# Passenger and Pedestrian Modelling at Transport Facilities

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**Abstract.** The modelling of passengers and pedestrians at transport facilities remains a complex issue to be addressed by industry within a transportation context. Passenger and pedestrian movements are a key component in all transport systems including public transport operations, interchange facilities and airport operations. Pedestrian performance is also a significant issue for design of retail centres, sporting grounds and special event locations. However, until recently passenger and pedestrian modelling was not integrated into traffic and transport simulation packages to accurately reflect the complexity of design. The recent release of VISSIM 5.1 incorporates a pedestrian simulation component that utilises Helbing's *Social Force model* for pedestrian movements.

PTV has undertaken the modelling of passenger movements at one of the largest and more complex rail stations within the Melbourne metropolitan region. North Melbourne station is to undergo an upgrade of facilities to better manage the significant interchange of passengers between regional and metropolitan rail systems. In addition a change in service planning will impact on the interchange movements at the station. The modelling addressed implications of a number of key components including platform location, access, grade, shelter and adjacent transport systems to examine the suitability of the design for passenger requirements. Various performance indicators have guided the design and operational refinements to optimise passenger conditions at the transport interchange.

## 1. INTRODUCTION

The representation of individual pedestrian movements within a complex transportation setting has to date reflected a significant barrier to the examination of many integrated transport infrastructure and operational planning projects. Although the PTV VISSIM micro-simulation software has always contained a representation of pedestrians within a traffic setting, there was little representation of actual object behaviour within this structure. Many transportation infrastructure, urban design and operational planning schemes were developed without appropriate consideration for the space requirements for pedestrian and passengers movements. This issue applies to the design and planning of integrated transport facilities including rail stations, airport operations, retail, residential and recreational settings and open space locations.

The pedestrian simulation component as part of the release of version 5.1 of the VISSIM micro-simulation resolves this issue. The current release of the VISSIM micro-simulation software can now simulate traffic, transportation and pedestrian interaction to evaluate and visualise the complex conditions within the above stated infrastructure and operational settings. The software allows for area based representation of pedestrian and passenger choices in addition to the traditional link based structure of previous versions.

PTV has undertaken the investigation to create a simulation of rail passenger movements at the North Melbourne Station. This station is adjacent to the Melbourne Central Business District and receives both metropolitan and regional rail services at this location. Key to this station is the significant interchange of the passengers between platforms to connect to other rail and transportation systems. Future projections of rail services at this station include a revision to operational timetabling and enhanced infrastructure facilities for passenger transfer between platforms.

This paper discusses the development and calibration of a base year pedestrian simulation model of North Melbourne Station within the VISSIM micro-simulation software. The paper outlines the various data sources and the process to simulate these behavioural conditions. The PTV structure will also outline how this process allows for investigation of both changes in engineering design and in operational planning. A number of performance evaluation methods are discussed.

## 2. PTV VISSIM MICRO-SIMULATION

VISSIM is a European micro-simulation product, developed by PTV AG and comprises a part of the PTV Vision suite for transport planning, journey planning, operations scheduling and engineering design evaluation and amelioration. There are currently more than 1,500 organisations in over 75 countries that use the PTV Vision Suite as the primary mechanism for resolving metropolitan planning issues. Across the globe PTV has undertaken continued research and development in technological improvements to the PTV Vision suite over the past 30 years.

Within the Asia-Pacific region there are a number of users of the PTV Vision software including state governments, local councils, academic institutions and engineering and planning consultants.

VISSIM is a microscopic simulation tool meaning that all vehicles and pedestrians are simulated as individual objects within a system. The VISSIM software has always contained a representation of pedestrians within the software. However, this element of the simulation was used to account for the additional delays that pedestrians achieve in inhibiting vehicular movements on the road network. The behaviour of pedestrians can now be defined individually, in the same way as previously pursued for vehicles. A new component of the VISSIM micro-simulation software allows for evaluation and assessment of complex operational pedestrian and passenger movements within the design of transportation systems.

Micro-simulation modelling software is an instrument for assessing operations where a multitude of factors within close proximity can limit capacity or the movement of individual objects. This simulation modelling utilises a time step based approach to identifying opportunities for each object within a network (Fellendorf, 1994). The simulation modelling approach provides substantial value in congested conditions, whereby numerous factors can inhibit flow. For this reason, undertaking a simulation model is of particular value for providing assessment and amelioration in the design and operations of a transport system. The models incorporate significant detail in a compact study area.

The VISSIM micro-simulation software also maintains a sophisticated visual interface that enables the viewer to conceptualise the performance and operational limitations of transport systems and networks. This provides value when presenting study findings to non-technical organisations including community liaison groups who appreciate more in presentations than simply the provision of quantitative data.

With its visualisation capabilities, VISSIM is a powerful tool for architects who participate in large scale design and urban planning, for presenting their plans graphically to the public. This connects the metaphorical bridge between engineers, planners, architects, and decision makers who have little or no traffic planning background. Moreover, local communities can more easily participate in discussions regarding the design of towns, cities and public places.

The system can visually identify bottleneck issues in design and planning for mitigation including provision of significant evaluation measures to assess the benefits in amelioration measures.

PTV Asia Pacific is the distributor for the PTV VISSIM micro-simulation software across Australia, New Zealand, South East Asia and India. We continue to advance the knowledge and awareness of the PTV Vision software including the investigation of complex development and enhancement projects. Recent applications in this field include complex CBD transport networks, motorways, public transport planning and scheduling, route assessments, railway station design and landside, concourse and airside simulation modelling of airport terminals. PTV is also involved in review and amelioration of urban design schemes, including construction staging of infrastructure works.

## 3. PTV PEDESTRIAN SIMULATION

The PTV pedestrian simulation component is a new feature in version 5.1 of the VISSIM micro-simulation software. The pedestrian simulation is built directly into the core of the exiting VISSIM micro-simulation software to further enhance the quality and functionality of the traffic and transport simulation capabilities. In this way users can simulate the movement of transportation systems, traffic operations and pedestrian movements entirely within a single software package.

The VISSIM pedestrian micro-simulation software introduces an area based modelling system including representation of multiple levels within a single model. This approach allows for an enhanced capability in modelling those locations that pedestrians consider for route choice. Rather than determining route choice through a series of small tile-based sections, the PTV VISSIM pedestrian micro-simulation allows for dynamic route choice within a study location – that is each individual passenger will determine their route over both a large section of travel and a shorter section of travel. Passengers are free to determine which paths best apply for their needs. In this way, passengers can travel over varied sections of larger scale areas (eg station ticket halls, concourses, platforms etc) without the need for the modellers to explicitly designate such considerations. Users have the flexibility to identify origins, destination and intermediate destination (eg ticket machines, information counters etc). The combination of these points is used to assist individual objects (passengers) through a complex network.

The pedestrian choice model within the VISSIM micro-simulation software is entitled as the "*Social Force Model*". This is a mathematical algorithm first published by Helbing and Molnar (1995) designed to represent the stochastic behavioural models of pedestrian movements.

Based on Newtonian ideas, the interaction of pedestrians considers a number of different forces to minimise journey time and reduce the overall number of conflicts to inhibit flow. Helbing and Molnar (1995, 1998a, 1998b) identify that pedestrians have a desired speed towards their destination. Each identified category of pedestrians can therefore be associated with a different desired speed, to simulate the variation attributable to demographic attributes.

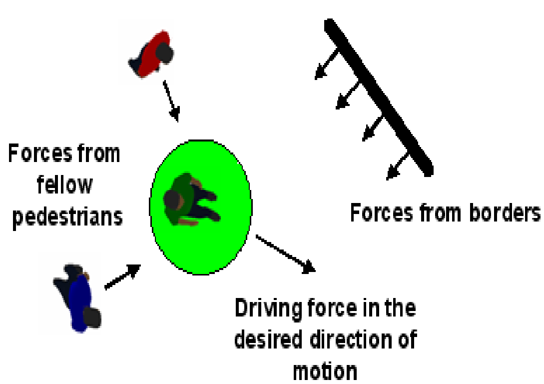
Within this concept each person maintains a safety distance – or private sphere which results in a territorial effect (Helbing and Molnar, 1995). Similar notions were identified by Fruin (1971). However, the varied desired speeds within a passenger composition results in "stop and go waves" (Helbing, 2003) and enhances congestion within an enclosed setting. To overcome this aspect, each passenger maintains an element of "relaxation time" but offsets this against the "pressure of time" (Helbing *et al*, 1998). Eventually individual persons chose to introduce a minor oscillation in the walking direction in order to overtake.

Pedestrians examine this opportunity in the context of the surrounding physical boundaries and barriers, such as walls, buildings and furniture – all of which are deemed to have a repulsive force to deter pedestrians from maintaining close proximity. Pedestrians moving in a contrary direction to the flow are also deemed to be a similar repulsive force. Persons ensure that their private sphere is maintained when walking within close proximity to other passengers or objects which generate a repulsive force.

Complementing this force, when pedestrians travelling under congested conditions within the same direction and maintaining similar desired speeds - an attractive force is generated. Walking behind one of these pedestrians is beneficial for minimising journey times. This process leads to trail formation and the development of walking paths or lanes. Helbing and Molnar (1995) describe the trail formation "not a result of the initial pedestrian configuration but as a consequence of the pedestrians' interactions. It leads to a more effective pedestrian flow since time-consuming avoidance manoeuvres occur less frequently". Helbing *et al* (2001) describe this as a "self-organisation of collective behaviour patterns". Additional attractive settings include shop fronts and window displays can be represented within the social force model.

A diagrammatic representation of the Social Force model is displayed in **Figure 1**.

**Figure 1: Attributes of the Social Force Model**




The social force model that sits within the VISSIM pedestrian micro-simulation software aims to minimise the travel times of individual persons. Within the simulation each pedestrian assesses the repulsive and the attractive forces, together with a desired speed to determine their movements in reaching the desired destination.

## 4. NORTH MELBOURNE STATION

The North Melbourne Station provides to be an interesting study for the simulation of pedestrian movements within the VISSIM micro-simulation model. The station is located to the immediate north of the Melbourne Central Business District and contains six platforms.

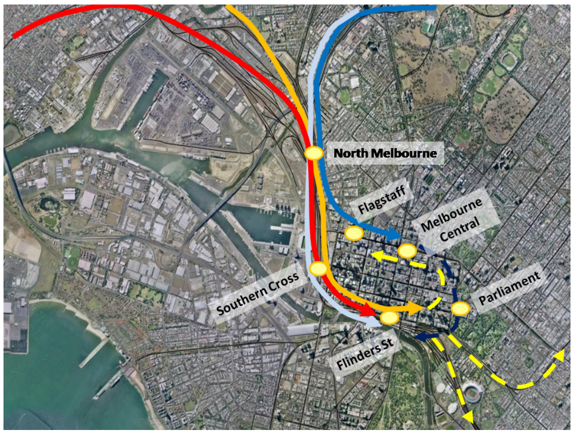
As identified in **Figure 2** there are four ramps at the northern end of the station connecting the platforms to the concourse. Platforms #1 and #6 each contain a separate ramp for access. The remaining two ramps are shared between the centre four platforms. There are road transport connections to the east of the station. Three platforms are utilised for train services in the "Down" (northbound) direction with a further three platforms for the services travelling in the "Up" (southbound) direction. The station is also within close proximity to Melbourne University and the "hospitals precinct" at north Melbourne.

**Figure 2: Attributes of the Social Force Model**

There are a number of regional services that pass through North Melbourne Station. Services provide connections across the Victorian state including Geelong, Ballarat, Bendigo and Warrnambool to the west, plus northern Victorian locations including Seymour and Echuca. There are also a number of metropolitan connections with services terminating at Werribee, Sydenham, Craigeburn and Upfield.

All regional services terminate at the Southern Cross Station (formerly Spencer Street Station). However metropolitan services culminate at the Flinders Street Station. Within the City Loop system, a proportion of these services travel anti-clockwise and a proportion travel in a clockwise direction. A number of the metropolitan services connect within the City Loop to additional lines across the rail system. These services passing through North Melbourne Station are diagrammatically represented in **Figure 3**.

**Figure 3: Rail Service Patterns through North Melbourne Station**




The frequency of rail services during the peak hour is listed in Table 1. This table identifies that a total of 57 services stopped at North Melbourne station in the peak hour period. A total of twelve services access Platform 1 and sixteen services access Platform 3. There are a total of 38 services travelling in the "Up" direction with the remaining nineteen rail services moving in the "Down" direction.

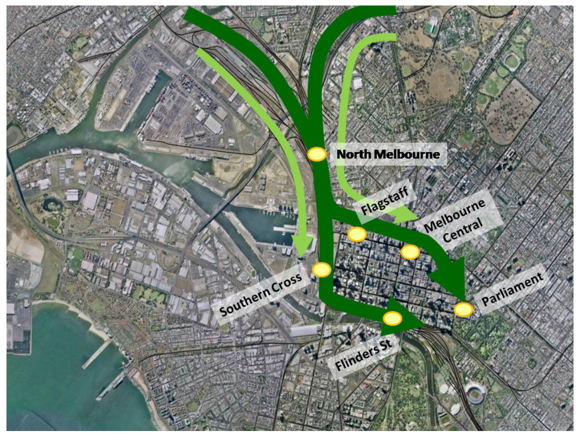
**Table 1: Rail Frequency at North Melbourne Station**

| Platform | Hourly Services |
|---|---|
| 1 | 12 trains |
| 2 | 9 trains |
| 3 | 16 trains |
| 4 | 7 trains |
| 5 | 10 trains |
| 6 | 3 trains |
| Total | 57 trains |

As a method for reduced travel times is an element of a regular journey to work, there is a significant movement of persons that interchange services at the North Melbourne Station. This situation arises from both the regional and from metropolitan rail services. Such an arrangement proves to create an interesting challenge in planning for future rail service operations and managing infrastructure development at this rail station.

One of the key movements at North Melbourne Station is the transfer between platforms as pedestrians alight from the regional services to access the City Loop services in the clockwise direction. The movement of passengers at North Melbourne Station, for a destination within the Central Business District is represented within **Figure 4.** That is, there is a definitive split in passenger movements from both regional and metropolitan services that is applied at North Melbourne station for access into the Melbourne Central Business District.

**Figure 4: Trip Patterns moving through North Melbourne**




A further complexity to the current conditions of passenger interchanges at North Melbourne Station is that a number of services do not have available capacity for the boarding of all passengers. That is, some pedestrians are not able to board the initial service that arrives at the platform, but are required to wait for a following train. For future year conditions, with all other aspects being equal, this situation would only be exacerbated – as significant increases in population growth is anticipated due to the continued residential land releases to the North West of metropolitan Melbourne.

In the morning peak hour, the North Melbourne station currently receives approximately 3,000 persons alighting from rail services. Approximately 40% of these passengers exit the station. The remaining 60% of passengers transfer within the station to other platforms. Given the proximity of this train station to the Central Business District, there is a number of competing inner city transport options. Consequently there are very few passengers that enter the rail system at this location.

Site visits indicate that the northern end of the platforms receive the most passengers both boarding and alighting the train services. This is due to the proximity of the ramps for interchanges and service connections. The distribution of passengers along the platform, including the relative density of demands can be viewed in **Figure 5**. Site visits have also identified that the location of shelter on the platforms contributes to the proximity of passenger waiting before a service arrives.

**Figure 5: Observed conditions at North Melbourne Station**

## 5. MODEL DEVELOPMENT

The model development for the North Melbourne VISSIM micro-simulation is derived for the period of 7:30 -8:30 AM. Services have been derived from the current timetable. Patronage data is based on a cordon count derived from October 2007. As the focus of this model has been developed for a morning peak hour, the simulation represents a commuter service and maintains a relatively homogenous demographic composition of passengers.

Locations within the model, including platforms and concourses were developed as pedestrian areas. The connections between these different levels are represented using ramps. Sites along the platform including the designation of shelters, poles and other furniture are demarcated as obstacles for which pedestrians recognise the repulsive force and avoid direct contact.

The simulation model also represents a number of different rolling stock designs. Each of the rolling stock systems are characterised with different features, including total capacity, number of carriages and the number of doors for passenger access. General observations indicate that regional services maintain fewer carriages with only two doors, while the metropolitan services run three door carriages.

The length of time that trains are stationary at each platform is derived from a calculation of occupancy of the service, plus the number of boarding and alighting of passengers. In this way, high occupancy services with few passengers boarding and alighting will remain at the station for a similar length to a low occupancy service with significant alighting and boarding volumes. Stationary times at the platform have been categorised into five classes of delay, based on observations from the site visits.

The management of passengers on and off the train service is administered by invisible signals. In this process the simulation model will represent the alighting of passengers off from a service before those passengers on the platform begin boarding onto the train.

The movement of passengers within the station is defined as a series of predefined paths with relative volumes. Within this paper the static routes do not limit the element of route choice within a system –any path can be chosen on provision that the key defined intermediate and destination points are achieved. In this manner variation in paths can be obtained. This includes the attributes that pedestrians pursue including a fanning out of paths in low volume sections and a trail formation of congested conditions.

However, the application of relative volumes between services is known to fluctuate significantly upon the arrival of each train. That is, passengers alighting from a service do not maintain a consistent distribution for connecting trains and platforms. Often these figures are significantly different between successive services.

To suitably represent complex conditions that match the existing data, PTV has chosen to develop a simulation interface for the operation of this model. Using the powerful VISSIM COM application, a spreadsheet was developed to list the characteristics of each service arriving at the North Melbourne Station. The relative flow of passengers to various platforms and to sites external to the station are identified for each arriving rail service. The data within this interface is then read directly into the VISSIM simulation software for application and evaluation of complex operational conditions at the station.

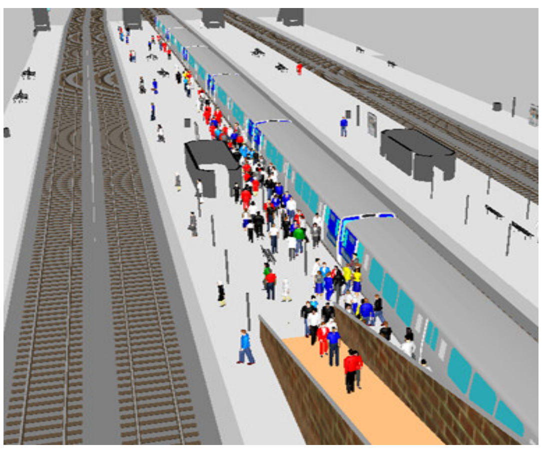
This process proves to be very successful for a number of significant reasons; Firstly, a spreadsheet format is a simple method for managing significant characteristics regarding each train service. Secondly, the spreadsheet approach saves significant time in coding the volumes alighting from each service and the relative volumes moving to each platform. Thirdly, the structure of the spreadsheet allows additional calculations and determination of characteristics relating to each service, including expected total number of persons boarding and alighting and therefore the associated dwell times. Fourth, this spreadsheet structure provides a mechanism for managing any changes associated with future year scenario testing. Simple manipulations to the spreadsheet can represent scenarios of revised schedules, variation in platform arrivals, enhanced patronage volumes, different rolling stock and associated service capacity, or even a subtle decline in maintaining timetable performance. From this approach the spreadsheet provides a clever and simple mechanism for modelling the complexities of pedestrian movements within a structured manner.

The spreadsheet process utilised by PTV also ensures a ceiling volume of passengers boarding onto the train services. The spreadsheet can identify those services where passengers cannot board a train service due to the occurrence of full occupancy. These passengers are required to remain on the platform for the next service.

Data within the spreadsheet is connected to the simulation software using a Visual Basic for Applications script within the Excel application.

A snapshot of the PTV VISSIM micro-simulation model is provided in **Figure 6**. The model shows the same significant level of complexity and congestion that is currently experienced. This is in line with the observed conditions identified from site visits. There is a considerable volume of passengers boarding and alighting at the northern end of the railway station, near to the ramps connecting to the concourse. This congestion is observed to be significantly more than at the southern end of the platform. A number of notable bottlenecks are identified on the platforms adjacent to shelters and additional platform furniture.

**Figure 6: VISSIM Snapshot of the North Melbourne Simulation**



## 6. MODEL PERFORMANCE

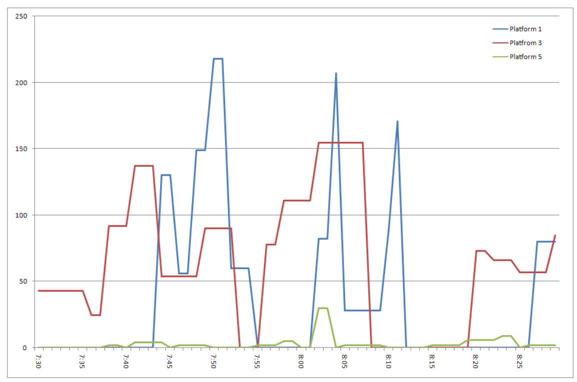
There are a number of varied performance measures from the PTV VISSIM micro-simulation software that are used to evaluate the conditions from the model. These include both quantitative and qualitative measures of evaluation.

The PTV VISSIM pedestrian simulation software maintains two primary measures of model performance. The simulation software allows for the definition of evaluation areas and for travel times. This evaluation area is independent of the areas used to define the pedestrian movements and choices. Pedestrian measurement areas have been allocated throughout the network to determine simulation conditions across the platform, for the area adjacent to each carriage's stopping location and the region surrounding each train door. Data outputs can be defined for any specified time interval ranging from individual seconds to the length of the simulation time period.

For this study PTV has evaluated the North Melbourne station model performance for a series of sixty second intervals. A measure of station occupancy for the Up direction platforms is provided within **Figure 7**. This approach provides a better representation of the platform occupancy than a single hourly performance measure might envisage. An approach such as this measure is further enhanced by the intermittent occupancy of the platform, for which pedestrian simulations imply different measures of consistency to traffic studies.

Other key performance measures from this output include density measures, from which Fruin (1971) style Level of Service thresholds can be applied for different settings, including platforms, ramps and stairwells. Model outputs include passenger volume and throughputs, lost time due to the deviation away from utilising the shortest path. The variation in quantitative performance measures extracted includes an average, maximum and a minimum for each output.

**Figure 7: Platform Occupancy in the Up (Southbound) Direction**




A number of performance measures from the simulation software comparing modelled pedestrian throughput relative to the observed passenger volumes are presented in **Table 2**. The data indicates that the flow volumes are very close, with all platform screenlines matching to within 8% of the forecast flow volumes. A screenline of all platforms indicates a total modelling variation in passenger throughput from the observed conditions of less than two percent. Platform six volumes have been omitted from this table as the observed screenline volumes are null, despite services continuing to stop at this platform.

A qualitative review of the modelling indicates that there is significant congestion that matches in line with the observed pedestrian behaviour at North Melbourne Station. In particular the measures of congestion on platforms #1 and #3 are noted to strongly resemble the current levels of congestion at the station.

**Table 2: Platform Simulation Flow Volumes**

| | Observed | Modelled | Absolute Difference | Percentage Difference |
|---|---|---|---|---|
| Platform 1 - Entering | 609 | 591 | 18 | 3% |
| Platform 1 – Leaving | 422 | 448 | -26 | 6% |
| Platform 2&3 - Entering | 275 | 282 | -7 | 3% |
| Platform 2&3 - Leaving | 764 | 701 | 63 | 8% |
| Platform 4&5 - Entering | 110 | 105 | 5 | 5% |
| Platform 4&5 - Leaving | 1,079 | 1072 | 7 | 1% |
| Total | 3,259 | 3199 | 60 | 2% |

## 7. CONCLUSION

This paper was produced to describe the process utilised for the creation and calibration of a pedestrian model of North Melbourne Station. This station is subject to a high volume of regional and metropolitan services, but encounters a significant volume of passengers interchanging between the six platforms.

PTV has developed a passenger model using the recently released pedestrian simulation component of the VISSIM micro-simulation software. This algorithm within this software is referred to as the Social Force Model, as derived from Helbing and Molnar (1995). The driving equation comprises those forces surrounding an individual pedestrian including desired speed to a destination, the repulsive forces from physical barriers and persons in conflicting flows plus the attractive pull of space created from those individuals moving in the same direction.

A spreadsheet approach with connections to the COM interface was used as a way to manage the data flow into the VISSIM simulation. This approach also provides significant time saving for the representation of simulating a number of future year operating scenarios. The North Melbourne station model will be used to examine future year scenarios including a number of operational service changes and infrastructure design improvements. The model can also represent the complex issue of full occupancy services arriving at particular platforms. Within the VISSIM micro-simulation software these changes can be suitably reflected by the dynamic route choice decisions that occur.

The model has shown to produce a broad number of quantitative outputs including throughput, density, platform occupancy and travel times for a study area. The strong visualisation features incorporate a series of qualitative measures of congestion on two platforms.

The interaction of the area based pedestrian simulation within the VISSIM micro-simulation to the traffic and transportation simulation suite can be used to represent complex passenger and pedestrian conditions at transport facilities. The software represents a significant enhancement to the increasing situation of planning for pedestrians within transport infrastructure projects, operational service planning and design studies.

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