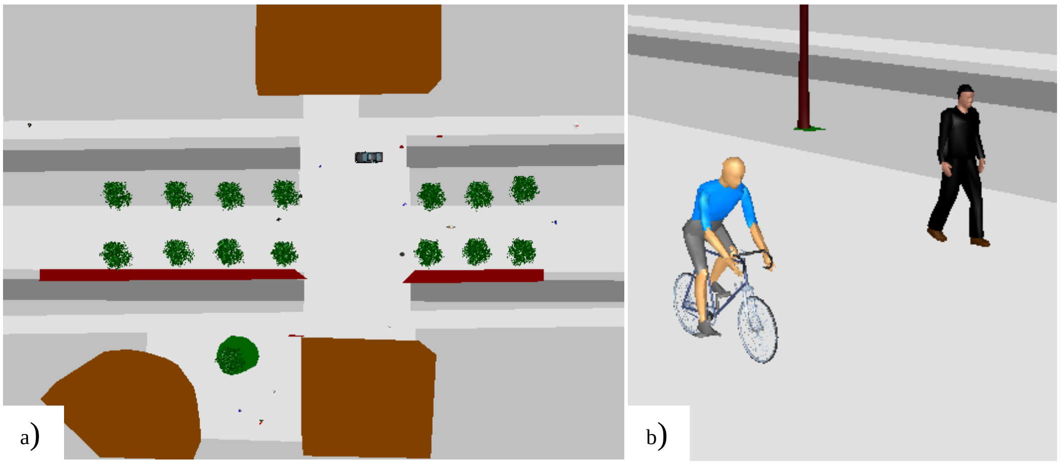


Figure 5.7 a) Calibration model seen from above in Viswalk. b) A close-up of a bicyclist and pedestrian in 3D.

Pedestrians walking too close to each other in the model

When running the simulation with pre-set parameters, it was observed that pedestrians that were passing each other seemed to be walking closer to each other than they would in real life. After studying the manual, it was tried to increase the VD parameter, aimed at making pedestrians evade each other earlier when meeting or passing. This gave positive results, as the pedestrian behavior seemed to reflect reality better.

Another parameter that was adjusted was the dynamic potential. This was due to the fact that pedestrians meeting and being in each other's paths seemed to be stopping and not being able to walk around each other. In order to get a better flow, dynamic potential was used. After trying different values, a value of 30 % was considered to give good results. 70 % and 50 % was tried at first; however those values gave an unrealistic behavior as pedestrians were turning in circles in order to avoid collision instead of walking around people who were blocking their path.

Pedestrians stopping and waiting in reality

The calibration model was adjusted in order to better reflect the movement pattern of pedestrians. Dwell times were added outside of building entrances and at one other location where a pattern was observed during filming that pedestrians were stopping and standing still, mostly to wait for someone. The dwell times were applied by adding an area at the location where waiting occurs. New routes were formed which passed the waiting area and allowed for a certain share of pedestrians to dwell at that area for a certain amount of time. Waiting times were inserted as an empirical distribution based on observed values and the share of pedestrians who stopped was based on observations from filming. Waiting times ranged between a few seconds up to eleven minutes.

Due to the irregular behavior of pedestrians in reality, meaning they can stop at unpredictable places to look at their phone, wait for someone to catch up, etc., they could suddenly be stopping anywhere in the area. Random stopping for shorter periods of time (a few seconds) was considered to be negligible. This could however be simulated by adding shorter dwell times to all areas in the location and direct a certain percentage of all pedestrians who are passing to stop by adding new routes. In Vissim, no reasonable solution to simulate stopping pedestrians has been found.

Obstacles

In order to get a realistic movement pattern of the pedestrians, obstacles were placed in the model to represent obstacles that exists in reality. There are obstacles such as trees, garbage bins and bicycle racks. There is also a bar outside of the western GU entrance, which forces pedestrians coming from the east to walk around it in order to enter the building. For the Vissim model, obstacles did not have any impact on the pedestrians since the links did not pass any obstacles in the model.

Unrealistic interaction between pedestrians and vehicles in the model

Priority rules were used between pedestrians and vehicles. In some cases during the simulation, it appeared that pedestrians were walking through the vehicles. This was due to the fact that pedestrians were walking freely across pedestrian areas and pedestrian links, occasionally crossing links diagonally. Consequently, on occasion pedestrians entered a link that a vehicle already had entered. Thus, the vehicle had already passed “the point of yield” and had “cleared” the link as free from pedestrians. This may have lead to pedestrians walking through vehicles.

By putting more time and effort into improving the priority rules, the collisions could most likely be eliminated. Since they only occurred rarely, it was not considered to be a big problem in this calibration process. This was only noticeable when visualizing the simulation and was therefore considered to be negligible or equated to walking around the car instead of through the car.

5.2 Case Study 2 – Pedestrian flow in one direction

In this study, a group of pedestrians were moving across a signalized crossing. When performing the study, observations were made regarding the accessibility of pedestrians when moving in large groups in the different software programs.

In order to be able to compare the results, the prerequisites were as similar as possible for the two models. The crossing was six meters wide and the green time was set to 20 seconds with a signal head cycle of 60 seconds. Velocities and accelerations were the same for both models and the input of pedestrians was 2200 per hour. Visual calibrations of the models have been made where different parameters have been adjusted in order to achieve a similar behavior in pedestrians regarding packing density, distances to fellow pedestrians, etc.

5.2.1 Evaluation

In Figure 5.8, a visualization from the simulation can be seen.

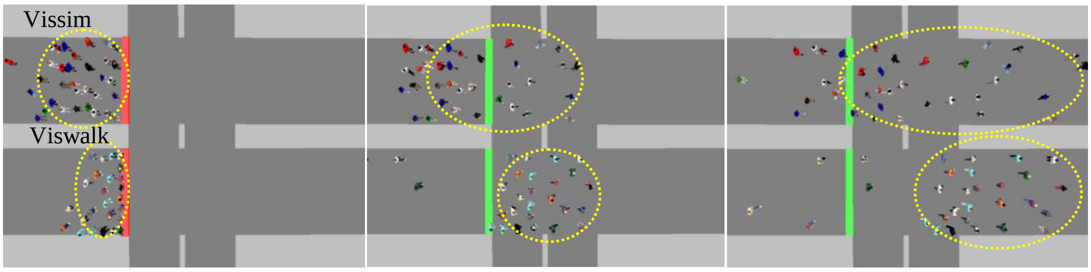


Figure 5.8 The figure shows a comparison between the models, Vissim top and Viswalk bottom, at three different times during a signal head cycle. The yellow ellipse-shaped dotted lines mark the location of the first cluster of 25 pedestrians in the system. a) The situation at time 0, right before turning green. b) The situation at 5 seconds in to the green cycle. c) The situation at 10 seconds.

Figure 5.8a shows the situation right before the signal turns to green. In the Vissim (top) model, pedestrians appeared to stand less densely packed than in the Viswalk (bottom) model while waiting for the signal to turn green. It was attempted to adjust this, however it was difficult to achieve a similar behavior in Vissim as in Viswalk. The distance between two pedestrians in Vissim was adjusted to be similar to that in Viswalk, however it appears that even though they are able to stand close to each other they can be restricted in doing so due to not being very flexible in their movement pattern. Thus, pedestrians in Vissim do not appear to be finding their way around each other as well as in Viswalk. Another observation in Vissim was the fact that pedestrians seemed to be jumping from side to side when passing each other. This may have disturbed other pedestrians behind and misled to them to believe a space being occupied due to the irrational movement pattern of others.

Five seconds after the signal turning green, all of the first 25 pedestrians in Viswalk have managed to pass the signal head. They are collectively moving forward, unlike in Vissim, where they are not all able to keep up. Thus, all pedestrians in Vissim have not passed the signal head yet. This can be seen in Figure 5.8b.

Ten seconds after the signal head turning green, the majority of the pedestrians in Viswalk have passed the crossing. In Vissim however, some pedestrians have just passed the signal head. See Figure 5.8c. At this point, the group in Vissim is quite stretched out, while the group in Viswalk is relatively together.

Five simulations were run in order to get an average of travel times for each model. The travel times during a distance of 15 meters was measured, starting at a position right before queue formations occur and ending on the other side of the crosswalk. The resulting travel times can be seen in Table 5.8.

Table 5.8 Travel times for Vissim and Viswalk based on five different simulation runs.

Rdm nr	Vissim (sec)	Viswalk (sec)
1	29,6	25.5
3	29	25,7
5	30	25,7
7	31	25,9
9	30	26,5
Average	**29,9**	**26,0**

As can be seen in Table 5.8, the travel times for the Viswalk model is approximately four seconds shorter than for Vissim. The difference is most likely due to the smoother flow of pedestrians using the Social Force Model. The pedestrian flow in Viswalk is considered to represent reality more accurately in this case study.

It should be mentioned that the width of the crosswalk was originally set to eight meters. This was later adjusted to six meters as pedestrians started to show an odd behavior in the Vissim model by walking on the spot when signal was red, slowly moving closer and finally crossing against red. When reducing the width, this behavior disappeared.

5.3 Case Study 3 – Pedestrian flow in two directions

This study further evaluates the accessibility of pedestrians by adding a flow in the opposite direction in the signalized crossing. Based on the real crossing at Drottningtorget/The Central Station, Gothenburg, the width of the crossing was set to eight meters and the pedestrian input to 2200 per hour in each direction. Focus in this study was on how the different software programs dealt with the meeting conflict over the crossing. As in Case study 2, the green time was set to 20 seconds with a signal head cycle of 60 seconds.

In order to achieve a more even distribution of meeting pedestrians over the crossing in Vissim, the model was built up by splitting it up in four links; two links in each direction, which can be seen in Figure 5.9.

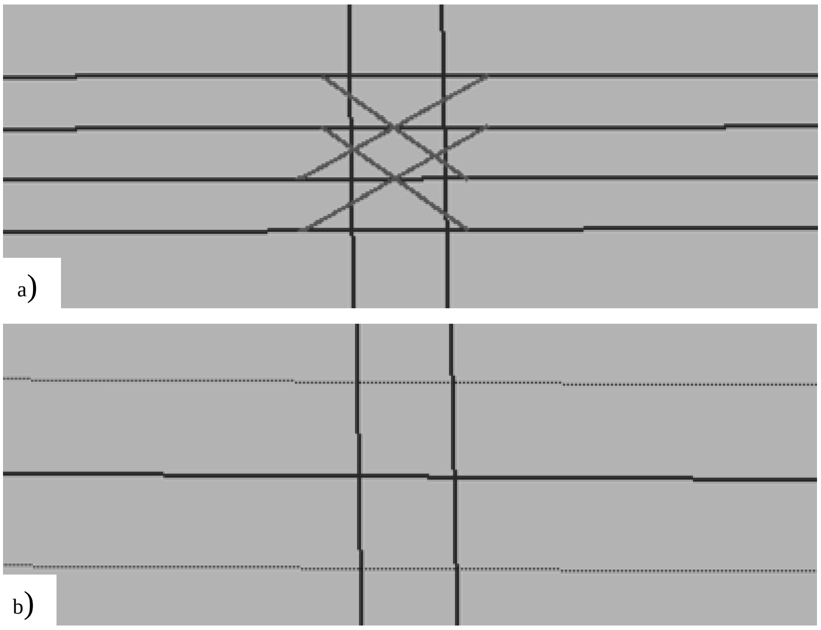


Figure 5.9 a) The figure shows the Vissim model, containing two links in each direction and 4 crossing connectors in order to allow for a more natural looking flow. b) The corresponding situation is shown in Viswalk, where only one link is necessary to simulate pedestrian flows in both directions.

Each link was two meters wide and had an input of 1100 pedestrians per hour. Since the Vissim links only provides pedestrians walking in one direction, which would give a free way for the pedestrians, four connectors were placed out diagonally over the crossing with the aim of getting some of the pedestrians to interfere with each other. Furthermore, priority rules were added give priority to diagonally walking pedestrians in order to provoke conflicts.

5.3.1 Evaluation

In Figure 5.10, a visualization from the simulation can be seen.

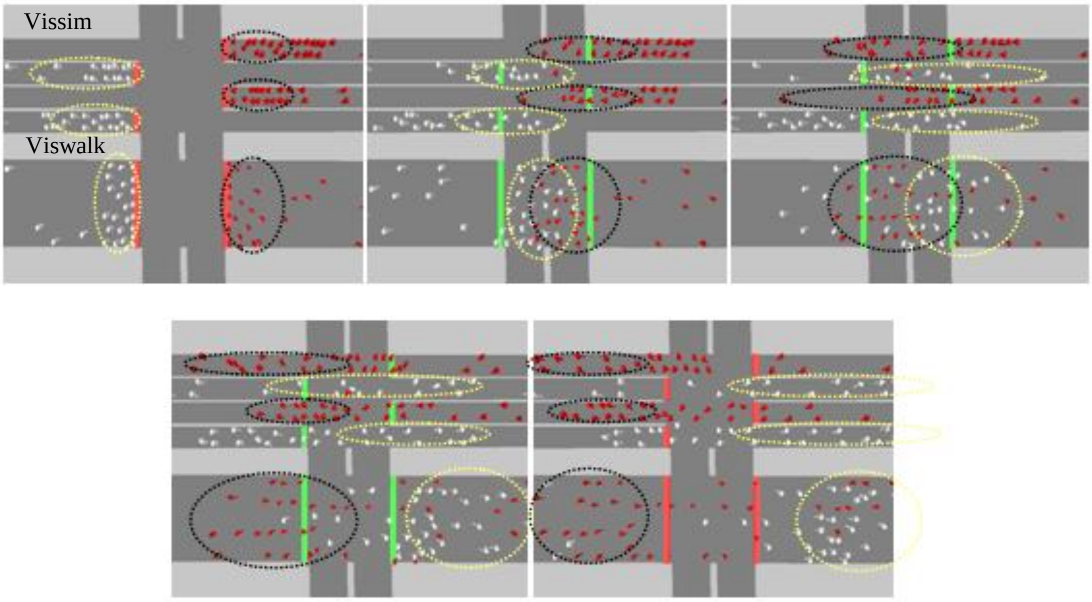


Figure 5.10 The figure shows a comparison between Vissim (top) and Viswalk (bottom) at a signalized crossing. a) The situation at time 0, right before turning green. b) The situation at 5 seconds in to the green cycle. c) 10 seconds in to the green time d) 15 seconds in to the green time e) 20 seconds after turning green, when the signal turns red again.

Figure 10a shows the situation just before the signal head turns green. The pedestrians in Viswalk (bottom) are lined up in the same way as in Case study 2. Similarly, the pedestrians in Vissim (top) also show the same pattern as in Case study 2. However, since the links in Vissim are only two meters wide, the pedestrians are limited to pass each other or walk up side by side which contribute to an even sparser and longer queue than in Case study 2. By just looking at the pattern in Figure 10a, it is obvious that the line up in Vissim is not a realistic view in real life.

In Figure 10b, all of the waiting pedestrians in the Viswalk model have managed to cross the signal head and seem to interfere with each other on a smooth and natural way. In the Vissim model, however, there are still several pedestrians remaining on the sidewalk. Among those who have entered the crossing, they seem to have a rather free way ahead, especially those on the outer links.

According to Figure 10d, it has taken 15 seconds for the groups in each direction to get all of the pedestrians over the crossing in Viswalk. In Vissim, there are still a couple of pedestrians walking on the crossing after 20 seconds when the signal turns red again, see Figure 10e.

Five simulations were run in order to get an average of the travel times in each model. The travel times were measured over a distance of 30 meters over the crossing. This was done in order to see how the meeting conflict affects the travel times in the different programs. The resulting travel times can be seen in Table 5.9.

Table 5.9 Travel times for Vissim and Viswalk based on five different simulation runs.

Rdm nr,	Vissim left (sec)	Vissim right (sec)	Viswalk left (sec)	Viswalk right (sec)
1	47,5	47,6	42,5	42,5
3	47,0	47,5	42,1	42,7
5	47,6	49,2	42,9	42,0
7	48,3	49,2	42,2	42,6
9	48,9	47,7	42,4	42,7
Average	**47,9**	**48,2**	**42,4**	**42,5**

According to Table 5.9, it can be seen that the travel times in Vissim were significantly longer than those in Viswalk. This is despite the fact that there were no meetings in Vissim. The delays in Vissim were most likely due to the sparse links that limit the pedestrians on the same link to pass each other, and hence contributed to a longer waiting time and a delayed start up for those that waited in the queue.

Considering the circumstances over the crossing, the pedestrians in Vissim were probably moving more undisturbed than in real life, which made the travel times as well as the objective view in Viswalk more realistic. Generally, it can be concluded that it is difficult to make the simulation in Vissim resemble reality when there is more than one relatively high pedestrian flow that causes a conflict. Therefore, it is more reasonable to make those types of simulations in Viswalk.

5.4 Case Study 4 – Pedestrian interaction with vehicles

In order to look closer at the interaction between pedestrians and vehicles, a narrow unsignalized crossing of four meters was studied. More specifically, the difference in interaction between pedestrians and vehicles in the two software programs was studied.

The amount of vehicles, 200 per hour and direction, was taken from a specific unsignalized crossing at Korsvägen, Gothenburg (Göteborgs Stad, 2013b). The amount of pedestrians was put to 500 at first, according to a study made at the location by M4 Traffic (2012, p. 14) and then de- and increased in intervals. Velocities and accelerations are the same for vehicles and pedestrians in Vissim and in Viswalk respectively. Furthermore, priority rules have been used in an attempt to create similar behaviors in vehicles and pedestrians in both software programs.

5.4.1 Evaluation

When running the models, they looked quite similar in both programs. The only visible difference was the fact that pedestrians in Vissim were walking on separate links depending on the direction. Starting at 500 pedestrians per hour, the traffic flow was even and both pedestrians and vehicles were able to move past the crossing. At 600 pedestrians, more queues were forming and at some occasions they built up to be quite long. At 400 pedestrians there were some formations of queues; however they did not last for very long.

Queue lengths for the vehicles were evaluated and five simulations were run for each scenario. The results can be seen in Table 5.10.

Table 5.10 Queue lengths for the simulations in the unsignalized scenario. The symbol " means that the model was unable to create all input.

Number of pedestrians	Rdm nr	Average queue length (m)	
		Vissim	**Viswalk**
400	1	16	19
	2	9	15
	3	9	10
	4	17	13
	5	8	9
Average		**12**	**13**
500	1	191	129
	2	41	93
	3	19	39
	4	75	102
	5	44	57
Average		**74**	**84**
600	1	243	323
	2	172	"
	3	237	294
	4	262	"
	5	165	259
Average		**216**	**292**

The evaluation showed that queue lengths for vehicles in Vissim and Viswalk fluctuated a bit, however overall they were quite equal and therefore it was difficult to come to any conclusions regarding whether this depended on differences in the software programs or differences in model constructions. It was attempted to increase the amount of vehicles and have a lower amount of pedestrians instead, to see if a larger flow of vehicles compared to pedestrians would give different results for the respective models. However, this gave similar results.

When the number of pedestrians was set to 600, queue lengths in Viswalk were so large that the model was not able to create the proper input on the link. It is possible that this could be solved by adjusting the priority rules further or adjusting some parameters. However, adjusting parameters too much would lead to a very specific scenario, which would require a study of a specific area. Thus, it is difficult to determine whether there is any difference in output based on this short study. A specific site would have to be studied so that the output from each model could be compared to the real scenario in order to determine which corresponds best to reality.

6 Discussion

The discussion is divided into three parts. The first will discuss the need for pedestrian simulation tools at the City of Gothenburg Urban Transport Administration. The second part will discuss the possibilities to reflect reality in an accurate manner when simulating pedestrians in Vissim and Viswalk respectively. The third part will discuss what added value Viswalk can bring to pedestrian simulations in general and particularly to the City of Gothenburg Urban Transport Administration.

6.1 Pedestrian simulations at the City of Gothenburg Urban Transport Administration

The interviews showed that there is a great interest in pedestrian simulations at the City of Gothenburg Urban Transport Administration. The common opinion is that pedestrians have been a non prioritized traffic group for too long and that this needs to change if future goals for the city of Gothenburg are to be met. The concerns regarding pedestrian simulations are that it requires a great deal of data. For pedestrian simulation in Vissim and Viswalk, the output is entirely dependent on the input, which means that the more site-specific data, the better and more reliable will the results be. There is an interest in studying pedestrians and their behavior further, especially pedestrian flows in Gothenburg. However, there are no optimal techniques for collecting data at present due to the methods that are being used today generally are considered to be too time consuming. The general wish of a pedestrian simulation tool with default parameter values and data specifically for Gothenburg is not possible today as most situations require data that is site-specific at a more detailed level. For example, pedestrians' route choices can never be general and will always have to be studied on site. The improvement opportunities in this area would be to find new methods that can register pedestrian movement patterns in an efficient way.

Another concern regarding pedestrian simulations is the lack of guidelines regarding pedestrians, as opposed to the multiple guidelines that are available for vehicular traffic today. Besides visual evaluations of a pedestrian simulation, which can give some indication on the quality of a situation based on experience, there are no guidelines that can be applied to those evaluation results that can be provided by Vissim and Viswalk. Thus, it is difficult to say anything about the results, if they are good or bad or somewhere in between. If more focus is going to be on pedestrians in the future, guidelines regarding acceptable values of for example level of service could be of interest. However, it is difficult to find general limit values on LOS as different levels can be acceptable in different situations, depending on the location, time of day, etc. For example, at a public transport stop or a popular shopping street it is expected and accepted by most that it can get crowded. On many other streets and spaces however, most pedestrians want their own space and would on most occasions choose a less crowded street if there is a choice between two. However, given the same choice at nighttime, many would prefer the more crowded street for safety reasons.

6.2 The ability to reflect reality in Vissim and Viswalk

In terms of reflecting reality, some observations have been made regarding possibilities and limitations in the two software programs.

6.2.1 Differences in Capacity

Capacity-wise, Viswalk is considered to be the better choice according to this study in terms of reflecting reality as true as possible, at least when simulating large volumes in more wide than narrow crossings. When using Vissim, such models can easily become too time demanding. Due to the more restricted movement patterns and the fact that pedestrians are only able to move on links and in one direction on each link, the models are generally more complicated in Vissim compared to Viswalk. This was shown in the calibration models of Case study 1, which required a lot more adjustments to the Vissim model and many links and routing decisions in each direction in order to manage the capacity requirements of the location. In addition, when a larger pedestrian flow was added in the calibration model in Vissim, another problem in Vissim occurs when there are a lot of conflicts between the pedestrian links. In these cases, no possibilities to simulate a realistic scenario have been found. In Viswalk, no pedestrian limitations due to capacity were noticed in either case model.

6.2.2 Pedestrian Behavior

When looking at a flow of pedestrians in one direction, as in Case study 2, a behavior that appears to be more natural than what was expected can be achieved in Vissim. With some adjustments to default values in Vissim, pedestrians are able to move laterally as in Viswalk, thus being able to pass each other provided the width of the link allows it.

Simulation of pedestrian flows in two directions, as in Case study 3, provides some limitations in Vissim regarding the possibility to reflect reality. Being unable to move freely in any direction and thus being unable to meet opposite flows is not corresponding correctly to reality. As pedestrians are walking separately in each direction, they do not have to take opposite flows into consideration. This will most likely contribute to a scenario with fewer conflicts than in reality which will lead to a non-representative output. For visual purposes, this can be somewhat improved by dividing one wider link into several narrower ones. This would give the appearance of a more natural behavior as the direction of the links can be altered so that every second will point in the same direction, thus giving the appearance of a mixed flow. However, pedestrians would still not be exposed to a meeting by implementing this. In order to provoke more interactions between pedestrians in a crossing, it would be possible to build up a more complex system by adding diagonal links and a system of priority rules. This would however be very time consuming compared to Viswalk, where such a behavior in meetings comes natural.

One observed behavior that could not be achieved in either software simulation during the setup of the calibration models in Case study 1 was the formation of groups. Being a student dense area, with a lot of students walking in groups, waiting in groups, etc., this behavior may be overrepresented at this location. Nevertheless, the attempt to visually reflect reality is an important part of the calibration process. It was found possible to add a representation of a small group of two people in form of a mother and a child. The width of these groups will provide some natural effects to the simulation models. However, there is no function to simulate more than two people in a group in either program.

Another issue related to the formations of groups was the observation of many groups of students standing still. As it was not found possible to simulate the formation of groups, it was not possible to have a certain group of people stopping and standing still together at the same time. However, in Viswalk it was possible to model single pedestrians stopping. This will not occupy the same space on the pedestrian pathway as a cluster of people would, it does however visually reflect reality. Due to the relatively low amount of pedestrians moving in the area, it is not believed to be likely that the inability to form groups has any larger impact on the results in Case study 1. Furthermore, the behavior of pedestrians stopping randomly that was observed during filming was found possible to simulate in Viswalk. However, no reasonable solution for this was found in Vissim.

6.2.3 Interaction with traffic

The interaction between pedestrians and other traffic was studied in order to compare how the different software programs dealt with the conflict. During the observations, both expected and unexpected results were found. One that gave about the same results that was expected was the interaction between pedestrians and vehicles in Case study 4, where the crossing was quite narrow. Although it was tried to provoke a difference in how the programs dealt with the conflict, no significant differences except from the anticipated visual effect could be found. Since the crossing is narrow, pedestrians are moving rationally and the pedestrian flow is not clearly dominant, the crossing pedestrian flow will impact on the vehicular traffic in a similar way in both Vissim and Viswalk. This makes it unnecessary to use Viswalk in cases like this where the main purpose only is to simulate a situation where the vehicular traffic gets occasionally “disturbed”, which can easily be done in Vissim.

In comparison to Case study 4, Case study 1 gave a different conclusion. In Case study 1, it was expected that the situation would look unrealistic and very rational in Vissim compared to Viswalk, which also proved to be true. However, it was not expected that there would occur such problems with the priority rules and conflict areas in Viswalk, due to the wide crossing. The basic problem was the fact that the crossing was 16 meters wide and that it was desired that the vehicles would be able to creep slowly forward if there was a pedestrian further ahead on the crossing. When four stop lines were placed out along the vehicle road, it occasionally happened that some of the pedestrians that crossed the transverse pedestrian links diagonally managed to elude the green lines that were connected to the red stop line. Consequently, these pedestrians were run over by the vehicles, which do not look realistic when it comes to the visual results. In addition to this, there were also a few pedestrians that walked over standstill vehicles that were waiting in line. Taking into account the lack in possibility to get pedestrians to zigzag between standstill cars, which would be the case in reality, it was concluded that the run over pedestrians could be considered as zigzagging pedestrians in terms of outcome.

Furthermore, it can be discussed whether the desire for creeping up cars is relevant for the result when the vehicular flow, as in this case, is rather small. If the crossing in Viswalk (Case study 1) for instance would be split up in two crossing pedestrian links instead, vehicles would not be able to creep over the crossing in the same extent as with four crossing links. However, there would probably not be as many over run pedestrians. In addition, further filming investigations are needed to make sure to what extent the cars really creep over the crossing in reality.

It should also be kept in mind that the crossing at Handels is located in a university area and is not a very common type of crossing. The main reason that this crossing was chosen was because it was desired to find an unsignalized crossing with an as large pedestrian flow as possible. This case study showed, however, that there was a greater difference between the programs due to the wide crossing compared to the other case studies.

6.3 What added value would Viswalk provide to the City of Gothenburg Urban Transport Administration?

In order to evaluate what added value Viswalk brings in comparison to original pedestrian simulation in Vissim, the differences in visualization and output will be discussed. Furthermore, the added value in using Viswalk at the City of Gothenburg Urban Transport Administration will be discussed.

6.3.1 Visual gains

When the purpose of a simulation is to visually present a scenario, Viswalk appears to provide an added value as long as the pedestrian flow is not significantly small. First and foremost, the ability to meet opposing flows adds to a visual advantage. This is quite an important advantage, as most real life situations allows for pedestrians to walk in any direction.

Given that only one direction is simulated, the pedestrian behavior in Vissim can be adjusted to be somewhat similar to that in Viswalk. However, some differences were noticed between the two models. As was shown by Case study 2, pedestrians in Vissim were unable to walk as densely as in Viswalk. It is however difficult to draw any conclusions whether Vissim or Viswalk reflect reality better without performing a more thorough study regarding pedestrian behavior. However, the accessibility of the pedestrians in Vissim was apparently more restricted in Case study 3, where somewhat large flows of pedestrians are walking in two directions. This is mainly due to the limited width of the links as they were made narrow in order to get the visual appearance of opposite flows. This observation leads to the conclusion that, despite no further studies on pedestrian behavior; Viswalk is more likely reflecting reality better than Vissim visually.

Furthermore, it was also shown that the irrational movement pattern provided by the Social Force Model in Viswalk allows for a more natural behavior than the one provided by the Wiedemann model in Vissim. This is particularly apparent in Case study 1 where the pedestrians are moving in a larger system.

6.3.2 Simulation outputs

In terms of output, it is probable that Viswalk would bring some advantages when compared to Vissim based on this study. This is mainly due to the fact that Viswalk allows for pedestrians to meet on the same link or area. Since Vissim is unable to simulate this in a realistic manner, it is assumed that this could affect the output of the model negatively, especially in situations with large flows of pedestrians. Having this said, in order to be able to come to any conclusions regarding the validity of outputs, real scenarios would have to be studied in terms of input and after a calibrations process the scenarios would have to be studied again in terms of output. Due to limitations in time, no such conclusions can be made on the basis of this study. Further studies are recommended in order to see which of the models results/outputs correspond to reality better.

It was however attempted to establish a difference in output in the two software programs, by comparing the outputs of each model in Case study 2, 3 and 4. In Case study 2 and 3, the travel times for pedestrians were compared for each model. Both case studies gave shorter travel times for the Viswalk models. This is most likely explained by the fact that Viswalk allows for a smoother flow and the pedestrians are not restricted by the width of the link as in Vissim. As the models are general scenarios aimed at finding the difference between the two software programs, they have not been observed in real life and thus no conclusions can be made regarding which travel times are more realistic. It is however, due to the visual advantage of Viswalk, assumed that Viswalk is the preferable tool when simulating pedestrian flows in two directions.

In Case study 4, the queue lengths for vehicles are measured in order to compare how vehicles are affected by pedestrian flows in the two software programs respectively. As was mentioned in Section 6.2.3, no significant differences between the outputs of the two software programs could be found. Thus, on the basis of this study, it is believed that the difference in output between the two software programs vary the most when looking at pure pedestrian flows, especially in situations where a large amount of people are moving.

It should be noted that the output of the simulation models are very much dependent on the parameter setting for each model. Even though the attempt was to always make the models look as similar as possible both to each other and to reality, the difference in setup of the two software programs allows for some insecurity whether the attempt was always successful. Thus, there is some insecurity regarding the validity of the output. More in depth studies of parameter settings are recommended in order to more fully comprehend the differences between parameter setting in Vissim and in Viswalk as well as to which parameters are the most relevant and efficient to adjust depending on the scenario that is simulated. For instance, the dynamic potential parameter was used in the Viswalk model of Case study 1. It was found that this parameter significantly increased the calculation time of the simulation. The significance of this particular parameter to the specific scenario in Case study 1 is however uncertain. The parameter was used in order to get a more natural flow between pedestrians when meeting, as some occasionally were not able to walk around each other. However, it is possible that other parameter adjustments could have given the same or similar results during the calibration without adding to the simulation time to the same extent.

6.3.3 Benefits for the City of Gothenburg Urban Transport Administration

Several of the requested areas of applications at the City of Gothenburg Urban Transport Administration could certainly benefit from using the more developed pedestrian simulation tool Viswalk. For some purposes, simulations are considered to provide equivalent results in both Vissim and Viswalk. However, Viswalk provides a visual advantage, which is of great importance when presenting a result to someone who may not be as familiar with traffic analyzes.

Capacity planning both in a large and small scale could be performed by the use of a simulation tool and Viswalk would, with less effort, most likely reflect a more truthful scenario than Vissim. Justification of projects and measures and planning of redirected flows during construction would also gain from using Viswalk, as an important part is to achieve a natural visualization of different suggested scenarios. Regarding follow-up of projects, the use of Vissim or Viswalk would depend on what the situation looks like. There was also an interest in simulating attractive forces in a scenario. At present, this is not possible in either of the simulation programs. This is due to the fact that the program is dependent on input from each specific location that is simulated and it would therefore be difficult to find default values for such attraction forces at present.

Regarding simulation of pedestrian interaction with traffic, which is an important aspect for the Urban Transport Administration, Case study 4 has not shown any great differences in output due to Vissim or Viswalk being used. However, when simulating larger systems and wider crossings such as Case study 1, Viswalk is the preferred option.

7 Conclusions

In this chapter, the general conclusions made during the study will be presented according to the main research questions addressed in the introduction.

Is there a need for using pedestrian simulations at the City of Gothenburg Urban Transport Administration?

The interviewed officials expressed that there is a great interest in pedestrian simulations at the City of Gothenburg Urban Transport Administration, which indicates a potential need for pedestrian simulations. This study shows that there are several areas of applications where the software programs Vissim and Viswalk could be used to satisfy those needs. However, knowledge in both programs is quite limited among the officials. Hopefully, this study will provide for a better understanding of the two and in what situations they can be used. Furthermore, this report could also provide practical guidance in pedestrian simulations at the City of Gothenburg Urban Transport Administration in the future.

What added value would Viswalk bring to the City of Gothenburg Urban Transport Administration in comparison to the original pedestrian function in Vissim? Which software program is more appropriate?

This study has shown that the choice of software program is entirely dependent on what type of scenario that is desired to be simulated. Generally, it can be concluded that Vissim handles pedestrian simulations well in some scenarios. When simulating an ordinary pedestrian crossing, the purpose of pedestrians is merely to act as an interruption for vehicles. In such situations, Vissim provides satisfactory simulations. In situations where the pedestrian scenarios get complex and irrational however, Viswalk is recommended in order to reflect reality in a trustworthy way. The main issue in Viswalk that was found during this study was related to the inability of simulating groups. However, the same issue exists in Vissim.

In general, Viswalk is considered to be the most appropriate program in cases of:

a) large pedestrian flows, e.g. in interaction with vehicles, crowded crossings
b) interaction between pedestrians and vehicles over longer distances, e.g. wide crossings or shared spaces
c) pure pedestrian flows, e.g. squares, large outdoor events
d) many conflicts between pedestrians
e) bottlenecks in city structures, e.g. staircases, narrow sidewalks, passages
f) visual presentations

Examples of all listed scenarios can be seen in Figure 7.1.

In addition to a more accurate reflection of reality for many scenarios in Vissim, it should also be taken into consideration that the model setup in Viswalk is much simpler and more timesaving when it comes to scenarios where the pedestrian routes and network get more complex.

Another important aspect of the conclusion is that the focus in this study has been on the differences between Vissim and Viswalk. Therefore, further studies are recommended in order to verify how well model outputs from both Vissim and Viswalk correspond to reality.

Figure 7.1 The figure shows different locations where pedestrian simulation in Viswalk can be useful. a) A crowded crossing at the Central Station in Gothenburg (Photo: Cecilia Friis) b) Shared space on Exhibition Road in London (Berg, 2013) *c) An outdoor event at Drottningtorget, Gothenburg* (Nilsson, 2011) *d) Pedestrian conflicts at Sergels Torg in Stockholm* (Eriksson, 2011) *e) Bottleneck at stairway to a subway station in London* (Shutterstock, 2011) *f) Microsimulation of pedestrians* (PTV Group, 2013d).

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APPENDIX I: TRAFFIC VELOCITIES

Pedestrian (Individuals)			
Distance (m)	Time (s)	Velocity (m/s)	Velocity (km/h)
23	17	1,4	4,9
23	15,7	1,5	5,3
23	16,9	1,4	4,9
23	14,9	1,5	5,6
23	13,9	1,7	6,0
23	13,9	1,7	6,0
23	17,3	1,3	4,8
23	14,9	1,5	5,6
23	13,7	1,7	6,0
23	20,1	1,1	4,1
23	17	1,4	4,9
33	15	2,2	7,9
33	17	1,9	7,0
33	17,9	1,8	6,6
33	15	2,2	7,9
33	15	2,2	7,9
33	16,9	2,0	7,0
33	17,4	1,9	6,8
33	14,7	2,2	8,1
33	17,6	1,9	6,8
		Mean	**6,2**
		Std.dev.	**1,2**
		70%-perc.	**8,1**
		30%-perc.	**4,3**

Pedestrian (Group)			
Distance (m)	Time (s)	Velocity (m/s)	Velocity (km/h)
23	18,5	1,2	4,5
23	19,1	1,2	4,3
23	16	1,4	5,2
23	21,8	1,1	3,8
33	38,6	0,9	3,1
33	20,1	1,6	5,9
33	19,2	1,7	6,2
33	21,2	1,6	5,6
33	20	1,7	5,9
33	22	1,5	5,4
33	20,6	1,6	5,8
33	25,7	1,3	4,6
33	18	1,8	6,6
		Mean	**5,1**
		Std.dev.	**1,0**
		70%-perc.	**6,8**
		30%-perc.	**3,5**

Pedestrian (Runners)			
Distance (m)	Time (s)	Velocity (m/s)	Velocity (km/h)
33	9,0	3,7	13,2
33	8,1	4,1	14,6
33	9,5	3,5	12,5
33	8,6	3,8	13,8
33	5,7	5,8	20,8
33	9,4	3,5	12,7
		Mean	**14,6**
		Std.dev.	**3,1**
		70%-perc.	**19,7**
		30%-perc.	**9,6**

APPENDIX I: TRAFFIC VELOCITES

Bicycles

Distance (m)	Time (s)	Velocity (m/s)	Velocity (km/h)
33	6,0	5,5	19,7
33	5,0	6,5	23,6
33	7,1	4,6	16,7
33	5,9	5,6	20,2
33	4,4	7,5	26,9
33	5,2	6,3	22,8
33	5,3	6,2	22,3
33	7,6	4,3	15,6
33	7,2	4,6	16,4
33	5,5	6,0	21,7
33	6,2	5,4	19,3
33	7,2	4,6	16,4
33	6,1	5,4	19,3
33	7,0	4,7	17,0
33	6,2	5,3	19,1
33	8,1	4,1	14,6
33	7,3	4,5	16,3
33	7,1	4,7	16,8
33	5,9	5,6	20,2
33	6,0	5,5	19,7
33	4,7	7,1	25,4
33	6,1	5,4	19,5
33	5,4	6,1	22,1
33	4,2	7,8	28,0
		Mean	**20,0**
		Std.dev.	**3,6**
		70% perc.	**25,8**
		30% perc.	**14,2**

Vehicles

Distance (m)	Time (s)	Velocity (m/s)	Velocity (km/h)
25	4,1	6	22
25	3,2	8	28
25	4,8	5	19
25	5,1	5	18
25	4,5	6	20
25	3,4	7	26
25	5,4	5	17
25	3,2	8	28
25	2,9	9	31
25	3,1	8	29
25	3	8	30
25	5	5	18
25	4	6	23
25	2,6	10	35
25	2,8	9	32
25	3	8	30
25	2,4	10	38
25	2,2	11	41
25	3,6	7	25
25	3,3	8	27
		Mean	**27**
		Std.dev.	**7**
		70%-perc.	**37,6**
		30%-perc.	**16,0**

APPENDIX II: PEDESTRIAN ROUTE CHOICES

From	To	Number 04-mar	Number 13-mar	Number 14-mar	Percentage (%) 04-mar	Percentage (%) 13-mar	Percentage (%) 14-mar	Percentage (%) Average
1	**2**	4	5		35	24		**30**
	4	0	0		0	19		**10**
	7	18	4		65	57		**61**
	8	0	0		0	0		**0**
	9	0	12		0	0		**0**
Total		**22**	**21**	**16**				
2	**1**	13	28		42	52		**46**
	3	2	2		7	4		**6**
	5	3	7		10	13		**12**
	7	2	4		7	8		**8**
	8	1	0		3	0		**2**
	9	10	13		31	23		**26**
Total		**31**	**54**	**26**				
3	**2**	1	1		3	5		**4**
	4	26	16		72	76		**73**
	6	1	3		3	14		**9**
	8	8	2		22	5		**14**
Total		**36**	**22**	**37**				
4	**1**	3	6		11	24		**17**
	3	16	15		57	60		**58**
	5	2	2		7	8		**8**
	7	2	2		7	8		**8**
	8	4	0		14	0		**7**
	9	1	0		4	0		**2**
Total		**28**	**25**	**33**				
5	**4**	0	7		0	41		**20**
	6	2	7		22	41		**31**
	7	1	1		11	6		**9**
	8	5	2		45	12		**29**
	9	2	0		22	0		**11**
Total		**10**	**17**	**25**				

APPENDIX II: PEDESTRIAN ROUTE CHOICES

From	To	Number 04-mar	Number 13-mar	Number 14-mar	Percentage (%) 04-mar	Percentage (%) 13-mar	Percentage (%) 14-mar	Percentage (%) Average
6	**3**	5	6		25	25		**25**
	5	8	11		40	46		**43**
	7	4	0		20	0		**10**
	8	3	7		15	29		**22**
Total		**20**	**24**	**43**				
7	**1**	37	29		39	39		**39**
	2	17	18		18	24		**20**
	3	0	13		0	17		**8**
	4	15	4		16	5		**11**
	5	13	5		14	7		**11**
	6	1	4		1	5		**3**
	8	8	2		12	3		**8**
Total		**91**	**75**	**75**				
8	**2**	0	1		0	4		**2**
	3	9	11		46	39		**43**
	4	2	6		7	21		**14**
	5	2	0		15	0		**7**
	6	0	9		0	32		**16**
	7	4	1		32	4		**18**
Total		**17**	**28**	**32**				
9	**1**	5	4		9	3		**6**
	2	29	96		55	66		**61**
	3	4	9		8	6		**7**
	4		5			3		**2**
	5	10	20		19	15		**16**
	6	2	3		4	2		**3**
	7	2	3		4	2		**3**
	8	1	5		1	3		**2**
Total		**53**	**145**	**88**				

APPENDIX III: GEH-VALUES

GEH- values in Vissim									
	Pedestrians					Bicycles		Vehicles	
Simulation run	9 to 2	7 to 1	7 to 2	7 to 8	8 to 4	East	West	East	West
1	2,0	0,1	1,1	1,3	0,6	1,7	0,1	1,5	0,6
3	0,7	0,8	1,9	0,5	0,0	1,8	1,2	0,1	1,3
5	0,9	1,0	0,8	1,5	1,1	0,7	1,5	1,1	0,1
7	0,4	2,3	0,4	0,7	0,6	1,7	1,5	0,6	0,4
9	1,1	1,4	0,7	0,5	1,1	0,4	0,0	1,3	0,3
11	0,4	2,0	1,1	1,5	0,3	0,4	1,5	0,5	0,8
13	0,3	1,7	0,3	2,6	0,9	1,0	0,2	0,0	1,6
15	0,9	0,8	0,4	0,9	2,4	3,4	0,4	2,6	0,9
17	1,9	1,4	0,1	0,2	1,6	1,8	0,4	1,3	0,2
19	0,7	1,1	1,9	0,2	0,8	0,6	0,5	0,7	0,4
21	1,4	1,4	2,0	0,2	0,6	0,7	1,3	1,3	2,2
23	0,2	0,8	1,0	0,7	0,3	1,0	2,3	1,1	0,3
25	0,3	2,0	1,7	0,9	0,8	0,4	0,5	1,2	1,7
27	1,4	1,0	1,2	1,7	0,0	0,6	0,5	0,8	0,1
29	0,7	2,0	0,3	0,7	1,6	0,1	0,6	0,5	1,3

GEH-values in Viswalk									
	Pedestrians					Bicycles		Vehicles	
Simulation run	9 to 2	7 to 1	7 to 2	7 to 8	8 to 4	East	West	East	West
1	1,4	0,5	0,1	0,9	0,3	1,7	0,2	1,4	0,5
3	1,4	0,6	0,3	1,4	1,1	1,8	1,2	0,1	1,3
5	0,3	0,4	0,1	0,2	2,4	0,7	1,5	1,2	0,1
7	1,0	0,8	1,2	0,2	1,6	1,7	0,6	0,6	0,4
9	0,3	0,1	1,0	0,0	1,6	0,4	0,0	1,3	0,3
11	0,4	0,2	0,1	0,4	0,3	0,4	1,5	0,6	0,8
13	1,4	1,1	0,3	0,6	1,1	1,0	0,2	0,1	1,6
15	0,3	0,9	0,8	1,4	2,0	3,4	0,4	2,6	0,8
17	0,2	0,6	0,8	2,0	0,3	1,8	0,4	1,3	0,1
19	0,9	0,2	0,3	1,5	0,9	0,6	0,4	0,7	0,3
21	2,7	0,5	0,4	0,2	1,3	0,7	1,2	1,4	2,2
23	0,5	0,6	0,7	0,0	0,3	1,0	2,3	1,1	0,3
25	0,3	0,7	0,7	0,2	0,8	0,4	0,5	1,3	1,7
27	1,6	0,2	0,3	1,2	0,6	0,6	0,5	0,8	0,0
29	0,3	1,1	0,8	0,2	1,3	0,1	0,6	0,5	1,3