Modelling pedestrians in transfer stations

Abstract
Holland Railconsult, in association with Delft University of Technology, has developed a simulation model for pedestrians, especially in transfer stations. The model is not only used to evaluate pedestrian areas (either existing, under development or new to build), but also consequences of changes in (dynamic) platform allocation and timetables can be investigated.

The model can be used for the analysis of pedestrian environments and is especially designed for transfer stations. The application of the model in pedestrian areas is not taken into consideration in this paper, but the model forms a welcome addition to the existing set of tools. The following types of applications are distinguished:

1. Early planning phase
2. Detailed design
3. Analysis of processes

In this article, each of these types of applications is illustrated by a case study. In the early planning phase, a study is described to the pedestrian flows on the forecourt of Rotterdam Central Station. The flows between four modes of public transport (train, metro, tram and bus) are modeled. As an example of detailed design, a study for the so-called base station of Rotterdam Central Station is presented, in which the width of the tunnel and the number and location of the stairs is evaluated. Finally, a study is described to the process of getting on and off the train, looking for a relation between the number of exit point on the platform and the time needed to empty the platform. This serves as an example for the analysis of processes.

1. Introduction
Holland Railconsult, in association with Delft University of Technology, has developed a simulation model for pedestrians, especially in transfer stations. Several reasons underlie this development. First, a simulation model shows pedestrian flows in a transfer station or other pedestrian environments, such as stadiums, shopping centres, large buildings or even great events (World Cup Football, …). This way, future circumstances (larger flows) can be predicted, thus showing the usefulness of the investigated area. Also, consequences of different solutions for current problems can be visualised. Second, a simulation model can supply quantitative value judgements for different designs. This helps to evaluate designs and makes it possible to compare them. Finally, while developing such a model, insight is needed in pedestrian behaviour, especially in transfer or station environments. Until recently, not so much of this knowledge was available.

The model is not only used to evaluate pedestrian areas (either existing, under development or new to build), but also consequences of changes in (dynamic) platform allocation and timetables can be investigated. To evaluate a pedestrian area, its geometric characteristics serve as input. Also, a matrix with origins and destinations of pedestrians must be known. Then, pedestrian flows are calculated, pedestrians are generated and move through the infrastructure network, performing activities (such as buying a ticket or a sandwich) and getting on and off trains or other forms of public transport. Finally, analyses can be performed on the results in order to make an overview of routes through stations, congested areas, walking and transfer times, etc. After performing this first study, parameters can be changed, geometric characteristics of the infrastructure can be adapted and origin – destination matrices can be changed to meet different platform allocations and timetables. By comparing all alternatives, the best combination of infrastructure lay out, platform allocation and timetable can be chosen.

This paper focuses on the use of the model for different types of questions and problems. However, before doing so, the developed simulation environment will be discussed in more detail. Then, in section 3 different application areas of the model are distinguished. In the following sections examples are given of some of these areas. Section 4 shows an application in the early planning phase, when not many details are known. Section 5 presents a more detailed study and section 6 discusses one of the specific processes in a railway station: getting on and off a train and the emptying of the platform afterwards. The last section contains some of the future ambitions of the simulation model.
2. The simulation environment

The simulation model describes both the behaviour of passengers and different (public) transport modes and the interaction between them. It consists of several modules to provide enough calculation power to model 100,000 pedestrians. A software architecture has been designed to combine the different modules of the model. An overview of this simulation environment is given in Figure 1.

![Diagram of the simulation environment](image)

**Figure 1: Overview of the simulation environment**

The simulation process can be divided in 3 phases:
- **Initialising**: all input data is entered.
- **Simulating**: execution of the actual simulation.
- **Analysing**: analysis of the results.

2.1. Initialising

In this phase, the model is drawn in SimInput. This model consists of the characteristics of the infrastructure (such as length, width and spatial form), the characteristics of the pedestrian types (such as free speed and familiarity with the environment), characteristics of the public transport vehicles (such as length, number and width of doors) and origins and destinations of both pedestrians and public transport vehicles in pedestrian generators and timetables. The application SimInput converts the drawn data to a database, which is used by other applications. Then, information on the simulation to be executed is entered in SimControl. This data is also saved in a database and consists of, among other things, the models to be simulated, the applications with which the simulation is executed and the length of the simulation.

2.2. Simulating

The simulation is started with the application SimControl. Then, SimPedestrian is initialised. The architecture is so general that also other simulation tools can be integrated, like the SimRail, a simulation tool for the train service, also developed by Holland Railconsult. A ‘ready-to-go’ message is then sent back to SimControl. SimControl then starts SimAnimation (if required) and SimArchive. Both applications initialise and return a ‘ready-to-go’ message. SimControl gives a ‘Start’ signal to SimPedestrian, which starts generating pedestrians. Produced data is sent by SimPedestrian to SimAnimation and SimArchive. SimAnimation visualises its messages, so the user can view the process. SimArchive registers the data in the messages into a database, which is called Result Data.
2.3. Analysing

The data produced by the simulation is stored in the results database. These data are analysed via the application SimAnalysis. This application consists of some forms in MS Access, which calculate for example mean walking times and routes of pedestrians. Also, SimAnalysis produces diagrams and overviews in Excel of for example the progress of the number of pedestrians in some part of the infrastructure over time, thus indicating the walking comfort for a pedestrian over time in this part of the infrastructure.

3. Applications of the model

Now the applications in which the model can be used are discussed in more detail. The model can be used for the analysis of pedestrian environments and is especially designed for transfer stations. The application of the model in pedestrian areas is not taken into consideration in this paper, but the model forms a welcome addition to the existing set of tools. The following types of applications are distinguished:

4. Early planning phase
5. Detailed design
6. Analysis of processes

In the early planning phase not much information is available. Indications are known of the sizes of the flows between the modalities, for example the number of passengers transferring between tram and train. The major question is: how large is the area needed for pedestrians to move through the station and where to locate the different functions? This question is then split up into questions concerning parts of the infrastructure: is a passage needed and what width does it need, is a hall necessary and what functions will it contain (such as the number of ticket machines, waiting area and baggage lockers), how many stairs and escalators are needed to go to the platform? Section 4 describes the study to the pedestrian flows on the forecourt of Rotterdam Central Station between four modes of public transport: train, metro, tram and bus.

When all functions are located, a detailed design can be made. The major question now becomes: is the comfort for pedestrians enough, under different conditions. This question can be split into more detailed questions concerning the required surfaces: what is the necessary width of these stairs, is the number of stairs and escalators sufficient and are the locations well chosen, how long will it take until a full train is emptied and all passengers have disappeared from the platform? After possible shortcomings have been identified, the design can be adapted and again ‘controlled’ on the comfort for the pedestrian. Also, different designs can be compared to choose the best one. Section 5 describes a study for the so-called base station of Rotterdam Central Station.

The last application on the list is the analysis of processes. Examples of these processes on a railway station are getting on and off the train, formation of queues of passengers buying tickets at ticket machines and the formation of queues when tourniquets are placed for ticket control. These processes will be changed to be prepared for the future. Two contradictory tendencies can be observed: on the one hand the increase of the number of passengers and on the other hand the lack of sufficient space, especially in inner cities. Therefore, all processes have to become more and more efficient, maintaining the prescribed comfort for pedestrians. A simulation model helps to reveal the consequences of changes in the process, not only for the process itself, but also for the pedestrian flows in a railway station. Section 6 describes a study to the process of getting on and off the train, looking for a relation between the number of exit point on the platform and the time needed to empty the platform.

4. Early planning phase: Rotterdam Central Station

The city of Rotterdam has plans for a new inner city. The American bureau of architects Alsop & Störmer has developed a master plan, in which the station area is involved. The architects have drawn a large concourse, continued from the tunnel under the train tracks, in the direction of the city. All pedestrians, including the transferring passengers to the metro, the tram and the bus, use this concourse. The public transport companies now wonder whether the level of comfort for the passengers is still acceptable. Therefore, Holland Railconsult performed a study consisting of three parts: an overview of pedestrian flows, calculation of walking distances and a determination of the levels of comfort for the passengers. In this study, the master plan (with the tram at the same level as the concourse) was compared with four variants in which the bus and the tram had other locations. The resulting variants can be described as follows:

1. Referential design of Alsop & Störmer.
2A. Design with the tram at the eastern side at ground level and the bus along the Weena in the south (as in master plan).

2B. Design with the tram at the eastern side at ground level and the bus for passengers getting off along the Weena in the south and for passengers getting on to the Conradplein in the north.

3A. Design with the tram at the western side at ground level and the bus along the Weena in the south (as in master plan).

3B. Design with the tram at the western side at ground level and the bus for passengers getting off along the Weena in the south and for passengers getting on to the Conradplein in the north.

4.1. Overview of pedestrian flows

An overview of pedestrian flows is given by drawing arrows between the four modalities. Each modality is represented by a node on the center of its location. The width of the arrows indicates the number of passengers transferring between these modalities. From these simple drawings, the number of crossing flows can be counted. Taking into account the width of the crossing arrows, points where problems may occur can be predicted. Finally the number of differences in height has been counted. The pedestrian flows of the referential variant are indicated in the following figure.
### 4.2. Calculating walking distances

Before a design was made, a plan of starting points has been formulated. In this plan norms were stated for the maximum distances transferring passengers have to walk, expressed like “at least 50% of the passengers has less than 100 m to walk”. These norms are presented in Table 1.

<table>
<thead>
<tr>
<th>Distance</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 100 m</td>
<td>50</td>
</tr>
<tr>
<td>≤ 150 m</td>
<td>60</td>
</tr>
<tr>
<td>≤ 200 m</td>
<td>70</td>
</tr>
<tr>
<td>≤ 250 m</td>
<td>80</td>
</tr>
<tr>
<td>≥ 300 m</td>
<td>100</td>
</tr>
</tbody>
</table>

For each of the five alternatives the mean distances between the different modes of transport were calculated and multiplied with the number of passengers transferring between them. This leads to weighted averages, presented in the following figure.

The figure shows that only variant 3B satisfies the norms. All other variants, the master plan included, do not meet the requirements, especially not for the shorter walking distances.

### 4.3. Determining levels of comfort

Until now, only static calculations have been executed and the comfort of the pedestrian has not been addressed. In international literature, the level of comfort is measured in the number of square meters available for each pedestrian. This performance indicator is compared to an international set of requirements, shown in the following table.

<table>
<thead>
<tr>
<th>Level of comfort</th>
<th>Density (m²/ped)</th>
<th>Speed (m/s)</th>
<th>Intensity (ped/min/m)</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&gt; 3.2</td>
<td>1.30</td>
<td>&lt; 23</td>
<td>Dark green</td>
</tr>
<tr>
<td>B</td>
<td>2.3 – 3.2</td>
<td>1.25</td>
<td>23 – 33</td>
<td>Green</td>
</tr>
<tr>
<td>C</td>
<td>1.4 – 2.3</td>
<td>1.15</td>
<td>33 – 49</td>
<td>Bright green</td>
</tr>
<tr>
<td>D</td>
<td>0.9 – 1.4</td>
<td>1.00</td>
<td>49 – 66</td>
<td>Yellow</td>
</tr>
<tr>
<td>E</td>
<td>0.5 – 0.9</td>
<td>0.70</td>
<td>66 – 82</td>
<td>Orange</td>
</tr>
</tbody>
</table>
To determine the level of comfort of the infrastructure the simulation model is used. Each of the four modalities is represented by a point, where pedestrians enter and leave the model. High frequencies are assumed for all modes of transport, so pedestrians are generated uniformly within an hour, thus introducing some kind of stochastic. The concourse is a large pedestrian area, in which only the entrances of company buildings form obstacles. When stairs or escalators are needed, they are taken into account and the model ends right after these rise points.

From the results of the simulation those parts of the infrastructure not having level of comfort A during the total simulation are looked at more closely. These results are presented in the following figure. The horizontal axis contains the parts of the infrastructure (e.g. stairs 1 to the metro platform, escalator 1 to the bus platform); the vertical axis shows the percentage of the total time the indicated level of comfort has occurred. From this figure can be concluded that especially the escalators to the metro platform and the tram platform cause problems.

### Variant 3B: Levels of comfort of congested infrastruct

In the next phase of the design process for Rotterdam Central Station, a more detailed design is made for the train station. A simulation study has been performed to see whether the pedestrian flows are permissible. Rotterdam Central Station consists of 14 tracks and 7 platforms. The entrance to these tracks is a tunnel, situated in the middle of the tracks. This tunnel has exits at both the northern side, in the direction of the Blijdorp Zoo, and in the southern side to a hall and further leading to the concourse in the direction of the inner city of Rotterdam. Figure 2 shows the infrastructure of the tracks, while Figure 3 shows the infrastructure of the tunnel and the hallway at the southern side. Table 2 contains the corresponding legend.
In this study a worst case scenario is simulated, in which six trains arrive at the same time. Each train consists of double-decked rolling stock with a length of 325 meters. From each train 1200 passengers get out and leave the station through the northern (30%) and the southern (70%) exit. As can be expected, large queues build up before the stairs and the escalators and it takes about 16.5 minutes until all passengers have left the model. For the stairs and escalators the number of pedestrians present over time is recorded and set out in a graph (see next figure).
This figure shows that the escalator has all the time level of service F, which is unacceptable. After the escalator is “full”, pedestrians start to use the stairs, on which level of service E occurs. When the first flow of pedestrians is over, the level of service on the stairs increases. At that moment, pedestrians walk from the other side of the platform to this stairs, thus initiating a second pedestrian flow, which lasts shorter. After somewhat more than twelve minutes, all pedestrians have left platform 5.

This study has proven part of the potentials of the model. It is possible to draw more conclusions of the simulation model, but the visualisation of the pedestrian process already helps to locate different functions (such as ticket machines, escalators and stairs) and, for example, gives an impression whether the number of rise points suffices.

6. Analysis of processes: getting on and off the train

In this study the time is calculated needed to empty the platform after passengers got off and on the train, depending on the number of rise points per 100 m of platform. The result of the research is a graph, in which the time to empty the platform is set against the number of rise points present.

The following assumptions are made:
- The demand of pedestrians (getting on and getting off) is considered uniform over time. Moreover, the number of pedestrians is considered constant.
- Each rise point is used by the same amount of pedestrians. This is caused by an optimal distribution of the rise points over the platform.
- Each rise point leads to the same origin or destination. If this is not the case, pedestrians will choose their most favourable rise point, leading to a disproportional distribution of pedestrians over the platforms and not meeting the predicted time to empty the platform.

The simulated platform has a length of 300 meters. Alongside this platform a train stops with a length of 300 meters, consisting of twelve passenger coaches with two doors for each coach. The width of the doors is 1.42 meter and it takes each pedestrian one second to get on or of the rail vehicle. This train appears ten minutes after the start of the simulation. Three scenarios have been simulated. In the first scenario there only were 1000 pedestrians getting of the train; in the second scenario 500 pedestrians get off and 500 pedestrians get in the train and in the third scenario 1000 pedestrians get off and 100 pedestrians get in the train. The rise points form the frontiers of the model. Figure 1 shows a platform with 4 entrance and exit points.
Figure 1: Lay out of a platform with four entrance and exit points

The results of the simulations are shown in the next figure. Each line shows a scenario and the indicated points are the simulated situations.

Also, an overview is made of the number of pedestrian on the part of the platform near an entrance / exit point. In the next figure, this number is depicted against time. Each scenario has its own line and the horizontal lines are the levels of comfort for the pedestrian. As could be expected, the number of passengers increases when people getting in the train arrive and wait for the train. Then, the train arrives and people get off the train, thus increasing the number of pedestrians on the platform. Pedestrians getting off the train then walk to the exit and pedestrians getting on the train also leave the platform, thus decreasing the number of pedestrians on the platform.
The conclusions of the study consist of some short comments:
- The calculated relationship is only valid for trains (with the location of doors as indicated) stopping alongside the total platform. In the Netherlands, trains of different rolling stock stop alongside the same platform so the location of the rise points is not ideal for all lengths and types of trains and the calculated relation is not valid. The model can of course be used to simulate these other situations.
- The hall, in which all rise points end, is by the location of these rise points larger than existing halls. This aspect needs to be considered at the integration of the station in the environment.

7. Conclusions
Holland Railconsult, in association with Delft University of Technology, has developed the simulation model SimPed for pedestrians.

The model can be used for the analysis of pedestrian environments and is especially designed for transfer stations. The model is not only used to evaluate pedestrian areas (either existing, under development or new to build), but also consequences of changes in (dynamic) platform allocation and timetables can be investigated. The application of the model in pedestrian areas is not taken into consideration in this paper, but the model forms a welcome addition to the existing set of tools. The following types of applications are distinguished:

1. Early planning phase
2. Detailed design
3. Analysis of processes

These types of applications cover all phases in the design process. Simulation studies have been carried out for all of the applications, as described in the sections before. This indicates that SimPed is useful in the total planning phase. Also in existing situations, SimPed can be used to look for best solutions for current problems.