Pedestrian traffic flow operations on a platform: observations and comparison with simulation tool SimPed

W. Daamen & S. P. Hoogendoorn
Department Transport & Planning, Delft University of Technology, The Netherlands

Abstract

Delft University of Technology, in co-operation with Holland Railconsult, has developed the tool SimPed for simulating pedestrian operations in transfer stations. SimPed models all processes that are related to pedestrians inside a transfer station, such as walking, performing activities and route and activity location choice.

In order to validate pedestrian flow modelling in SimPed and to study pedestrian traffic flow operations on a platform in detail, observations have been collected on a platform of a Dutch railway station. These observations concerned boarding and alighting times, (individual) walking times, and levels-of-service (indicating the number of pedestrians present on a part of the platform over time).

This paper describes this data collection effort and discusses in detail the results of the study, such as numbers of boarding and alighting passengers, individual walking times and densities on the platform. Finally, a comparison is made between the observations and modelling results of SimPed, in order to show the validity of SimPed concerning pedestrian traffic flow operations.
Keywords: pedestrian traffic flow, platform, observations, simulation tool.

1 Introduction

SimPed is a simulation tool designed to model pedestrian flows in transfer stations (Daamen [1]). The aim of the tool is to assess designs of public transport facilities and similar public spaces with intensive pedestrian flows. Figure 1:

Computers in Railways IX, J. Allan, C. A. Brebbia, R. J. Hill, G. Sciutto & S. Sone (Editors)

shows a virtual reality based on SimPed results in order to give an indication of the functioning of a station design to both designer and decision-maker.

Figure 1: Overview of Virtual Reality based on SimPed results.

One of the most important processes is the validation of the simulation tool, which is a check whether the model gives a sufficiently accurate representation of reality (Kleijnen [2]), where sufficiency obviously depends on the intended model application. This contribution describes the validation of SimPed with respect to pedestrian traffic flow operations on a platform by comparing simulation results with observations. For remaining aspects concerning the simulation tool, including verification and validation is referred to (Daamen [3]). The paper starts with an overview of the collected observations in Delft Station, the Netherlands. Then, a short description is given of the model input. Section 4 describes the comparison of walking times, while section 5 covers the comparison with respect to densities over time and space. The paper ends with conclusions and remarks on future research.

2 Collection of observations in Delft Station

As this validation is mainly concerned with pedestrian traffic flow operations on a platform, the main variables to be observed and compared with the model predictions are the following:

- Walking speeds.
  - On the stairs (upward and downward direction).
  - On the platform (alighting and boarding passengers).
- Densities over time and space.

As speeds are hard to observe, walking times are measured from which walking speeds are derived. Besides walking times and densities, other variables need to be observed to complete the input of the simulation model, such as the number of boarding and alighting passengers and the configuration of the infrastructure.

Computers in Railways IX, J. Allan, C. A. Brebbia, R. J. Hill, G. Sciutto & S. Sone (Editors)
© 2004 WIT Press, www.witpress.com, ISBN 1-85312-715-9

2.1 Observation location

We have chosen to perform the observations at Delft Station on platform 2. This platform has only one entrance / exit. This way, traffic flow characteristics are observed, while influences of route choice are omitted. As the entrance / exit is located at the end of the platform (see Figure 2:) mainly one-directional flows occur. All dwelling trains have similar destinations, thus all waiting passengers will board the first arriving train. Finally, the number of passengers is sufficient to observe high densities without having problems for the measurability of the pedestrian flows.

Delft Station is situated alongside the main rail connection between The Hague and Rotterdam and has the function of regional train station, indicating that both local and regional trains stop in Delft Station.

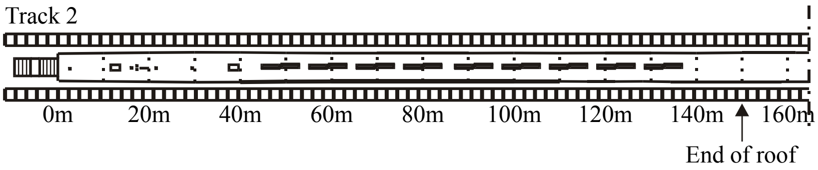

Figure 2: Overview of platform 2 of Delft Station.

2.2 Data collection

Three types of observations are performed: boarding and alighting related observations, walking times and densities.

Observations with respect to the boarding and alighting process concern the number of boarding and alighting passengers per door, per train and individual boarding and alighting times. The distribution of both boarding and alighting passengers over the train may be derived from these data.

The second type of observations concerns individual walking times. To measure walking times, both boarding and alighting passengers are followed ('stalked'). The moment that a passenger is at his origin and the moment that he is at his destination are registered, as well as the moment of passing the top of the stairs in order to distinguish between walking times on the stairs and walking times on the platform. Also, the start and duration of activities, such as buying a ticket or looking at the information panel, are measured. Finally, locations of origin, destination and possible activities of the passenger are registered. To do this, the platform is divided into areas with a length of 10 metres.

To observe the density on part of the platform, the average number of passengers being present during a specific period of time needs to be measured. Visually counting the number of pedestrians at a specific moment may be too involved, especially when a train has arrived and the number of pedestrians changes quickly. Therefore, cumulative flow curves will be constructed, out of which densities will be derived afterwards. For the construction of a cumulative curve the moment a pedestrian passes a cross-section of the platform is recorded, as well as his walking direction. The difference along the y-axis between two

Computers in Railways IX, J. Allan, C. A. Brebbia, R. J. Hill, G. Sciutto & S. Sone (Editors)
© 2004 WIT Press, www.witpress.com, ISBN 1-85312-715-9

cumulative curves indicates the number of pedestrians present on the area between the two cross-sections at a specific moment of time (see Figure 3:).

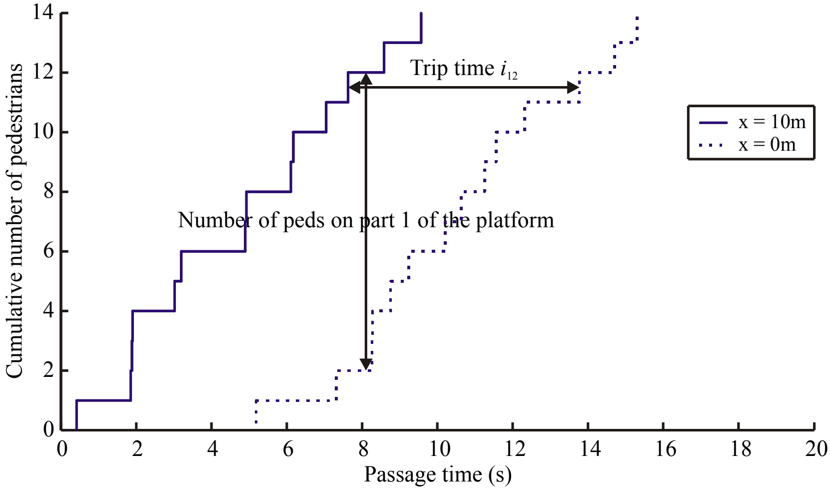

Figure 3: Cumulative flow curves for a part of the platform.

2.3 Observation tool

The observations will be manually using a handheld computer, a so-called palmtop. The interface of this palmtop has been designed dedicated for these observations and is shown in Figure 4:.

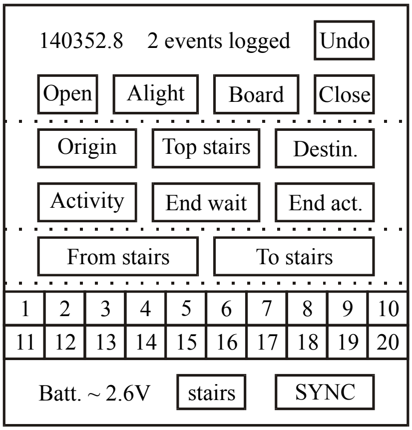

Figure 4: Interface of the palmtop for manual observations.

Computers in Railways IX, J. Allan, C. A. Brebbia, R. J. Hill, G. Sciutto & S. Sone (Editors)
© 2004 WIT Press, www.witpress.com, ISBN 1-85312-715-9

The top part is used to observe the boarding and alighting process by registering the moments of door opening and closing and the moment that a passenger boards or alights.

The middle part is used to observe walking times. The time a pedestrian starts walking from his origin is registered as well as the location of this origin. The bottom part of the interface is used to record locations of origin and destination. Each number indicates a part of the platform (1 = 0-10 metres from the stairs; 10 = 90-100 metres from the stairs, see also Figure 2:). Pushing the button 'Top stairs' indicates the moment a passenger passing the top of the stairs. The lower three buttons indicate that a passenger performs an activity ('Activity' refers to the start and the location of the activity, 'End wait' to the moment that a passenger actually starts the activity and 'End activity' the moment that an activity ends).

The lowest part is used to construct the cumulative flow curves. Each observer handles a cross-section and each time a passenger passes this cross-section the passing moment and the passenger's walking direction are registered.

2.4 Performance of the observations

All observations took place on Monday October 3rd in the afternoon and appeared successful.

During the total observation period of three hours, 15 trains stopped alongside the platform. The number of boarding and alighting passengers has been measured from ten trains: the mean number of boarding passengers was 82, whereas on average 72 passengers alighted. For one train, the observed number of boarding and alighting passengers was twice this average due to a previous train falling out.

In total a group of 176 passengers has been followed to register individual walking times. This group consisted of 149 boarding and 27 alighting passengers. Sixteen boarding passengers performed an activity, such as buying a ticket. The destination of 60% of the boarding passengers was in the first forty metres on the platform, whereas 36% of the boarding passengers walked to the next 50 metres (40-90 m from the stairs). There were no observations of passengers walking more than 120 metres away from the stairs.

The final observations concerned the visual counting of cross-sections: 391 boarding passengers were observed passing the bottom of the stairs, whereas 326 alighting passengers were observed. The ratio between the number of boarding and alighting passengers (83.3%) is similar to the numbers observed in the boarding and alighting processes (87.8%).

3 Input of the simulation model

Figure 5: shows the platform configuration as well as the configuration of the rolling stock and the timetable being input for the simulation tool. The input is the result of both configuration measurements and observations.

Computers in Railways IX, J. Allan, C. A. Brebbia, R. J. Hill, G. Sciutto & S. Sone (Editors)
© 2004 WIT Press, www.witpress.com, ISBN 1-85312-715-9

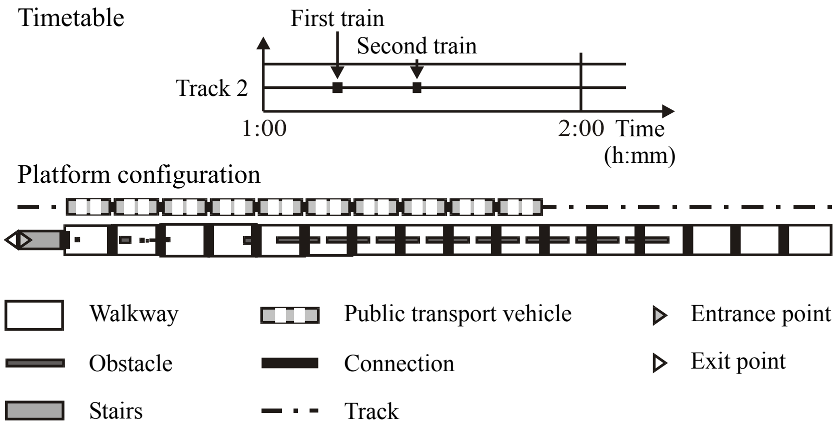

Figure 5: Timetable, platform and rolling stock configuration as input for the simulation tool.

The timetable indicates that two consecutively dwelling trains have been modelled. The number of boarding and alighting passengers has been derived from the observations (train 1: 78 alighting and 98 boarding passengers; train 2: 25 alighting and 50 boarding passengers), as well as the distribution of these passengers over each train.

Boarding and alighting passengers have been modelled differently with respect to their speed choice behaviour. While alighting passengers have a clear purpose and walk straight towards their destination, boarding passengers may walk (loiter) around when waiting for the train to arrive. This leads to an average free speed for alighting passengers of 1.34 m/s and 1.27 m/s for boarding passengers.

4 Comparison of walking speeds

Table 1: shows the mean and variances of walking speeds in both observations and simulation results. A distinction has been made for walking speeds on stairs and on the platform, as well as for boarding (upward direction) and alighting (downward direction) passengers.

Table 1: Overview of observed and simulated walking speeds.

		Observations		Simulation results	
		Median	Variance	Median	Variance
Stairs	Upwards	0.70	0.06	0.64	0.04
	Downwards	0.75	0.16	0.76	0.04
Platform	Alighting	1.35	0.11	1.34	0.07
	Boarding	0.97	0.11	1.21	0.14

Computers in Railways IX, J. Allan, C. A. Brebbia, R. J. Hill, G. Sciutto & S. Sone (Editors)

From Table 1: may be concluded that the median speed of pedestrians walking on the stairs in downward direction and walking speeds of alighting passengers on the platform are similar in the observations and the simulation results. The difference in median speed on the stairs in upward direction is remarkable, as other studies in literature generally indicate lower speeds as well. As this is one of the input parameters of the model, further research is needed to see whether this is a common observation in railway stations and when this is the case, the input parameters are adapted. The difference of the median speed of boarding passengers can be explained by the behaviour of boarding pedestrians in choosing their waiting location on the platform. It appears that a correlation may be found between the walking speed and the destination of the passenger on the platform, which is different from the assumptions (Daamen [3]). This is subject for future research as well.

Figure 6: and Figure 7: show more details with respect to the frequency distribution of walking speeds on stairs in upward direction as well as walking speeds on the platform for boarding passengers.

Figure 6: shows that both frequency distributions have a similar form, whereas the variance of the observations is twice as large as the variance of the simulation results. Also, the frequency distribution of the simulation results lies on the right side of the frequency distribution of the observations, indicating that walking speeds in the simulation are smaller than speeds in the observations. To get a better match, the free speed in the simulation might be increased, in order to shift the total frequency distribution to the right (this way, the observations are used for calibration of the model).

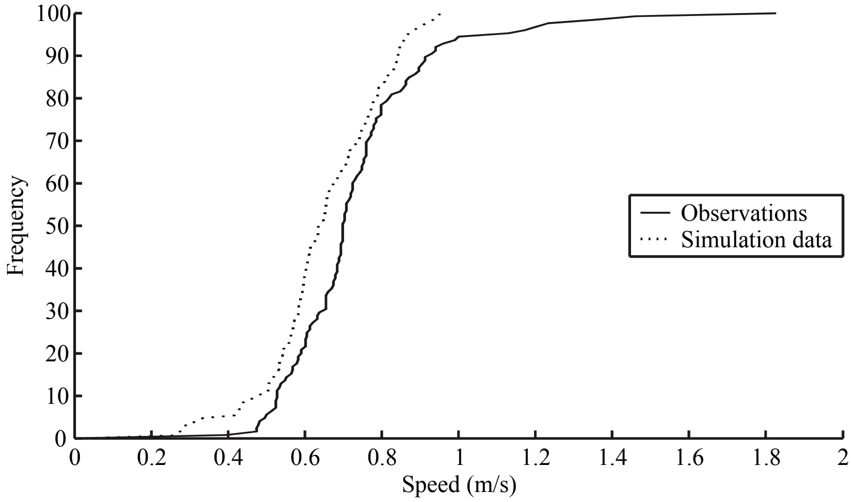

Figure 6: Frequency distribution of walking speeds on stairs in upward direction.

Figure 7: shows that the median speed of both observations and simulation results does not differ significantly along the walking distance on the platform. Also, the median speed is similar for both cases (1.35 m/s vs. 1.34 m/s), whereas maximum and minimum values of the observed walking speeds are higher respectively lower than the simulation results (see also Table 1:).

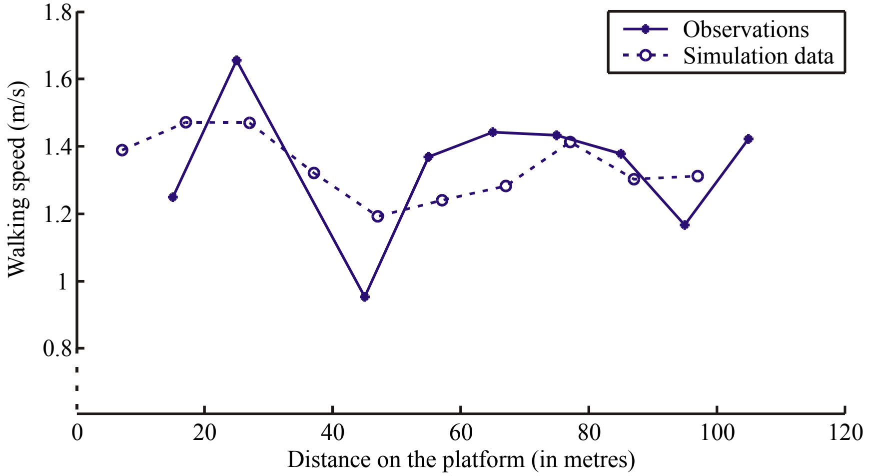

Figure 7: Walking speeds of boarding passengers on the platform.

5 Comparison of density

Figure 8: and Figure 9: show the densities on the platform over time for the observations respectively the simulation results.

The process in the simulation is clearly less fluctuated than the process in the observations. At the beginning of the observations, already some passengers are present on the platform, while the simulation starts empty. In general, the number of passengers on the platform is higher in the observations than in the simulation, partly due to the initial state of the platform. However, the height of the peaks is similar as well as the clustering over the platform at the arrival moment of the train. The moment of clustering differs: in the simulation passengers walk straight to the expected location of the door, whereas in the observations passengers only start to cluster at the arrival moment of the train due to the walking of passengers in the driving direction of the train the moment it enters the station. The duration of the peak of alighting passengers from the first train is similar for both observations and simulation results (about 100 seconds on the stairs). The process of 'walking with the train' is clearly visible for the second train, where the observations show two peaks before the train arrival reducing to one cluster when the boarding process starts. This is due to the fact that this train did not stop nearby the stairs, but its rear carriage passed the first cluster of passengers and stopped at the second cluster.

Computers in Railways IX, J. Allan, C. A. Brebbia, R. J. Hill, G. Sciutto & S. Sone (Editors)
 ISBN 1-85312-715-9

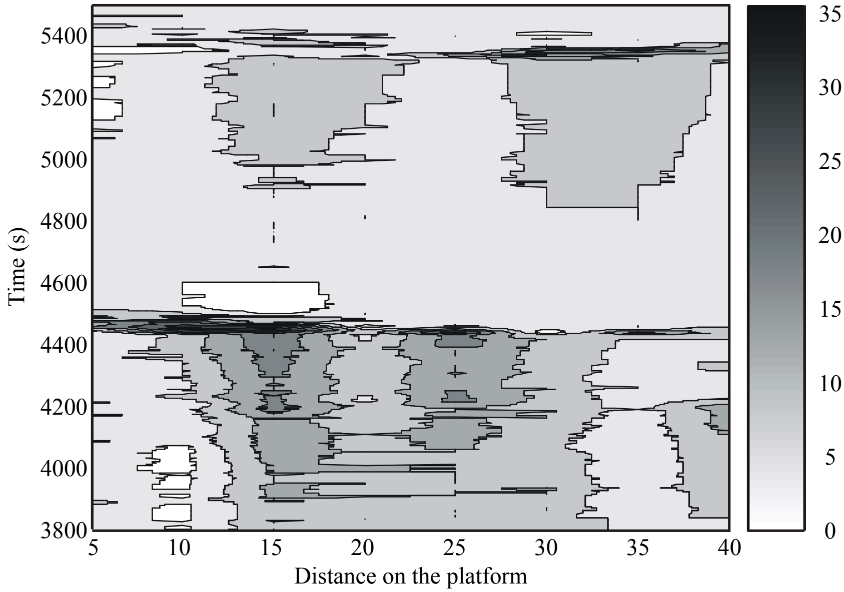

Figure 8: Observed densities on the platform over time.

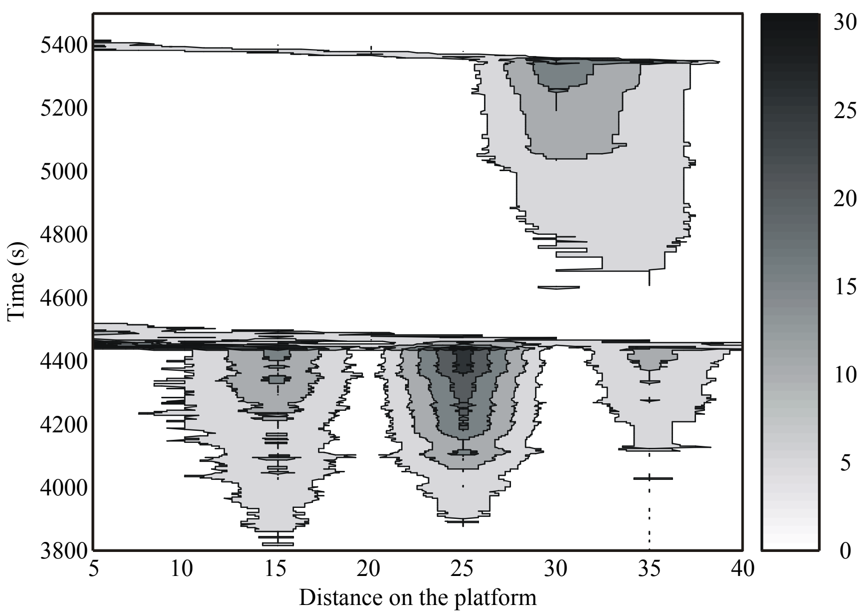

Figure 9: Simulated densities on the platform over time.

Computers in Railways IX, J. Allan, C. A. Brebbia, R. J. Hill, G. Sciutto & S. Sone (Editors)
© 2004 WIT Press, www.witpress.com, ISBN 1-85312-715-9

Summarising it can be stated that although the density over time and space is not completely similar, the main characteristics of the process (peaks at the arrival moment of the train, clustering on the platform) are modelled satisfactorily.

6 Conclusions

This contribution shows the validation of the simulation tool SimPed with respect to traffic flow characteristics on a platform by comparing observations with simulation results. This validation considers both walking speeds and densities over time and space.

The median speed of pedestrians walking on the stairs in downward direction and the median speed of alighting passengers on the platform are similar in the observations and the simulation results. The observed walking speeds on the stairs in upward direction are about 10% higher than in the simulation results. This is remarkable, as studies in literature generally indicate lower speeds as well. Both walking speed in upward direction on stairs and a possible correlation between walking speed and destination location on the platform are subject for future research.

The second aspect considered is density. While the simulation results show smoother flow operations than the observations, the spatial-temporal characteristics of the process (duration of peaks of alighting passengers at the arrival moment of the train and number of passengers involved and distribution of passengers on the platform at the moment of boarding) are modelled sufficiently close. One of the possible extensions in the modelling of pedestrian behaviour are the choice of their waiting location and the interaction between passengers at the moment that the train enters the station (especially the fact that passengers start walking en mass in the driving direction of the train).

Despite some points for improvement, the simulation tool appeared to model passenger flow on the platform sufficiently close to assess designs of transfer stations on passenger walking times and the levels of service of passengers on the platform.

References

[1] Daamen, W., A quantitative assessment on the design of a railway station, Computers in Railways VIII, pp 191-200, 2002.

[2] Kleijnen, J.P.C., Verification and validation of simulation models, Tilburg University, 1992.

[3] Daamen, W. (2004), Modelling pedestrian flows in public transport facilities, Thesis, Delft University of Technology, 2004.

Computers in Railways IX, J. Allan, C. A. Brebbia, R. J. Hill, G. Sciutto & S. Sone (Editors)
 ISBN 1-85312-715-9