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A Hitchhikers Guide to the ETH

Project thesis

by

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Abstract

This paper is based on a traffic and pedestrian simulation study for the GESS subject at the Swiss Federal Institution of Technology Zurich. Everyday, thousands of students travel from and to thee said institution and therefore heavily strain the public transport system. This paper analyses the movements and the decision making of the students and simulates them with an agent-based, time-based model. While mostly homogenous agents are the regarded, one must also take into account special persons such as handicapped ones.

SHORT RESULT ABSTRACT

Contents

1. Introduction

1.1.

Nowadays, our everyday life becomes faster and faster, especially in big cities. We have to change locations quickly and therefore, an effective and reliable public transporation system is crucial.
In urban clusters, they are several places which particularly attract crowds. To come up to the transportation demand, there are often multiple routes which lead from a certain place to a specific other one. However, the paths might differ from each other in regard to the travel time, thus, one path will be favorized over another if the aim is to travel as fast as possible from A to B. Yet, a single path can have a limited capacity of how many individuals it can carry; e.g. a bus can transport 60 people from A to B every 10 minutes. If the number of individuals aiming to get to the same place exceeds the capacity of the shortest path, individuals will be forced to take the second fastest and therefore less favorable path and so on.
There is only one path that has a nearly unlimited or rather rarely reached capacity: Walking, which was long neglected in urban-mobility research[1], can always be used as the last resort when all other means of transportation are overloaded or not available. Of course, there are situations where walking is the fastest way of locomotion. Nevertheless, in this study, we only consider situations when walking is the least desired option in terms of travel time.

Pedestrians are a well-documented and researched topic. However, most of the work groups concentrated on the actual trail formation of the pedestrians[2] or on their dynamics as a group[3]. However, those studies do not compare walking with other means of transportations such as public transport.

This work is about the scenario, in which ETH students aim to get from the "Central" station to the ETH main building as fast as possible . We offer our agents three paths, which all lead to the desired destination but differ in both travel time and means of transportation.

The aims of this thesis are:

- Simulating an abstracted version of the current situation in Zurich both quantitatively and visually.
- Developing a dynamic modell of the situation that shows how homogenous agents will disperse over paths with different characteristics.
- Study how improving capacity of the favorized paths influence the situation of the evasion path.
- Analysing how handicapped students that are limited to a single path change the dynamics of the entire system.

2. Materials and Methods

2.1. The three paths

We abstracted the situation and chose three entirely different means of transport to get from the Central station to the ETH main building.
The first path regarded is an agent taking the Polybahn. Corresponding strongly to reality, the time the Polybahn needs to get to the ETH was decided to be 2 minutes, while the interval between two consecutive polybahn has been set to 2 minutes. There is space for approximatelly 40 persons in one cab, and maximally another 80 persons waiting in front the station.
The second possibility is to take the tram from Central over Haldenegg to the ETH/Universitätsspital stop. For this distance, the tram needs 5 minutes. It was assumed that each tram has the capacity of taking 50 additional students; even though there are a total of 238 places in a typical "Cobra" tram, only a small amount is still unoccupied when arriving at the Central stop. The time between two consecutive trams has been set to 6 minutes, whereby two different tram lines were simplified to a single one.
The third and longest option is to walk from the Central to ETH main building. With a lenght of 8 minutes, this is the longest path. As the path is wide enough, no passage limitation can be observed in reality. Therefore, the capacity is unlimited and the waiting time for walking is obviously not existing. The detailed trail can be see on the map in figure 2.1.

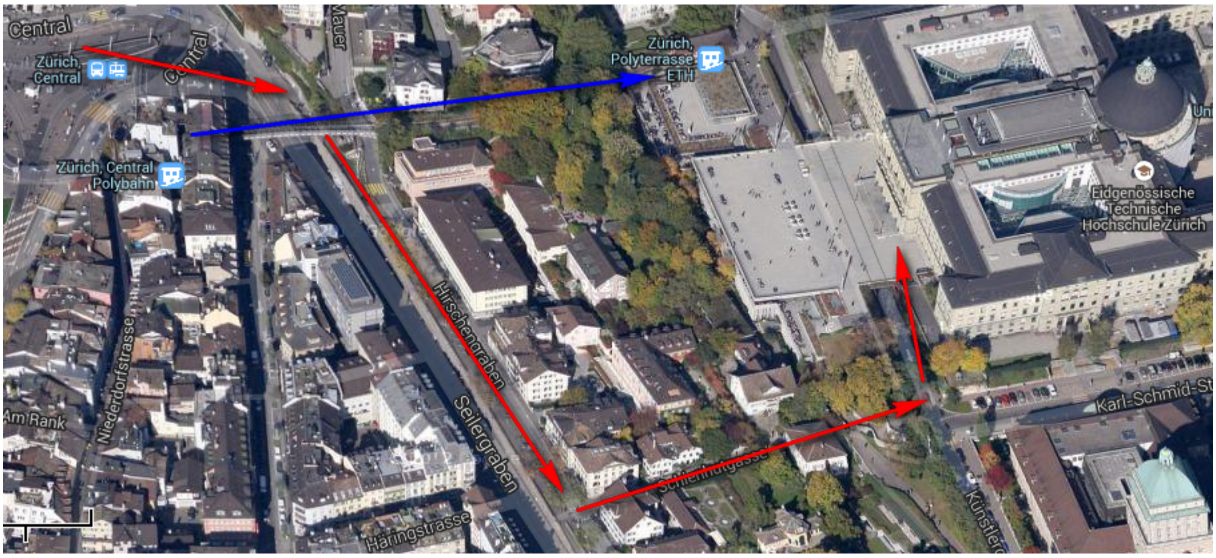

Figure 2.1.: Walking path in red, compared to the Polybahn in blue

2.2. Agents modelling

2.2.1. Homogeneous agents

The homogeneous agents all represent students which are going to the ETH, whereby each agent has the exact same starting conditions. Each agent was programmed with three attributes. For reasons of efficiency, we chose to save the agents in a matrix, as object orientation is not implemented in an arithmetically preferable way in MATLAB. For this, we defined a function that creates a M x 3 matrix, with M being the number of agents and 3 the number of attributes.

Attribute 1 is an integer number storing the path chosen by the agent and can be -1, 1, 2, 3, 4 and 5. The numbers 1 to 3 stand for the three different paths an agent can chose from, i.e. taking the polybahn, the tram or walking . The numbers 4 and 5 represent the actions of waiting for the polybahn and waiting for the tram respectively. Once a homogeneous agent reaches the ETH, his first attribute becomes -1, indicating that he has finished his voyage and is no longer part of the active simulation. Latter is important, on one hand since we wanted to quantify the operating grade of each path over time and also since this allowes us to exclude all finished agents from the further computation in the next time step.

Attributes 2 and 3 are double numbers representing time values. The first one indicates the time an agent has been on a certain path, while the latter saves the amount of time waited in a queue. This allows for statistical evaluation of the different paths and comparing time consumption of different paths.

2.2.2. Heterogeneous agents

While homogenous agents all evaluate the system and act correspondingly, there may be certain percents that are unavailable of walking. Sports accidents, serious illnesses, the increasing obesity and a general ageing of the population create a strain on public transport and increase transportation problems. As they are handicapped, those agents are not able to choose from all paths available and are required to use certain routes that are perhaps less favourable.
In our simulation, the heterogenous agents try to simulate these circumstances. Even before the actual simulation starts, a fixed percentage of agents is being bound to use the Polybahn, as walking is no option and the trams are much less favourable in terms of sitting opportunities and entrance possibilities when it is crowded. As those agents do not respect the waiting capacity of the specific transportation medium (as they have no other option and cannot cancel their voyage), waiting times can reach a certain threshold, after which the waiting time constantly increases. This threshold can be located at the point, at which on average more handicapped agents arrive at the station per interval than the medium can carry in the same time slit. Therefore, this path is rendered useless and no more option for (general) public transport.

2.3. Simulation

The Simulation part of the modell is stuctured into three different subsections.

In the initialization, the agents are created by an extern function specified previously and the global variables are specified. While crucial data, such as the number of agents per time interval (APTI) and the time step dT, are stored in a separate "data" file and are accessible for all files, simulation specific files such as the waiting time, capacities as well as frequencies are defined and initialized here.

The main part of the program is the simulation loop. As this moddel bases on an agent-based, time-depending structure, the most outer loop implements time and increases once every iteration by a previously defined time step dT.
The inner loop iterates through all the agents that are currently in the system. To prevent redundant calculations of agents that already left the system, those agents are automatically excluded and the beginning and the ending of the loop are adjusted accordingly. The old agents that were already treated are checked again to see whether any change has occured; this is either because they arrived at the destination, or if a tram or Polybahn is departing and they can change from the queue to the actual moving vehicle. New agents are put into one of five categories: they can either catch a departing tram or Polybahn (if those are not full yet), start waiting for the next one or directly walk.
With an average of 200 agents in the system, the inner loop iterates the same amount per time interval. With a default of $6 * 60 * 4 = 1440$ time steps, there are $1440 * 200 = 288'000$ iterations through this inner decision loop. Whenever one time step has been entirely calculated, the "Visualisation" function draws the current situation into a figure and saves the image for further use in a video.

If the calculations are finished, the last phase of the simulation is initiated. Here, statistical data is calculated and data sets are getting prepared for saving. At the very end, a figure displaying the graphs of usage of the different paths and their waiting time is displayed and saved for further processing.

2.4. Visualisation

This function is used to display the calculated results visually on a map. This map shows the real paths from the "Central" station to the ETH as well as the buildings surrounding it. Each agent receives an x- and y-Coordinate according to the time it has already spent traveling. The entire matrix is then displayed as a scatter plot and plotted over the background image.
In order to reduce the computing time, the paths are calculated in the first call of the function and afterwards stored for the next 1439 ones. A loop then reads each agent and gives it its coordinates corresponding to the way taken.

3. Results and Discussion

3.1. Modelling of the Current Situation

The model the curren situation the model has been runned with only homogen agent in the system. The Matlab model ouputed Figure 3.1 representing graphically the amount of agents at each time step on the different paths as well as in the dfferent waiting queues. Note that each time step equals 10 seconds, which means that the plots are representing the situation for 4 hours.

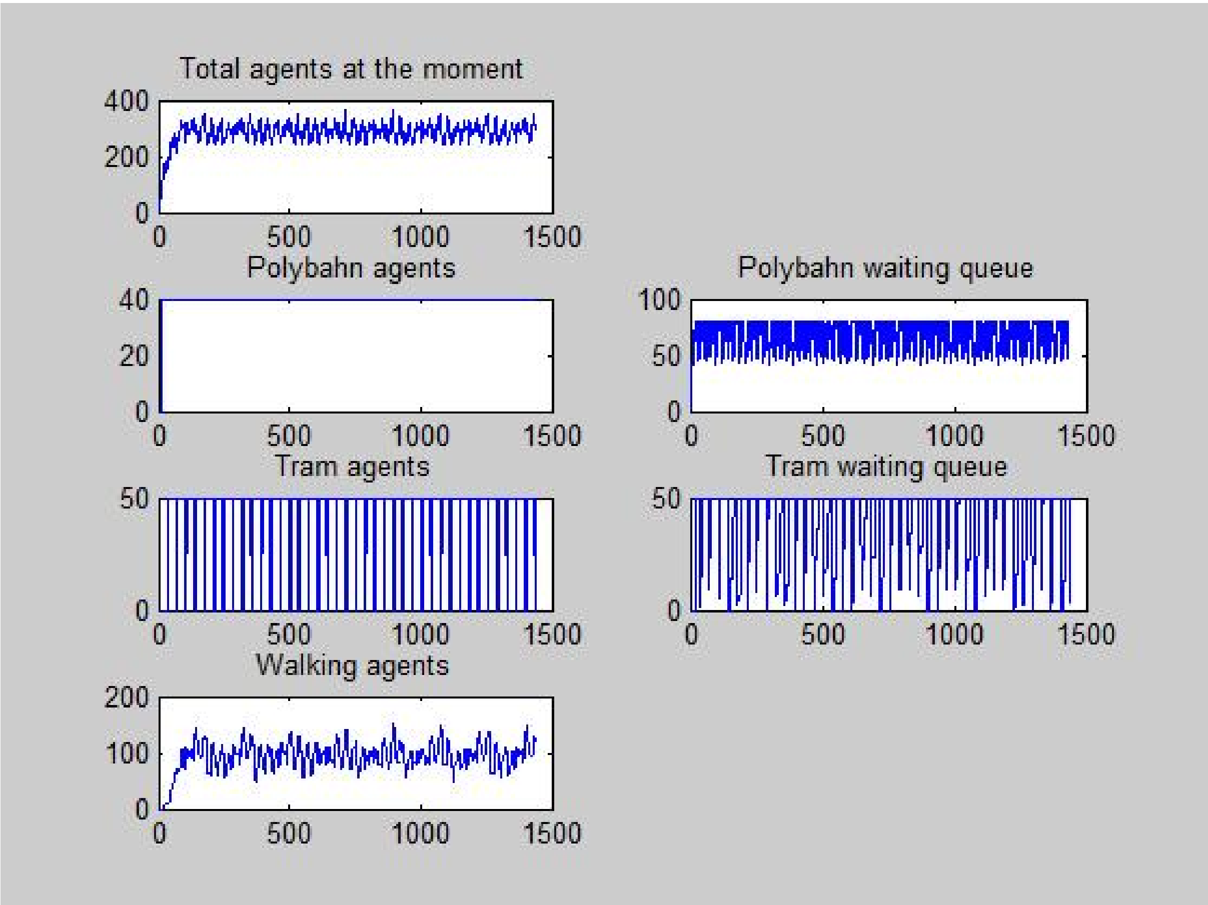

Figure 3.1.: Number of agents over time

Although the plots are hard to read, some important aspects can be derived. Approximatevely atarting at time step 50, all curves, except the one representing the number of angents in the polybahn, seem to exhibit a certain periodicity. Also by looking at the plot on the left top corner of Figure 3.1, one can see that the average number of agents who are simultanuously in the system is about 300. The figure also shows that the Polybahn is always used to capacity under the conditions of the current situation.

The Matlab command window showed following results:

Average agents in Polybahn: 39.666667
Average waiting time at Polybahn: 3.795183
Average agents in Tram: 42.013889
Average waiting time at tram: 4.647436
Average agents walking: 92.734028

As one can see, the calculated 93 average agents walking correlate well with the "walking agents" subplot. On the other hand the 42 average agents on the tram path can not intuitively be deduced from the "tram agent" subplot. This is due to the fact that while the average is the mean of the temporary numbers and therefore interpolates times with no agents on the path, the plot displayes the current data. Therefore, if no tram is in the system at the time, no agents are on the corresponding path and therefore the temporary number is equals to zero. This is temporary the case for one minute, as the time between departures is 6 mins, but the tram only needs 5 mins to reach the ETH station. In this minute, no agents are on the path; this minute is nevertheless considered in the calculation of the mean.
This fact can clearly be seen when analyzing the simulated data: If the tram is always full, it will be full in 5 out of every 6 minutes, which would correspond to the ratio of the average usage compared to the capacity of 84% (5/6 * 100%), which is exactly what can be observed in most of the simulations. As the tram departes every 2 minutes, and it reaches its end in just the same time, the capacity usage of the Polybahn is near 99%.

Another interesting observation is that the average waiting time at the Polybahn (3.8 minutes) is almost twice as long as the travel time with the Polybahn (2 minutes). If considering the average tram waiting time though (4.6 minutes), one can see that latter is inferior to the travel time with the tram (5 minutes).
The reason behind this fact can be found in the corresponding capacities and frequencies: While someone waiting for the Polybahn waits up to two departures until he himself can use it, a tram user only waits for the next tram. Therefore, the maximal waiting time of a tram agent is equals the time interval between two departures (6 min), whereas a Polybahn agent waits up to 4 min (2 * 2min) for his turn.

3.2. Handicapped Agents

By running the model several times with different percentages of handicapped agents, we tried to simulate how an increasing ”walk disability” may impact the waiting time at the polybahn as well as the loading of the walking path. As already precised in the method, the handicapped agents rely only on the polybahn and therefore also do not consider taking the tram.
According to those assumptions, Figure 3.4 shows the variations of the number of agents walking and the waiting time at the Polybahn as a function of the percentage of handicapped agents.

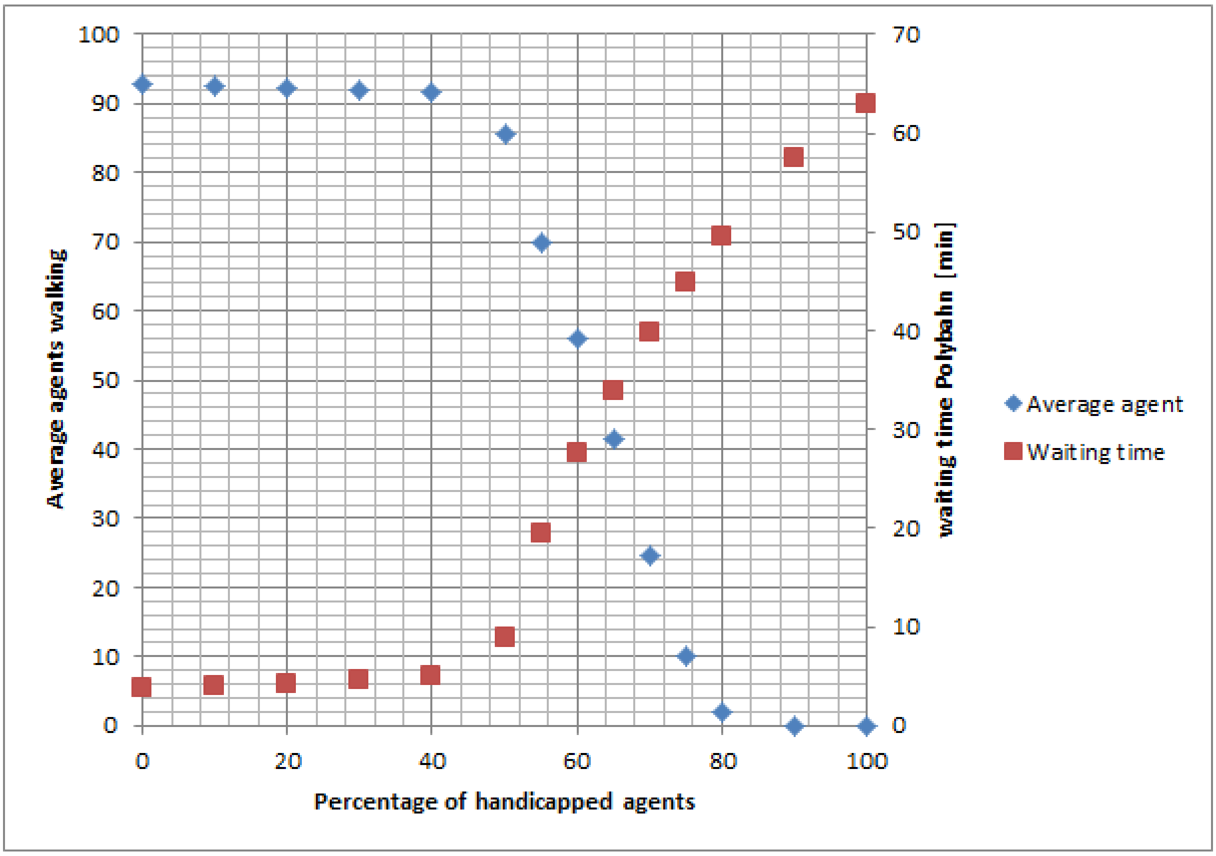

Figure 3.2.: Influence of handicapped agents polybahn waiting time and number of walking agents

As can be seen, an handicapped agent fraction up to 40 % has almost no effect on the polybahn waiting time neither on the average number of agents walking. However, this changes when the percentage of the agents which imperatively take the polybahn exceeds 40%. Between 40% and 80% the average number of agents walking drops from 82 to 2. Similarily, the waiting time at the polybahn increases from 5 minutes to 50 minutes. Thus we can say, that the critical percentage of handicapped agents that the transportation system can afford lies between 40% and 45%, since the waiting time at the Polybahn shoudnt exceed the travel time on the walking path.

3.3. Frequency and Capacity Changes

The other main goal this project has been targeted was to determine whether the current conditions can be improved by increasing the departure frequencies of the public transport and by increasing its transport capacity.
As the Polybahn is a fixed installation and its cabins cannot be replaced by larger cabins due to the space available in the depots and the width of the path, the Polybahn capacity has been considered unchanged. The same counts for its frequency: As there can be maximally two cable cars on the tracks at the same time due to its technology, more vehicles are not a possible option. Furthermore, faster travel speed is hardly possible due to the steep terrain.
Therefore, only the tram parameters were considered when evaluationg possible improvements.

3.3.1. Improving the tram capacity

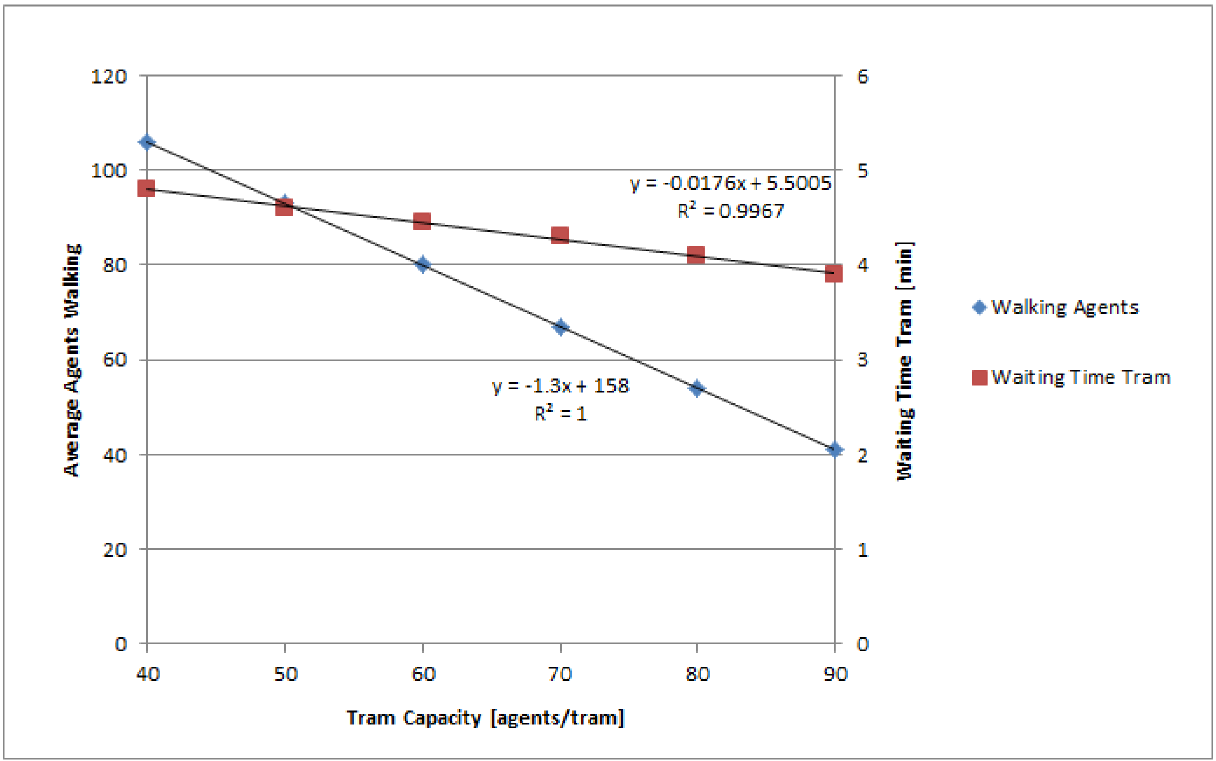

Figure 3.3.: Influence of enlared capacity on the waiting time and number of walking agents

3.3.2. Improving the tram frequency

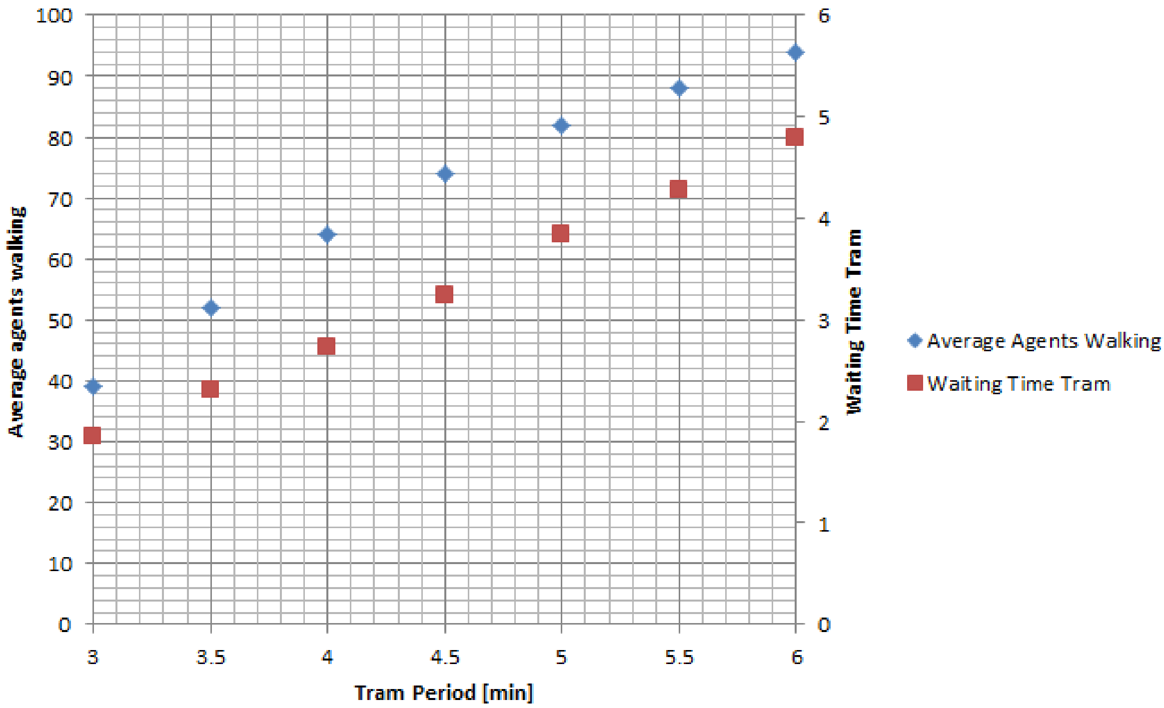

Figure 3.4.: Influence of increased frequency on the waiting time and number of walking agents

3.4. Visualisation of the Model

The Visualisation aspect of the simulation was mainly important for debugging and enable the user to interpret the data in an easier way.

The full video can be found in the GitHub folder.

4. Conclusion and Perspective

We used a multi-agent approach with predetermined paths that are not altered by external factors during the simulation. In contrast to other proposed methods such as 'deviation analysis'[1], the agents stay on their path once they decided and will continue until they reached their target. With the simulation, we developed a tool that enables us to better understand how the system reacts to changes in the parameters. While other groups used cellular automata to achieve this[4], we chose a time-descrete, but spacial unlimited modell which enables detailed time measurement.

A. Code Appendix

A.1. Simulation

A.2. Visualisation

A.3. Heterogenous agents

The homogenous agents can be calculated by setting the handicapped percentage to zero.

Bibliography

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