Pedestrian assessment of a new football stadium in Zürich, Switzerland

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Työn ohjaaja/t	Teppo Sotavalta	

TIIVISTELMÄ

Tämän opinnäytetyön tavoitteena oli saada analysoitavat tulokset jalankulkuun liittyvästä tutkimustyöstä. Opinnäytetyön tutkimus on tehty sveitsiläiselle konsulttiyritykselle ja tutkimus keskittyi Zürichiin rakennettavan jalkapallostadionin välittömään lähialueeseen, joka sijaitsee Hardturm -nimisellä asuinalueella. Toimeksiantajana toimi sveitsiläinen liikennealan konsultointiyritys IBV-Hüsler Oy.

Tavoitteena oli erityisesti tutkia lähtevien katsojien uloskäynnin ja päämärän välistä toteutettua matkaa. Opinnäytetyössä käytettiin tutkimustyökaluna Vissim -mikrosimulaatio-ohjelmaa ja saavutetut tulokset opinnäytetyössä ovat tämän ohjelman tuottamia.

Tuloksiin perustuvat johtopäätökset sekä ohjelman tuottamien tuloksien analysointina voidaan sanoa, että alueellinen rakennelma on toimiva isojen massatapahtumien purkuun. Alueella ei havaittu suuria ongelmia tai pullonkauloja. Opinnäytetyössä todettiin, että julkisen liikenteen toimivuus massatapahtumissa on todella tärkeä.

Keskeisenä johtopäätöksenä voidaan pitää myös sitä, että kaupunkirakentamisessa on aina hyvä tutkia mikrosimulaatioiden avulla maankäytön toimivuutta mitä tahansa kulkumuotoa koskien, koska nykypäivänä liikkumismäärät kaikissa eri muodoissaan ovat huomattavasti suuremmassa mittakaavassa kuin ennen. Toimivuustarkastelut olisi hyvä olla normaali käytäntö nykypäivän yhdyskuntasuunnittelussa, jotta liikennevirrat pysyvät sujuvina.

Avainsanat Analyyttiset menetelmät, jalankulun simulaatio, mikrosimulaatio, Vissim

Sivut 25 sivua

ABSTRACT

Traffic Management
Riihimäki

Author	Joel Peiponen	**Year** 2017
Subject	Pedestrian assessment at new football stadium in Zürich, Switzerland	
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ABSTRACT

The purpose of this thesis was to have analyzable results according to pedestrian behaviors. This thesis was made for a swiss traffic company and the project focused in Zürich where the new football stadium is in the Hardturm residential area. The commissioning company was IBV-Hüsler Ltd.

The main goal of this project was to examine how thousands of spectators leave the stadium after the game from the exit points to reach their destinations. This project focuses on the areas between the exit points and the desired destinations. The author used in this thesis microsimulation software called Vissim. All the results of this thesis are produced from Vissim.

All the conclusions and analyses were based on the microsimulation results, and we can say that the structure of the area is capable of handling mass events. The author did not notice any significant problems in the area or any bottlenecks. In this project, it was discovered how public transportation has an important role in mass events.

As a fundamental conclusion, we can say that it is always good to have microsimulation examination in spatial planning to recognize any possible problems according to land usage. There is always traffic in some form and it is growing in higher numbers in future, therefore, microsimulation is important so builders and designers can be assured of good traffic flow in the area.

Keywords Analytic methods, microsimulation, pedestrian simulation, Vissim

Pages 25 pages

CONTENT

1 INTRODUCTION

The main goal of this project was to examine pedestrian behaviors in crowded events and to have correct analyzed results. The project was completed in spring 2017 and it was located in Zürich, Switzerland. The author wanted to have an international thesis project and managed to have one in Europe. As a future traffic engineer, it is important to have international experience as well, even if working in the homeland.

Microsimulation is an important part of traffic designing. The new football stadium in Zürich gave an interesting chance to examine pedestrian behavior in a large mass event. When designing new recreational areas or residential areas it is important to take in mind all sorts of traffic users so the traffic flow will be fluent and safe for everyone.

This project was carried out with Vissim microsimulation software. In the beginning of the thesis project, the author traveled to Zürich to get the main data for the thesis. Most of the writing process was conducted in Finland.

In the following chapters, the author explains the parameters that were used in this project and their significance, the background of the thesis, its limits, research questions and the methods that author have used in this thesis. The author will describe walking theories and previous research on pedestrian traffic in crowded events. This thesis was concluded from an empirical and quantitative perspective.

2 PARAMETERS

The purpose here is to present all the parameters which are important for getting realistic results from the model in order to imitate correctly pedestrian and movement and behavior. All the following parameters were used and assessed in this project, to reach reliable research results.

2.1.1 Level of service and color scheme for areas

The purpose of the level of service is to show what crowded areas are like and to detect whether there are any bottlenecks. Bottlenecks mean that there is an area filled up with pedestrians who cannot move forward or backward so that they are jammed and gather more pedestrians to group up. Usually, the level of service is expressed in letters from A to F, where A stands to the best-case scenario and F for the worst. A means that there are no existing bottlenecks and the pedestrian flow is uninhibited. Also in this thesis, the level of service is shown up in grid cells, which means that there are colors used for visualization, where Blue stands for situation A and red for situation F. In this case, F and the Red situation do not mean that there is a bottleneck. It means that the place is highly crowded and it is highly vulnerable for creating a bottleneck.

2.1.2 Lambda values

The lambda value counts and calculates pedestrian decisional movements by the influence of other pedestrians. These pedestrians which affect the most to the Lambda value are the value front of the pedestrian. Pedestrians who are behind the target still affect, but not as much as the pedestrians front of the targeted person. The Lambda value counts possible obstacles that may affect pedestrian movement and routing decisions as well.

The Lambda value affects Social Force and it makes pedestrians in the model to walk through tight areal gaps to make the model most realistic. (Gibb 2015, 11.)

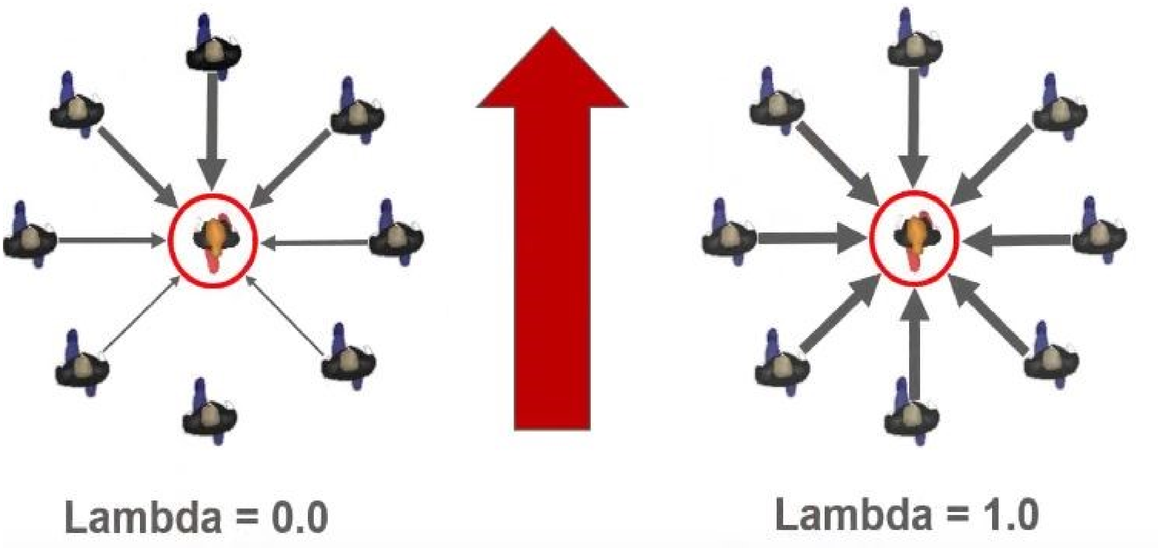


Figure 1, Pedestrian simulation with PTV Vissim & PTV Viswalk (Kretz 2014)

The purpose of figure is to show the effect of using the Lambda parameter while modeling. Value 0.0 means that lambda was not used in simulation and 1.0 means that this parameter is valid and on while simulating. In this thesis, we used situation value 0.0 because there were tight and crowded areas and to get a most realistic image of pedestrian behavioral movement.

2.1.3 Social Force Model

Figure 2 illusrtates how modeling realistic pedestrian movement in Vissim is based on social force which is based on mathematic formulas. These formulas govern all the decisions that pedestrians take in different scenarios and situations. Social Forces are based on Social Force F-, B and A. All the forces are associated and affected by lambda values, noise values, and VD values. These formulas control destiny, routing path and movement.
The very basic conclusion of the Social Force model is that there are physical, psychological and social forces which together controls the movement of pedestrians. (Kretz 2014.)

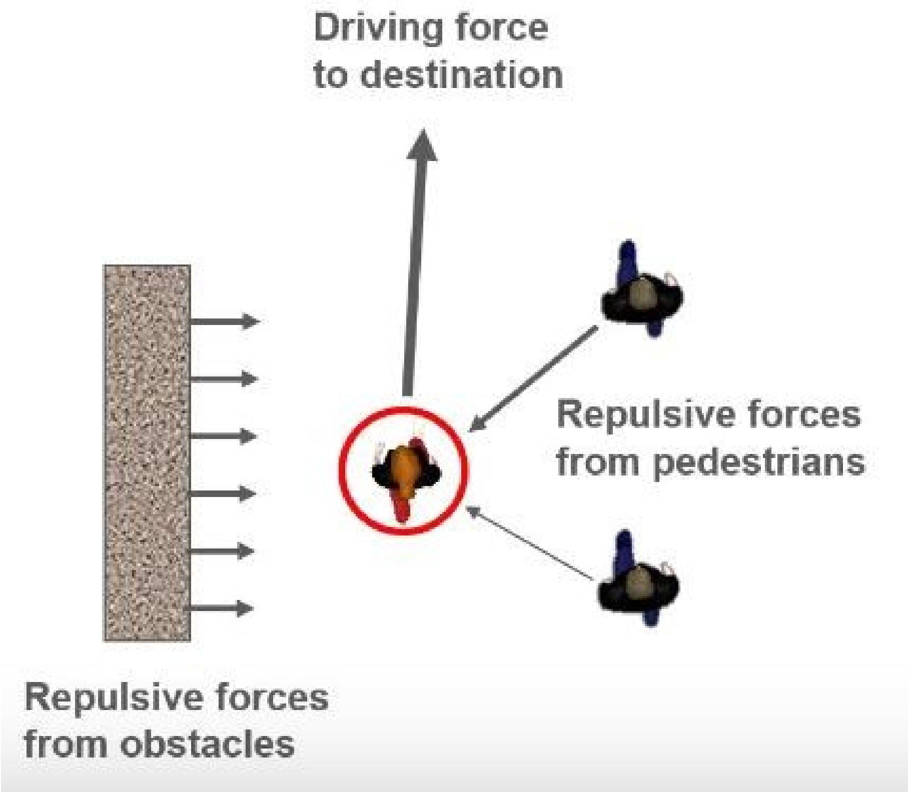


Figure 2, Pedestrian simulation with PTV Vissim & PTV Viswalk (Kretz 2014)

2.1.4 Density and grid cell data

In this thesis model, the author used grid cells to gather data how crowded pedestrians are in certain areas. Grid cells show the density of the pedestrians in the area which develops the level of service in the area at the current time interval of the simulation. The result will be shown in different color range.

2.1.5 VD

In Vissim models VD purpose is that pedestrians evade facing each other and trying to find the path that there are no other pedestrians on the same route. VD is taking pedestrians relative walking speeds (velocities) and contributes it to social force F.

2.1.6 Noise

Noise evaluates the random force of the model. Noise will systematically count different forces when pedestrians desired velocity is below the normal. In this thesis, noise was valued to 1 which means when forcing the pedestrians to crowded and narrow areas they will realistically step back and try to find more relaxed space, while other pedestrians will pass the noise affected pedestrian. (PTV Vissim 2016, 757.)

3 BACKGROUND

In this chapter, the author explains different theories on behavioral walking and movement. The author, also describes previous researchers concerning pedestrians, he's time in Switzerland and the background of the project with detailed information about it. The author tells which crowded events affect on pedestrian's movement. The author also describes the background of the commissioning company.

3.1 Walking in theory

Walking is the most common way to travel in human history and its one of the least researched habit to travel. Walking is something that everybody basically does every day at some point. When we travel distances, we don't think that who is behind us or why to decide to take this certain path, route or why we circled or avoided certain obstacles. All this mostly happens subconsciously, and we don't think how we walk or move. Mostly what effects to our decision making while the walk is in our senses. For instance, high amount of noise is an irritant and it sends to our brain a message that we want to go to lower noise areas, so this one reason why pedestrian changes his or her route. (Bovy & Hoogendoorn 2002, 4.)

Regarding lambda value, we see people front of us and we might want to changes again path and routes by overtaking them, but people behind us that we cannot see does not affect to our routing system that much because there is no visual contact. All the social forces make our path to change, and difference's our decision-making whether it's an obstacle which could, for example, be a trash can in walking area or other pedestrians. Geographical shape of the area effects naturally to walking speed and pedestrians ages as well. The shape of high terrains and different pedestrian ages makes higher density which has high possibility to create a bottleneck already in crowded places. (Daamen & Hoogendoorn 2003, 9-16.)

3.2 Previous researches of pedestrians

As already mentioned that walking is the largest way to travel however it still lacks a good amount of researches. Mostly in this era researchers have focused to health point of view. That how effective walking is to your health and how important it is and how many steps per day you should walk to stay in certain health level.

The author is going to find a previous researcher that are concerning the way we walk and why we do certain choices while we walk.
Mostly till today researchers have tested the pedestrians behavioral meaning and forces which effect to pedestrians by creating different mathematic formulas and computing the pedestrians. Winnie Daamen and Serge P. Hoogendoorn did experimental research what effects to pedestrians walking behaviors in 2003. W.Daamen & P.Hoogendoorn tested that how bottlenecks are created and what are the effect of the width of the walking area. W.Daamen & P.Hoogendoorn discovered that there is the very low amount of researchable material of walking behaviors, and they gathered all the available data across the world, to create legit empirical data. (Daamen & Hoogendoorn 2003, 1.)

The very first official mathematic formulas in 1995 were created by Dirk Helbing's who created the physics of the walking which is now computed into software. Overall in these days' researchers, interest and priority towards walking are higher than ever, in this era, we have now several simulation programmers that make possible to have more classified data than ever before. (Helbing & Molnár 1995, 1.)

3.3 Crowded events

The meaning of the crowded events is, for instance, many people or spectators leaving the area in limited space or in a rather small walking areas. In these scenarios, single pedestrian behavior can change drastically what is in non-crowded areas or there are no other pedestrians at all. The crowded events are very difficult to model correctly, due to the power of the computers. In mass events, we can speak for example more than 10 000 pedestrians in the area, where computer have count every step and decision making for 10 000 pedestrians. This means that there is a large number of different parameters at the same time. For having most realistic results is always mandatory to set the values and to create right compounds of parameters. In this thesis, the author was forced to not use dynamic potential due to a number of pedestrians. Due to these reasons of modeling, crowded events lack quantity of research.

Louis Kratz and Ko Nishino have researched extremely crowded pedestrian areas by using a video camera and creating motion patterns. L.Kratz and K.Nishino conclusion and results were compared to other analysis and find out that average errors were lower than in other research. This will summarize the difficulty of researching and examining crowded events in any case. (Kratz & Nishino 2011, 28.)

3.4 IBV-Hüsler Ltd

IBV-Hüsler Ltd was the commissioning company for this thesis. The company is located in Switzerland, Zürich. It was established by Willi Hüsler 30 years ago. IBV-Hüsler Ltd is specialized developing and designing traffic systems, for instance, public transportation, traffic research and improvements in land use.

3.4.1 Time in Switzerland, Zürich

The author stayed in Zürich, Switzerland for a week. Purpose was to create a network or an area where pedestrians move, and to gather results and set the different parameters into the model. The software was decided to be Vissim due to the commissioning company already have a license for it. The commissioning company supervised the work there and made it possible to the author to work at the company's office. After doing the network and gathering the results, the analysis part was written in Finland. The results were realistic and all the participants were satisfied with the work.

3.4.2 Project area

The area is called Hardturm and it is located in Zürich, Switzerland. The citizens of Zürich voted against the project in late 2006 now the vote has been passed by the citizens and the project started to gather funds and main investors. The main investors for this project are Suisse Credit Bank and HRS Investment Ltd. The total capacity of the, stadium is 18 500 spectators. The whole project is worth 350 million Swiss francs which is approximately 327 million euros. The project includes two new skyscrapers beside the stadium. (StadiumDB, 2015)

Figure 3, 2D picture of the stadium area

Figure 4, Models of the stadium

3.5 **Limits**

In this project the research topic and research questions were limited by the author and the supervisor from the university. The commissioning company limited the model and the area. This thesis focuses only on pedestrians leaving the stadium and large sized events. The author and the commissioning company as well as the supervisor decided that it was more important to examine departing pedestrians instead of arriving, because the time scale of departing pedestrians is usually smaller than arriving ones, which might create bottlenecks and unexpected movement in the area. In this project, the author tried to find out what affects pedestrian behavior and movement in crowded areas.

The author also, provides here knowledge on walking researches and compares this project to projects which are conducted in Finland. In this project, the purpose was to find new information and new solutions and to present the importance of working public transportation in crowded events.

3.6 Research questions

The purpose of this project was to the answer following research questions:
What is the effect when people at a fully crowded football stadium begin to exit from the exit points to their destinations? The examination focuses on the area between departing and arriving points where pedestrians execute the travel.

3.7 Research methods

In this thesis, the author used Vissim software as a research tool. Vissim is a major international simulation software which enables simulating on vehicles and pedestrians. In this case, we used Vissim module called VisWalk, and with these parameters, the author could do research project on pedestrians.

Functions and parameters have been defined in
Viswalk professor called Dr. Dirk Helbing, who is a scientific researcher and advisor for Vissim (PTV GROUP). According to Dr. Helbing's theory, Vissim creates Social Force meanings and walking behavior into software which generates pedestrians paths and routes by mimicking real pedestrians.

4 PEDESTRIANS DEPARTING FROM THE FOOTBALL STADIUM

In this chapter the author explains what were the problems and challenges in the simulation, what practically happened, explaining the possible bottlenecks, the importance the of crossing areas and the bridge, and the risk of mixing mass events with vehicle traffic at the departing time.

The challenges in the model were mostly the size of the area and the number of the pedestrians. The simulation began creating the network and the basics of the area, for instance, possible obstacles, setting the right backgrounds, creating the areas for pedestrians and figuring out the parameter values. Changing the seed value did not affect the simulation results. A very important part the project was to set the correct matrix values and interval times. Was defined what was included in the matrix, for example, the bridge in the area was only under the club's official fan usage. Therefore, the author had to calculate the estimated 900 pedestrians out of the matrix, because club fans were placed with static routing which means that the author defined the exact route that these pedestrians used.

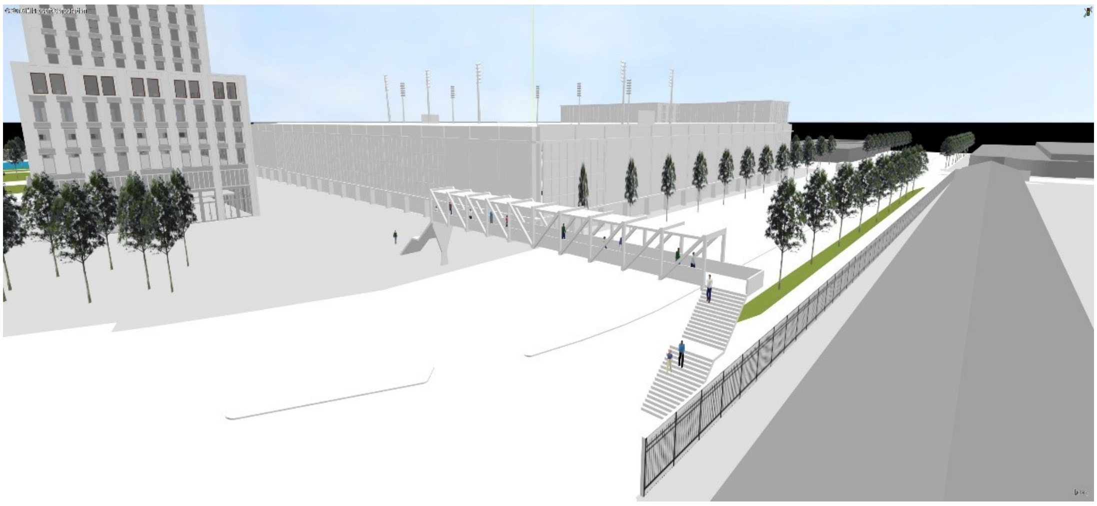


Figure 5, 3D picture of the pedestrian's bridge

Figure 6, 3D picture of the pedestrian's bridge from the front

In these picture captures from the simulation, is shown the exact 3D model of the upcoming bridge which is under use of official club fans.

The simulated area was relatively large compared to usually what simulated pedestrian areas are. The importance of the simulation is that it's not parted, which means that every section must be simulated alone. In this case, when the simulation is done by the matrix and in one big area, the results are easier to see and analyze.

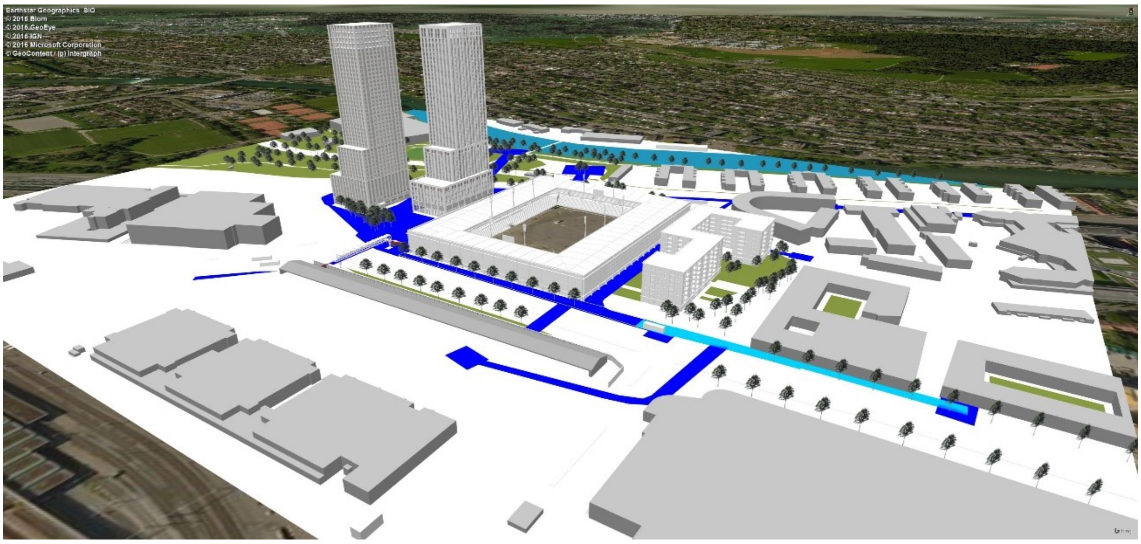


Figure 7, 3D picture of the area

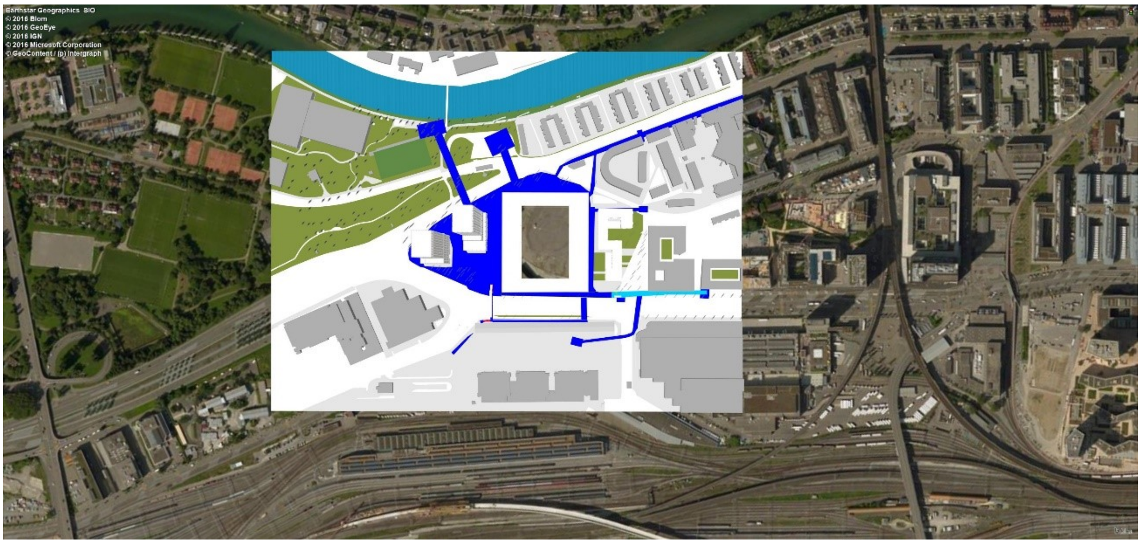


Figure 8, 2D picture of the area

The idea in this captured 3D picture is to show the area in overall. Blue and light blue colored areas are the areas where pedestrians can walk. Colors are defined by the level of service values, however in this case, these colors do not indicate the right value or the right results of the certain area. Colors are for visualizing the correct walkable areas, and the large squares are the destinations.

Figure 9, Pedestrians departing the stadium

The purpose of this figure 9 is to show the real amount of departing pedestrians from the stadium after the game at an early stage.

At the early stage of the simulation, the author faced several bottlenecks areas in tight corners. To avoid this unrealistic result or phenomena one has to use the travel points where you can define the partial route which is the first destination of the pedestrians before the last destination. It is important to create these travel points so the travel point boxes are placed correctly into the corners because otherwise wrongly placed travel points could cause unrealistic results which are not analyzable. Another way to avoid this problem is to use dynamic potential on pedestrians, where the computer and software calculate each step by a 1-second interval to get realistic movement and to avoid the shortest way to get to the destination. The purpose there is that if every pedestrian in the model tries to find the shortest way to the destination this will cause bottlenecks, also if the scale of the model is rather large, pedestrians in the network do not use the area correctly compared to how people walk in real life. Therefore network needs to be adjusted using the dynamic potential, separated destinations or partial routes.

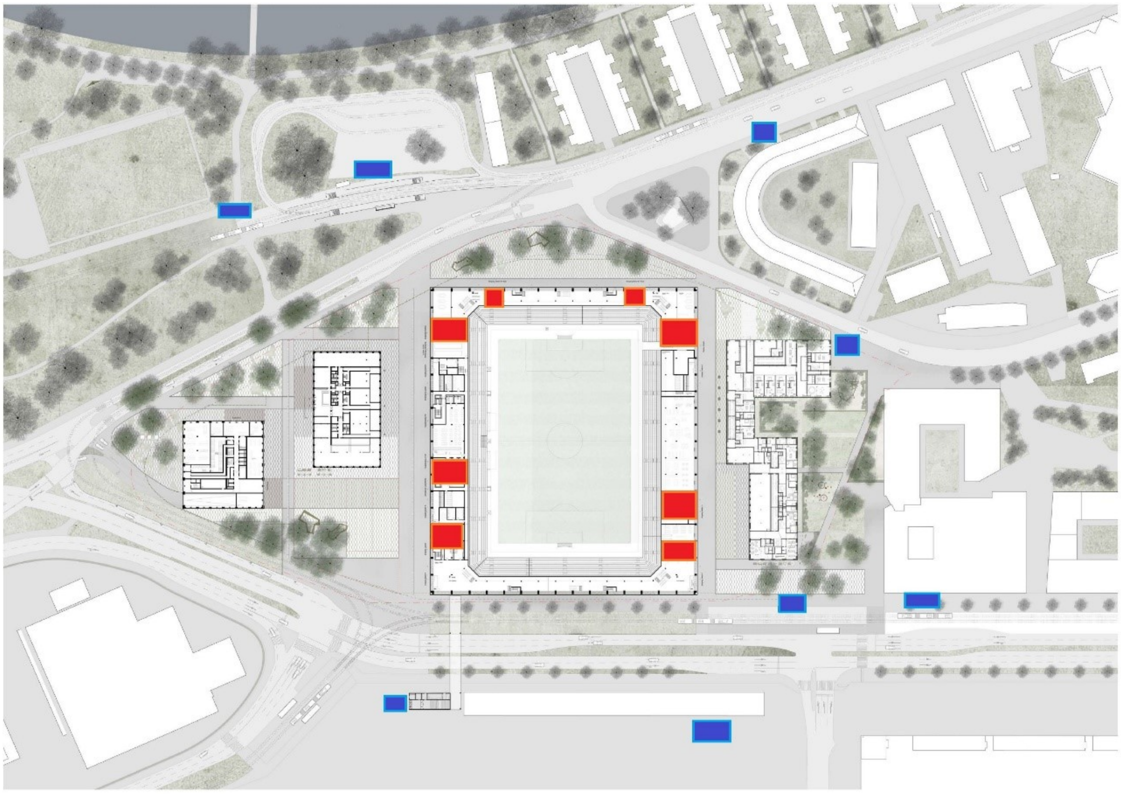


Figure 10 Stadium's exit and destination areas

Figure 10 illustrates all the red and blue boxes. The red boxes represent departure areas and all the blue boxes represent destination areas. There are no direct lines how the pedestrians should walk or where are their destinations. In this work the author used matrix, which means that pedestrians define the shortest route by their selves to the desired destination. Also in the matrix, there are some pedestrians that walk longer distances, for instance from the north departing points to south destinations points. The purpose of this system in the matrix is that there is still in followed realistic possibility that you may have seat place from another side of the stadium where you would like to have and therefore when you depart after the game you seek the same route which may be the longest.

4.1 EFFICIENCY OF WORKING PUBLIC TRANSPORTATION

In time to time people have built stadiums and big event places, for example, shopping malls with the great public transportation system. Project Hardturm is comparable and almost similar to Hartwall arena, HIFK's stadium, and Tampere's stadium. All these stadiums and projects similarity that the way they are funded and there are other buildings under construction at the same time. All these projects have great transportation lines built for crowded events. It means that it's also a current trend to build more than one building in the area to have higher incomes to investors and construction companies.

The importance of working public transport in mass events is undeniable. The very critical points are the waiting areas, how they should be designed and size of the platforms. In this simulation scenario, the author found if the public transportation vehicles do not have good shifting times means that there are not enough transportation vehicles in certain time. It creates large bottlenecks which are a safety risk to the people. Also in this scenario, the bottleneck did not dismantle within the simulation hour. To underestimate the public transportation users, tram and bus modules should be maximized to as many as possible in case of the high number of users. Maximizing the tram modules will help possible bottlenecks to be dismantled faster or in the best scenario, it helps to avoid a bottleneck near on waiting areas. Also in the network model, everything correlates everything and if the bottleneck is not avoided early it can show as a problem in other location of the area due to correlation. In the mass events, it’s incorrect and inappropriate to expect that certain amount of public transportation modules and vehicles are enough to carry the burden of people’s needs. It is clear when approximately 18 500 pedestrians are departing the area there is still a high number of public transportation users.

Also in this Hardturm stadium, one of the tramlines and vehicle routes may be closed after the match due to the safety issue of the people. Which means it lacks a higher number of public transportation vehicles in the area.

5 HELBING’S THEORY ON VISWALK AND HBS WALKWAYS

In this chapter, the author clarifies the basics of the Helbing theory, how the software has created pedestrian behavior and movement. The author, also explains the color schemes used in the model and what the level of service and the pedestrian flow was based on.

PTV Viswalk is the leading product currently in pedestrian modeling. Pedestrian simulations in Viswalk are based on Dr. Dirk Helbing’s Social Force Model. It imitates the human’s walking behaviors and it makes possible to simulate, analyze pedestrian flows in outdoors and indoors. Helbing’s theory is only made for pedestrian simulations, not for vehicles. The principle in social force model pedestrian’s movement power is based on Newtonian mechanics. Characteristically there are three important compounds which together creates one total force, these compounds are social, psychological and physical forces. These phenomena originate the pedestrians to reach the goal with taking the influence and the effect of the other pedestrians and possible obstacles. In this project, obstacles are for example trees and indoor simulation usually obstacle could be, for example, a counter desk. (PTV Vissim 2016, 747.)

To establish perfect pedestrian simulation network or model it has to be based on macroscopic parameters, which are the parameters that researchers had examined from the human movements and these parameters have to be calculated into the software and adjust the empirical data.

Also, the behavior of the pedestrian's is in three different hierarchical stages. First, the pedestrian in the network is calculating the route of the all possible destinations and creates the list of it. After that pedestrian chooses the desirable route and takes it to the action. While the pedestrian is traveling, it performs the real human movement and therefore pedestrians navigate through the other pedestrians and pedestrians who are facing it. The pedestrian will not end the travel until it has reached the destination. This is called strategic level and it's based on Hoogendoorn's research in 2002, strategic level is divided to minutes to hours on planning point, seconds to minutes on choosing a route, and milliseconds to seconds while performing. Usually, the total simulation time is 3600 seconds. (PTV Vissim 2016, 748.)

HBS Walkways purpose is to evaluate and visualize by using color schemes that what is happening in the network with the pedestrians. HBS comes from words "German Highway Capacity Manual", in this case, this the author used HBS Walkways. HBS generates color lines when it's at the same time with grid cell data it's detailed with analytical data and HBS is based on pedestrian's volumes and densities which generate pedestrian flows. This data can be determined by the level of service (LOS). The HBS Walkways makes possible that designers and engineers can have high-quality analyses from the desired area. (Leyn & Vortisch 2014, 2−3.)

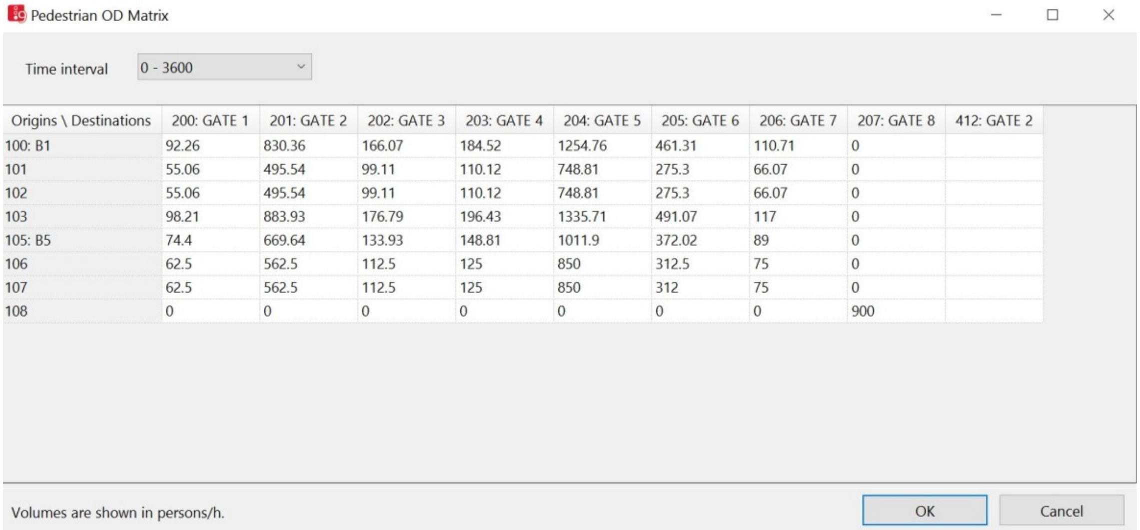
The level of service computed with HBS walkways threshold is defined by lower bound and upper bound and these values mean that there are pedestrians per square meter and pedestrians per minute per meter. In this project the author used following blue color means LOS value A since its first value there is no lower bound but upper bound was set to less than 0,100. And the worst-case scenario the LOS value is colored red and written with alphabet F there is no upper bound value due to the highest value what is defined. Lower bound in this case is 1,800 or more. The HBS walkway uses average values of pedestrian flow ratio and pedestrians space in terms of service levels. (Allen, Hummer, Milazzo & Rouphail 1998, 15−16.)

5.1 EFFECTS ON PEDESTRIAN BEHAVIOUR IN CROWDED AREAS

In crowded areas, pedestrian behaviors will change. The way the pedestrian move is effected always by the surrounding noise, another pedestrian, obstacles and the state of the mind. For instance, is clear that in riots the movement behaviors are faster and more aggressive comparing to departing pedestrians from music festivals. It is calculated in this network average movement speed is 1,1-1,4 meters per second. And coming to the crowded areas the velocity variance values come

6 ANALYSIS

In this chapter, the author analyzes the network results and explains how the matrix and the interval times were created.



Origins \ Destinations	200: GATE 1	201: GATE 2	202: GATE 3	203: GATE 4	204: GATE 5	205: GATE 6	206: GATE 7	207: GATE 8	412: GATE 2
100: B1	92.26	830.36	166.07	184.52	1254.76	461.31	110.71	0	
101	55.06	495.54	99.11	110.12	748.81	275.3	66.07	0	
102	55.06	495.54	99.11	110.12	748.81	275.3	66.07	0	
103	98.21	883.93	176.79	196.43	1335.71	491.07	117	0	
105: B5	74.4	669.64	133.93	148.81	1011.9	372.02	89	0	
106	62.5	562.5	112.5	125	850	312.5	75	0	
107	62.5	562.5	112.5	125	850	312	75	0	
108	0	0	0	0	0	0	0	900	

Figure 11 Matrix of the area

The matrix as seen in Figure 11 was based on estimations on which part of the stadium each pedestrian would depart and how many percentages would leave in certain exit point. The stadium has 8 different exit and entry points. Estimations were easily conducted because we had the knowledge where the pedestrians enter the stadium. Therefore it works likewise and we can have estimated calculations which direction pedestrians would depart. In this matrix, the calculation of pedestrians was not 18 500. Because in the area have constant 900 bridge users defined by the static route, because the seat places of these users are known as the route itself. Also, the commissioning company estimated calculation based on other football matches that 5% of the spectators will leave 10 minutes before the game so these are not in the simulation. Spectators who leave before the game are mostly avoiding the big rush or they are not pleased with the game. This 5% of total 18 500 is 925 spectators and knowing the other 900 of bridge users we have the total amount of 1825 pedestrians out of the matrix. Which left us 16 675 pedestrians and it is still a high number of areal users and can be considered as a mass event.

In this usage of the matrix and with all other mass event simulations it highly important to set the correct interval times. Interval times define that, is not constantly leaving the same number of pedestrians divided 60 minutes from the total number of pedestrians. The interval times were set to following percentages: 20% of the people leaving in 0-10 minutes, 40% of the people leaving in 10-20 minutes, 25% of people leaving in 20-30 minutes and 10% beginning depart within 30-40 minutes. The commissioning company assumed that no one will leave at the time of 40-50 minutes after a match, however, due to long distances pedestrians are still in the area after 50 minutes. These pedestrians will naturally affect the density and level of service values.

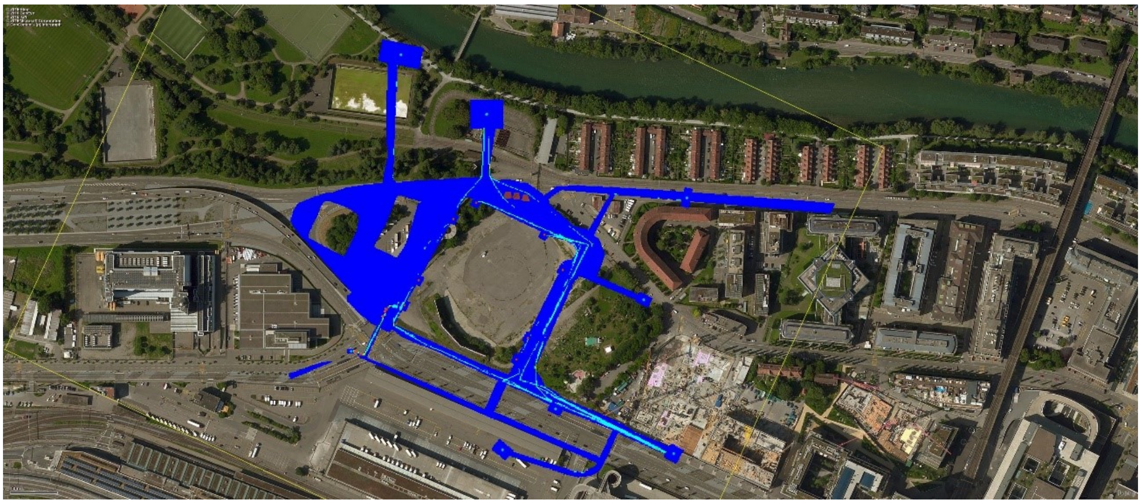


Figure 12 Interval time 400-700 seconds

Figure 13 Interval time 700-1000 seconds

Figure 14 Interval time 1000-1300 seconds

Figure 15 Interval time 1300-1600 seconds

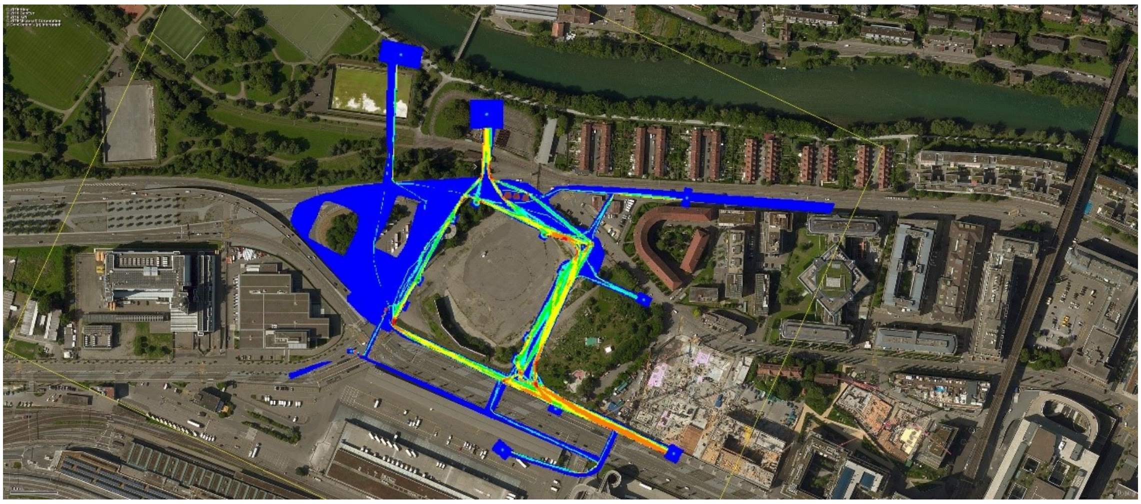


Figure 16 Interval time 1600-1900 seconds

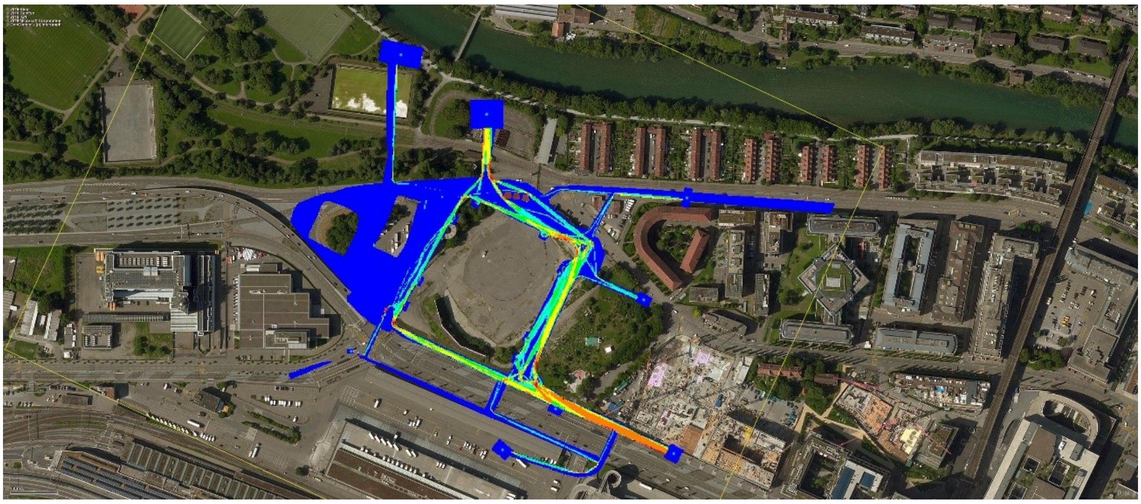


Figure 17 Interval time 1900-2200 seconds


Figure 18 Interval time 2200-2500 seconds


Figure 19 Interval time 2500-2800 seconds

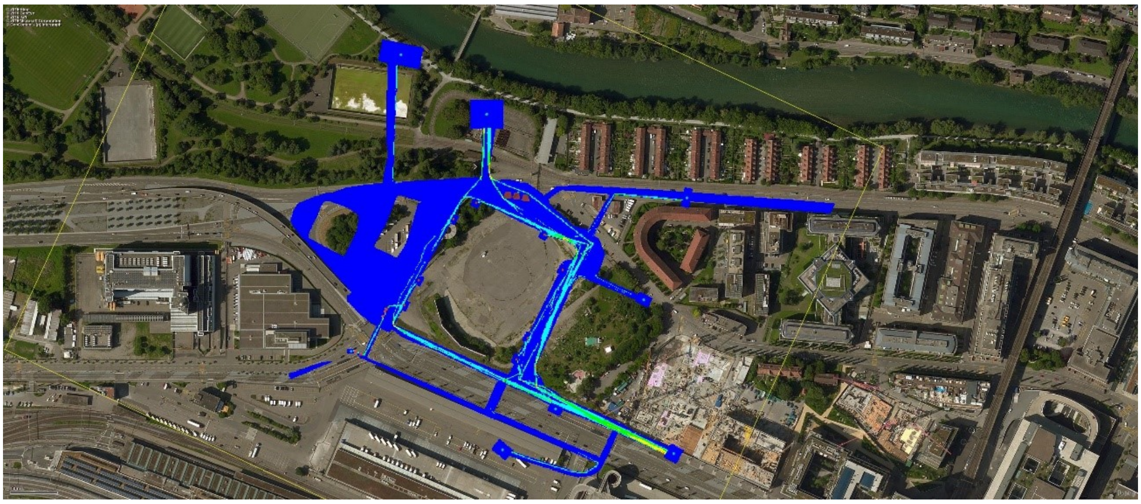


Figure 20 Interval time 2800-3100 seconds

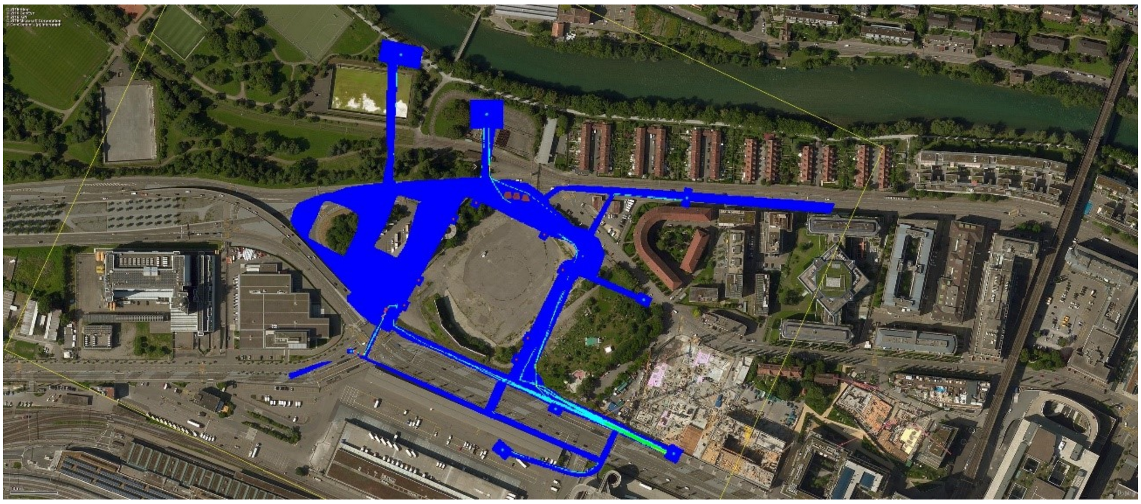


Figure 21 2800 Interval time 3100-3400 seconds

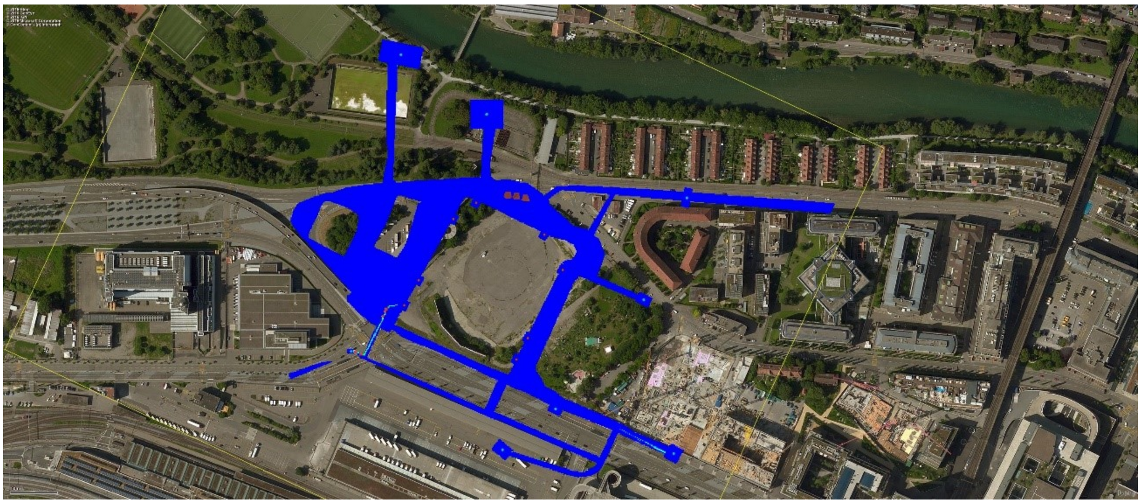


Figure 22 Interval time 3400-3600seconds

The purpose of all the interval figures is that we can easily see where pedestrians are heading and the density of the certain area and the level of service. From the figures, we can see that worst level of service in the area is between 1600 – 2200 seconds which approximately 27 minutes – 37 minutes after the game. Notable point is that the level of service does not drop to red area in large areas. Only we can see red in the tight corners. And most other colors are an acceptable level of services and densities. This means that there are no problems and designers do not have to re-figured out the areas. The current and designed width of the area is enough to carry the burden that pedestrians are producing. The road below the stadium might be closed and this means this area could be to use for pedestrians to reach other public transportation stops and parking lots. This is not shown in the network. However, it is clear that if we add more crossing areas it rises the level of service value and multiplies the possible routes. This solution is not mandatory, as it works with the current model.

Also, you can see that most of the pedestrians are departing in interval time set at 10-20 minutes which is 600-1200 seconds after the game. In the network, the worst density effects are at the time of approximately 27 – 37 minutes which are 1600- 2200 seconds. Due to these, we can see that pedestrians move to end of the areas in average time of 16 minutes which is approximately 1000 seconds. This is only in crowded areas where travel time is slower when its compared for example to pedestrians who leave the stadium at the early stage (0-5 minutes).

If public transportation will be available after the game, there is a higher possibility to have bottlenecks. At the network where crowding is visible in orange areas, there is also the possibility that tram will stop there. However, this moment pedestrians who are walking at this certain area will reach their destination and will disappear from the network. If the tram will be available pedestrians will have so-called “waiting area” and “platform edge”. This means that pedestrians will not disappear from the network, instead of that they will keep crowding until the tram is there.

But at this state where pedestrians move it is possible to have good conclusions and predictions from this simulation. We can say that there will not be very high risk for bottlenecks or the area is not safety due to the number of pedestrians. Also, we can say that pedestrians reach their destination inconvenient and realistic amount of time.

7 CONCLUSIONS

Why are pedestrians examined and what is the importance of it. Researching pedestrian behavior and movement especially in crowded places such as shopping malls, music concerts, big stadiums, and airports, will help public transportation planners for example to calibrate time schedules and to get the most out of it. The density of pedestrian and public transportation flows are very high, therefor all the research is mandatory due to the vulnerability because, of errors. Nor to forget areal improvements that can be done in land use and inside of the areas where pedestrians move, this may help pedestrians to reach their destinations as fast and as safely as possible.

Pedestrian walking or movement behavior is depending on the emotional state of mind. For instance, good comparables here are big riots and music festivals. These create different behaviors to different people, therefore, they affect on pedestrian travel time and density. When densities and travel times are affected there is a higher possibility to disarray in these areas.

The main goal of this project was to find possible problems in the network. The model itself was problematic at the begin of the project due to tight corners. However, this problem was fixed rather easily and it was possible to have a good, realistic simulation. We can say that pedestrians mostly want to find the shortest route or the route they think is the shortest, with this means pedestrians are more likely to walk near walls or the end of the areas instead of the middle. Also, when pedestrians are in a walkable area and want to walk to another walkable area they cut the lines more straight instead of a linear shape to reduce their traveling time in the model. This is also comparable to real situations in some cases where people want to reach point A from point B, they will walk faster and will constantly try to find the fastest routes, for example at train stations or with connection flights at airports.

In the network, we could see that most of the pedestrians are departing from the area within the simulation time of 10 - 20min, but they are more visible within the time of 27 – 37 min in the area. We could see that the level of service value was descending in certain areas in 1600 – 2200 seconds which equals 27-37 minutes. Figures 13 and 14 which are from 700-1300 seconds the network is not yet on its highest stress point, but most of the spectators begin to depart at this time which is 40% of the total amount. This means that we can see in Figures 16-17 there is a lot of movement in the area and a small amount of crowding. This way, it is possible to calculate the that the 40% of the spectators causes that crowding in the area and we can have an estimated travel time from exit points to destinations.

It was also found out in this project that pedestrians who are leaving, earlier than the majority of the pedestrians will have faster travel times to reach their destinations. This phenomenon exists because there are no other pedestrians affecting the lambda value and to the parameters which affect the most to the pedestrian velocity and routes in crowded areas there is a high density of pedestrians. We can also say that these areas were rather large in this case, and distances are long which expanded the time of travel.

The importance of areas where there are mass events should not be underestimated in land usage. The width of walkable areas has a significant effect on the pedestrian that pedestrians do not create bottlenecks. With the correct width and design, pedestrians can import themselves easier and safer to their destinations. For example, these major effects could include building a bridge or a tunnel for crossing a road. The downside of these is the expenses, a bridge or a tunnel would have high costs to build. However, again the main question is how much we want to see the safety of people in the area. In this case, people could leave safely from the stadium, there would be no large issues in the area that could affect them negatively. Travel times can be considered to be quite long, but the space of the pedestrians can be considered a good and hence is the level of service is positive at a good level. To have better densities of pedestrians there could be more crossing points designed in the area, also the author would consider that the bridge could be open for the use of everybody. Zebra crossings would make pedestrian routes more versatile. Therefore there is a good possibility to create better service levels to the area. If the bridge were not open for everybody it would work as a contrary solution compared to the zebra crossings. It is also important to mention that the bridge has only approximately 900 users out of thousands, which make the bridge as much not worth as it should be valued. The capacity of the bridge time in one hour is clearly higher than 900 users.

This results of the project were good and the author was able to reach a good conclusion of the areal influence. The effects and the flow of the pedestrians were relatively realistic in this case. In this thesis, the main starting point was to answer the research question without manipulating or distorting the network results. In this thesis, the author created possible ways to improve the area by analyzing the results of the network.

The research topic of pedestrian behavioral movement is still open and could be examined. Further or advanced research could focus on the pedestrians and public transportation and their efficacy and safety. What affects internationally the safety in crowded events as well, and how we could improve and design crowded areas and large areas for accessibility and to enable people with disabilities to move or walk there normally.

The author came to the conclusion that it is very important to have proper and correct guidance into the stadium and out of the stadium to the nearby tram stops and other public transportation stops. We should always think that pedestrian behavior might be different in unknown places, therefore, it is important to have visible guidance labels. If the area is lacking guidance labels pedestrians do not have a comfortable feeling of where exactly to go, since with mass events where we always need to avoid all sorts of disarray situations. As a conclusion, it is important to control the pedestrians to move away from the stadium as planned.

This thesis was very interesting process of relatively still small science research. The process was long and included traveling to the foreign country, the project was also difficult due to lack of source materials which didn't exist or was not free of charge. However, the author was still able to have decent conclusion of the area.

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