Development of an Object-Oriented Pedestrian Traffic Flow Simulation Environment for Transport Terminal Planning

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Abstract

In recent years, simulation has become an essential tool for planning, designing, and managing terminal operations. Simulation modeling of various aspects related to the dynamic nature of the pedestrian/passenger behavior within a transport terminal can effectively assist in the analysis, evaluation, emergency response planning, and decision support phases of the terminal's operation. In this paper, the development of an object-oriented environment that enables both the graphical description and simulation of pedestrian traffic flows at the microscopic level is discussed. The simulation environment provides generation capabilities so that a terminal station model is directly formed on the basis of preconstructed component models. Essential experimentation capabilities, including graphical representation, are provided for pedestrian-oriented and system-oriented measures of interest with explicit emphasis on the level of service. A case study for a 4-level station in the new Athens subway system is also used to demonstrate the potential and functionality of the simulation environment.

Keywords: Pedestrian Traffic Simulation, Pedestrian Traffic Modeling, Transport Terminals

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1   Introduction

Effective and efficient terminal planning, design and operation attract considerable research interest because of the wide variety of possible implications. Transportation engineers, for example, are interested in identifying factors influencing terminal performance and operations to improve its design and to provide a more comfortable yet economically feasible terminal environment. Terminal operators and users on the other hand wish to identify the parameters allowing for the most efficient and fast operation. Traditionally, these problems have been addressed either by simple space versus Level of Service (LOS) charts (Fruin 1971, McShane et al. 1997), or more recently with the use of cellular automata models (Nagel and Schrekenberg 1992, Blue and Adler 1998).

In general, normal pedestrian movement involves many complex characteristics of balance and timing. The qualitative design of a pedestrian environment requires a basic understanding of related human characteristics and capabilities (Fruin 1971). Further, it is widely recognized that humans value personal space. The level of service provided to the pedestrian therefore strongly depends on the perception of personal space. There are examples of poor human environments where pedestrians may be required to accumulate in large groups, resulting from a lack of understanding of the traffic-flow relationships and space requirements of pedestrians when using maximum capacity as a basis for design (McShane et al. 1997).

To address some of these issues, modeling and simulation techniques have widely been used. Simulation enables an in-depth evaluation of complex pedestrian environments under real conditions, which cannot be provided by analytical methods due to the size and complexity of the systems under study, to indicate potential errors or design inefficiencies. Pedestrian flow modeling has been oriented towards methodological approaches, such as the cellular automata for single-directional and multi-directional flows (Blue and Adler 1998, Blue and Adler 2001, Dijksra 2000), providing both discrete and continuous modeling approaches (Helbing et al. 2000). Models have also been developed for specific application domains, such as bus terminals (Lee and Khoo 1997), airport terminals (Cheng 1998, Young 1999) and ships (Meyer et al. 2001). When available, the specific pedestrian dynamics

of the system under study can also be used to provide more effective modeling solutions (Lam and Cheung 2000, Zacharias 2000).

A number of traffic simulators has so far been developed. Tools, such as TRANSISM (Nagel 2001), MITSIM (Qi 1997), DYNASMART (Mahmassani et al. 1995) and HUTSIM (Kosonen and Davidsson 1994) enable microscopic simulation by assigning individual routes to travelers, but are oriented towards either other modes of transportation or the integration of pedestrian traffic with other modes of transportation. SimPed (Jiang 1999) is a tool examining pedestrians flows in an urban environment. Researchers have also focused on evacuation scenarios, which are either proposed (or evaluated) using tools such as EVACNET (Kisko et al. 1998), SIMULEX (IES 2002) and PedGo (Meyer et al. 2001). However, they do not emphasize pedestrian flows under normal conditions and thus do not reach conclusions for the corresponding level of service provided to pedestrians. Moreover, most of them are commercial products and either cannot be customized at the implementation detail level to support case-specific requirements (e.g. user-specified pedestrian behavior, implementing new models through extending the behavior of existing ones) or are domain-oriented (e.g. for evacuation onboard passenger ships). Commercial pedestrian traffic simulators are LEGION (Crowd Dynamics 2002) and PEDROUTE (Halcrow Group Limited 1994). LEGION analyzes the dynamics of crowds using microscopic simulation of pedestrian behavior. PEDROUTE supports the evaluation of pedestrian facility designs with orientation on train terminals. Simulation results from a tool analyzing passenger flow of an airport terminal are also presented in (Kiran and Og 2000).

In this paper, we present an integrated Pedestrian traffic Simulation environment, abbreviated to PEDSIM. PEDSIM is oriented towards underground subway terminals, evaluating flow and design characteristics and enabling the physical description of the terminal, the specification of pedestrian flows, the determination of the design parameters and the analysis of simulation results via a large number of "what-if" design and operation scenarios. PEDSIM supports an increased degree of automation, enabling the user to specify both the terminal design and pedestrian routes and constructing the overall model based on these specifications. Terminal design constructs are available

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as object-oriented models, organized in object hierarchies. Object hierarchies reside in model libraries, where both primitive (atomic) and composite models, representing the key entities of a terminal station, are preconstructed and maintained. A terminal station is thus considered as an composite entity, consisting of different segments, each one being of a specific type. Potential segment types considered are: walkways, stairways, escalators, platforms and ticket issuing facilities.

Key features of PEDSIM are i. the integration of terminal design and pedestrian flow simulation into a graphical environment providing constant visualization of the level of service provided within the various terminal segments, ii. the capability to evaluate the terminal design under various, user-defined conditions of load, iii. the flexibility to create either customized segment models corresponding to specific conditions (i.e. modify how pedestrians behave) through redefining the corresponding object methods, or even new segment models, corresponding to new types of constructs, such as ticket barriers. In this way, PEDSIM may also be used to evaluate the design of other systems, such as airport terminals. The overall terminal description is parametrical (e.g. experiment parameters involve issues such as the time schedule and train capacity). To achieve this, all potential pedestrian routes must be analytically specified, based on either real observations or traffic forecasts, prior to the initiation of the experiment.

The remainder of this paper is organized as follows. Pedestrian flow modeling is discussed in Section 2 for walkways, escalators, stairways, platforms and ticket issuing facilities. Section 3 includes an in depth description of PEDSIM modules and phases. A case study for a multilevel terminal of the new Athens Metro system during peak hours is presented in Section 4, while results and some conclusions are discussed in Section 5.

2   Traffic Flow Modeling

The basic principles of pedestrian flow analysis are similar to those used for vehicular flow, involving the fundamental relationships among speed, volume, and density. Pedestrian traffic volumes and queuing relationships are introduced on the basis of the average pedestrian area occupancy, providing easily understood measures for design (Fruin 1971, McShane et al. 1997). The most

important of these parameters are: i. *pedestrian speed (D)* ii. *flow volume (F)* iii. *pedestrian density (D)* and, iv. *module (M)*. Module is the inverse of density and is considered as a more manageable and practical unit.

As the volume and density of a pedestrian stream increase from free-flow to congested (crowded) conditions, speed and ease of movement decrease. When pedestrian density exceeds a critical level, volume and speed become erratic and rapidly decline (Fruin 1971, McShane et al. 1997). The classic flow equation in traffic can be expressed as follows:

$$F = S * D = (Average\ Walking\ Speed) * (Average\ Density)$$

An alternative and more useful expression, for practical applications, is obtained using module, as follows:

$$F = S / M = (Average\ Walking\ Speed) / (Average\ Pedestrian\ Area)$$

PEDSIM reaches conclusions for the level of service provided to pedestrians within the various terminal segments. The flow modeling approach is based on the relationship between pedestrian speed and module, which provides an analytical representation of pedestrian traffic at the microscopic level compared to other approaches, such as cellular automata modeling (Blue and Adler 1998, Nagel and Schrekenberg 1992). This is due to the fact that it represents realistically the actual process where pedestrians change their speed according to the area density with a variable rate, which may be very high, imposing that speed be updated within a very small time quantum, whereas such flexibility is not provided in cellular automata modeling. Considering the pedestrian speed and module relationship, in the following paragraphs we determine an efficient mathematical approximation for calculating the speed of individual pedestrians as a function of the area density for both walkways and other terminal segment types, such as stairways and escalators.

2.1   Walkways

A walking section should be sufficiently wide (i.e. meet specific standards) to allow for normal walking convenience and avoidance of conflicts during all expected traffic fluctuations. Level of service, introduced by Fruin in his classical research on pedestrian planning and design

[Fruin 1971], is the widely adopted standard. Walkway standards are operative within a definitive range of flow for which meaningful relationships have been observed. Beyond this range, pedestrian flow tends to be erratic and cannot be efficiently approximated using a mathematical model. Six levels of service (A-F) were originally introduced for walkways and were standardized by the Transportation Research Board in 1994. We employed these standardized criteria for moving pedestrian streams (TRB 1994). The maximum threshold for LOS E was set at M = 6 sq ft/ped, and this is the space module at which capacity flow is generally observed. At less than 15 sq ft/ped, all walking speeds are restricted, making this an appropriate threshold for LOS D. At 24 sq ft/ped, most pedestrian speeds are unrestricted, while at 40 sq ft/ped, virtually all pedestrian speeds are unhindered. LOS A was set at 130 sq ft/ped, as this is the threshold beyond which pedestrians are virtually unaffected by the presence of others in terms of speed, walking path, and positioning within the pedestrian stream (McShane et al. 1997). Speed – module relationship in walkway traffic is depicted in Figure 1, for which the following analytical model approximation is reached using non-linear regression. This classical relationship was considered, as it was also used in the design of the terminal station being the domain of our case study presented in Section 4.

$$S = max\left(0, a - \frac{b}{M}\right), a = 285.4, b = 858.856$$

To model pedestrian flow in walkways, essential parameters are the walkway area and the effective walkway area, the latter being used to calculate pedestrian density.
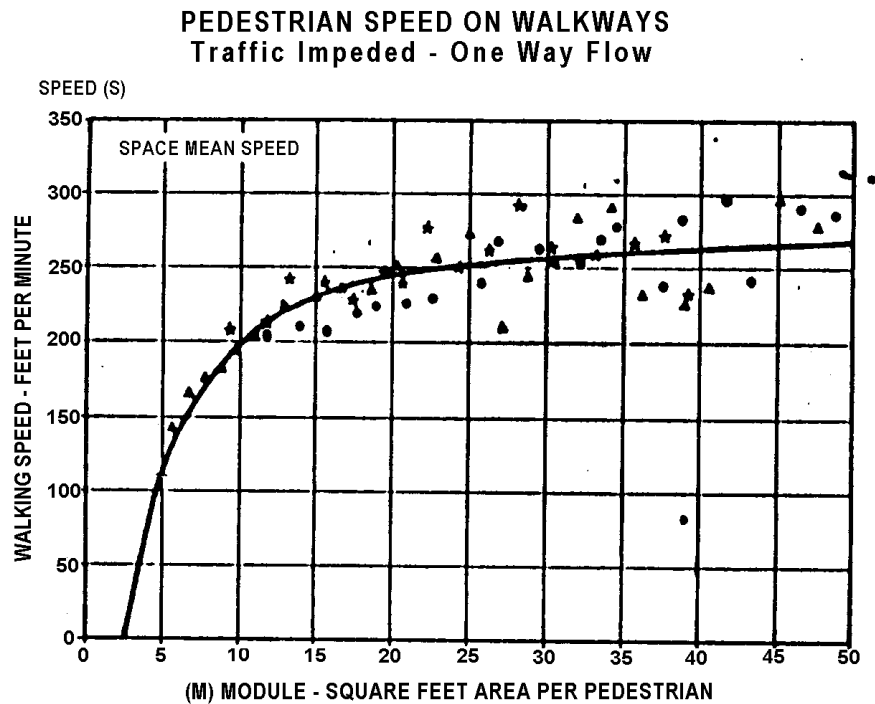
PEDESTRIAN SPEED ON WALKWAYS
Traffic Impeded - One Way Flow

Figure 1: Speed – Module relationship in walkway traffic (Fruin 1971)

2.2 Stairways

Movement on stairways is more restricted, as the dimension of stairways determine pedestrian flow characteristics more than walkway dimensions do, especially in the case of congestion. It is estimated that unrestricted stairway movement speeds are attained at an average area occupancy of about 10 f^2/pedestrian (Fruin 1971). The following analytical model approximation can be reached.

$$S = \begin{cases} max\left(0, a - \dfrac{b}{M}\right), a = 114.513, b = 224.392 \text{ (up direction)} \\ max\left(0, a - \dfrac{b}{M}\right), a = 132.229, b = 255.127 \text{ (down direction)} \end{cases}$$

2.3 Escalators

Escalators have a constant speed and a maximum capacity. When this is reached, a queue is formed to enter to escalator and pedestrians must either join the queue or use a stairway. The usual angle of incline of escalators is 30 degrees. The average pedestrian is taking about 1 sec to get through the boarding section under average traffic conditions. An in-depth analysis of escalator boarding times

can be found in (Fruin 1971). Essential escalator properties are direction, speed, capacity and status (either operational or out of order).

Using capacity in escalator modeling, we avoid referring on how each specific escalator is actually used, that is, whether passengers fill both sides or one side is kept free for people walking. Depending on how escalators are used, capacity can be set to the actual number of passengers using the escalator, as an "effective" capacity. As use of escalators is generally combined with this of stairways, we introduced the escalator unit construct for modeling purposes. Escalator unit is composed of two single escalators and a stairway. Either of these three components can be enabled or disabled to accurately represent the actual escalator under study.

2.4   Platforms

Platforms are the segments where pedestrians are assembled when entering from street and waiting for the subway. Trains arrive at platforms according to a pre-defined schedule. Only those passengers waiting for the specific train will take the train and depart from the station, under the constraint that they do not exceed the remaining train capacity. Passengers entering the terminal through platforms are heading either to street or to other platforms. Movement on platforms is similar to movement on walkways, except for the fact that module calculation is occasionally performed on the basis of motionless pedestrians.

Modeling pedestrian flow cannot be efficient when platforms are considered as a single entity due to the fact that pedestrians may choose to embark the train from either specific entries (as they take into account the location of their exit or they know likely passenger density on the train) or the least crowded platform locations. As pedestrian behavior throughout the platform is not homogeneous, we decomposed it into *subplatforms* and implemented *platform group* models, consisting of subplatform models. Using this modeling approach, it is also possible to realize platforms designed for landing two directional trains at either side. Concerning pedestrian movement, we considered two scenarios for a pedestrian heading to a platform group to get on a train:

a. The train is not currently at the station - the pedestrian thus proceeds to the specific subplatform accommodating the least number of pedestrians and joins the respective boarding queue.

b. Boarding is underway - the pedestrian thus joins the boarding queue of the closest subplatform.

Passengers not managing to get on board remain in the queue along with the ones waiting for other trains. As previously discussed, pedestrians may also wish to move to specific locations (i.e. subplatforms). Although not currently supported, object-oriented modeling enables extending platform behavior to support this feature through appropriately redefining platform group methods, and this is a significant capability of PEDSIM.

2.5   Ticket Issuing Facilities

The majority of pedestrians in underground terminals are passengers that either enter from or exit to the street (i.e. they do not just use the terminal as a shortcut). Passengers entering the station from the street may already possess a ticket or may purchase it from the ticket issuing facilities. A segment designated as a ticket issuing facility may include one or more servers. Pedestrians join the server queue and wait to be served. When they have obtained a ticket, they follow the same route with the other pedestrians heading to the same destination (i.e. station platform). This is further discussed in paragraph 3.1.1. Ticket issuing facilities can be modeled as multiple-server/single-queue or multiple-server/multiple-queue systems. We adopt the multiple-server/multiple-queue approach.

3   Simulation Environment

PEDSIM operation is distinguished in two main phases: the design phase, where the terminal station and pedestrian flows are described, and the experimentation phase, where the model is executed and simulation results are obtained. User interaction with PEDSIM is performed via its two corresponding modules, namely the Terminal Station Editor and the Simulator. The terminal

description is exported by Terminal Station Editor and is automatically transformed into the terminal model using the preconstructed object-oriented models residing in the Model Library.

PEDSIM is implemented in Modsim III, an object-oriented, discrete event simulation language (CACI 1998a). The application programmer interface (API) includes a graphical user interface (GUI) and is implemented as object classes, so that it is also extendable. PEDSIM architecture is depicted in Figure 2. Dark rectangles represent PEDSIM modules. Interconnections denote data flows.
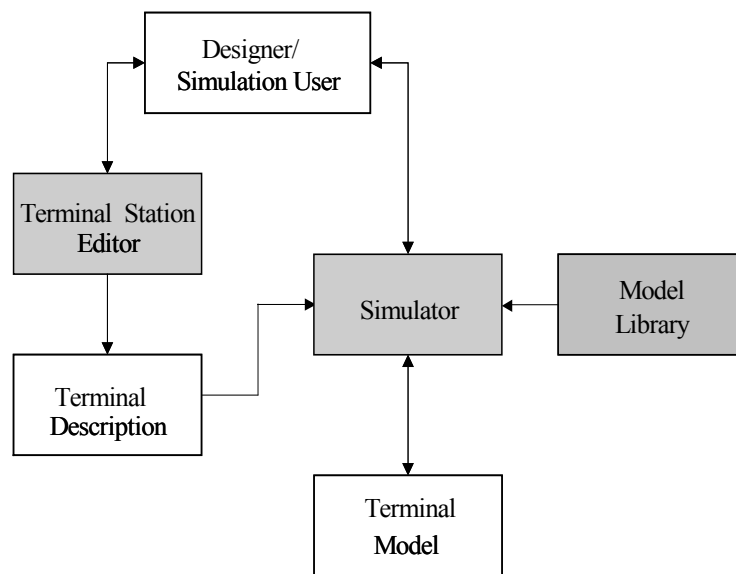

Figure 2: PEDSIM architecture

3.1   Terminal Station Editor

Terminal Station Editor supports the in-depth terminal description, embodying the following activities:

1. Station segment design

2. Determining operation parameters

3. Defining pedestrian routes

Terminal design involves the description of both spatial and operational characteristics so that, when accomplished, pedestrian traffic flows are analytically specified. Terminal description is then exported to Simulator.

3.1.1   Station segment design

The terminal is comprised of discrete segments of the predefined supported types. A distinguishing graphical representation is used for each type. A terminal may also extend to more than one level and thus creation, removal and editing levels are enabled. Icons can be repositioned and resized so that the station layout and spatial characteristics of individual segments are efficiently represented. Segment properties (e.g. dimensions) are also determined for each specific type.

3.1.2   Determining operational parameters

This activity involves determining operational parameters for each terminal segment, concerning critical issues, such as whether this segment acts as pedestrian traffic generator, whether it interconnects neighboring levels and whether it participates in a platform group. The corresponding dialog box for determining escalator operational parameters is displayed in Figure 3.
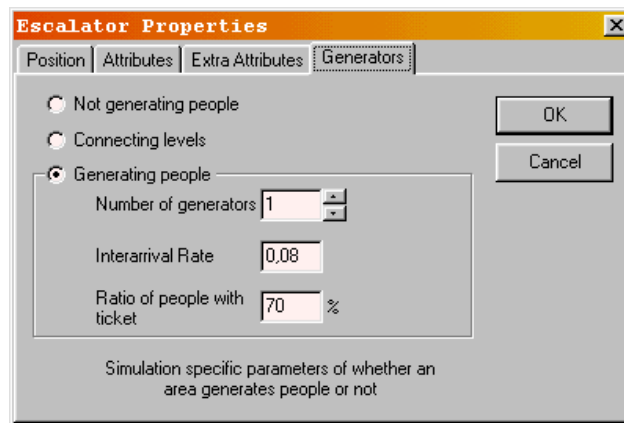

Figure 3: Escalator parameter definition

Models of pedestrian traffic generating segments include a generator module. Renewal models are used to provide pedestrian interarrival times. Generators create pedestrians that enter the terminal station from street heading to the boarding platforms, and vice versa. Segments that interconnect neighboring levels are usually either stairways or escalators. Segments corresponding to subplatforms of an overall platform are grouped together to form platform groups. As previously discussed, this feature enables modeling the heterogeneous behavior that passenger exhibit on platforms.

3.1.3   Defining pedestrian routes

The most significant activity in terminal design is the definition of pedestrian routes. Entry segments can either be street entrances (when pedestrians enter from street) or boarding platforms (when exiting to street). Exit segments are respectively defined. Routes for all entry/exit segment combinations have to be analytically defined, so that passenger flows within terminal segments are explicit. In this process, a number of entry/exit segment combinations are not valid and are thus excluded. Pedestrians entering the terminal either possess or must purchase a ticket before they proceed. Each route of pedestrians entering from street must thus be defined for pedestrians with and without a ticket. In the second case, routes must also include an intermediate destination, the ticket issuing facility.
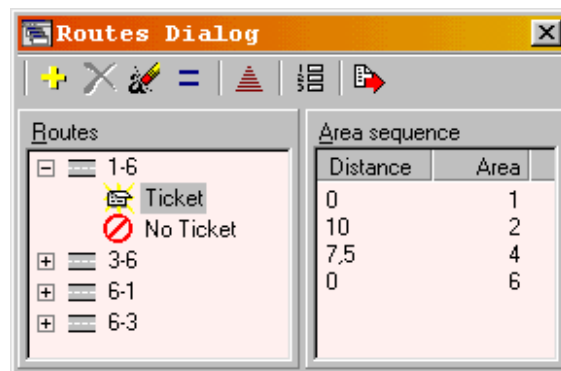

Figure 4: Routes definition

Routes form a directed graph extending throughout the terminal station, connecting segments and levels. Each node of a single route contains the walking distance for a pedestrian crossing a specific segment following a specific route. Evidently, there is a different walking distance for pedestrians crossing the same segment, depending on the specific route they follow. Pedestrian routing is thus performed on a step-by-step basis. Graph creation is accomplished through the GUI, as depicted in Figure 4. The flow diagram for route definition is depicted in Figure 5.
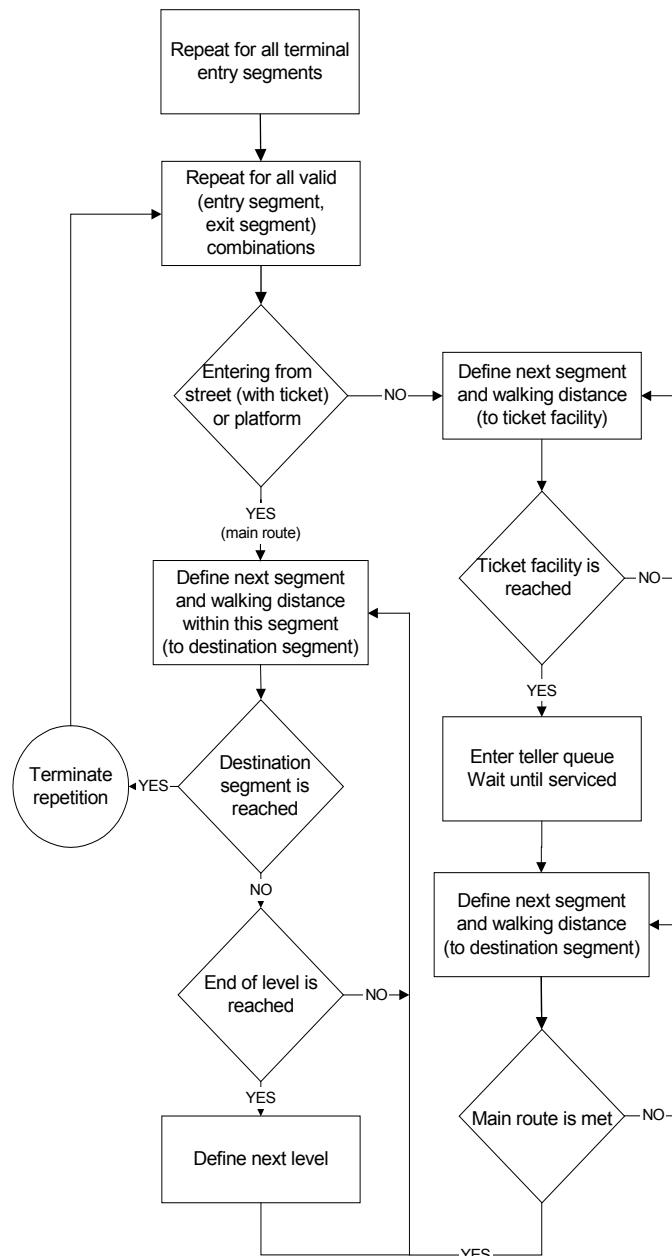
Figure 5: Route definition process flow diagram

The last activity in terminal design is assigning the corresponding probability to each specific route. This is performed for all entry segments and is accomplished via the Terminal Station Editor, which traverses the directed graph formed by the previously defined routes in all levels and creates pairs of entry/exit segments. Routes for all exit segments for a single entry are presented to the designer, who is responsible for assigning the appropriate values, as illustrated in Figure 6. These can be calculated based on either real observations or pedestrian traffic forecasts.
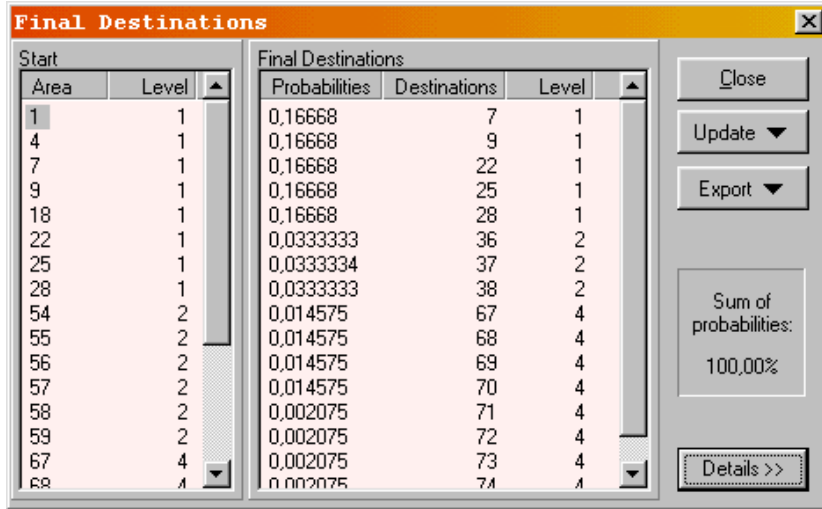
Figure 6: Route probabilities for a specific entry/all exit combinations

Walking speed is calculated for each pedestrian as a function of the current density and is adjusted in predefined time intervals. In this way, traffic is modeled more accurately, as both pedestrian speed and density within the same segment are constantly changing. Considering that each route consists of n segments $s_1, s_2, ..., s_n$, that need to be traversed and that the delay (i.e. time elapsing) within each segment i for walking distance l_i is denoted at d_i, the overall time (rd) required for each pedestrian to follow a specific route can be calculated as $rd = \sum_{i=1}^{n} d_i$. Calculation of d is accomplished depending on the specific segment type. For walkways, escalators, platforms and stairways, d is a stochastic function of pedestrian density (D) and l. For ticket issuing facilities, d is the sum of wait time (in the queue) and service time. We used the normal distribution for modeling pedestrian speed (S) as a stochastic process, based on the speed-module relationships discussed in section 3. Then, for each pedestrian within segment i,

$$d_i = l_i / S .$$

Considering that there is a maximum speed of 400 feet/min that may be attained by pedestrians (Puskarev and Zupan 1975), d is calculated for walkways as follows [note that, according to Fruin, the theoretical maximum pedestrian speed when module is infinite is equal to 470 ft/sec (7.833 ft/sec)].

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$$S = min\left(max\left(Normal\left(m,\sigma\right),0\right),400\right)$$

where $m = max\left(285.4 - \dfrac{858.856}{M}\right)$ is the speed corresponding to the current value of M (S should always have a positive value and also be less than 400). Both normal distribution parameters are subjected to calibration for the specific terminal segments under examination.

When walking speed is adjusted to the current density in predefined time intervals, both d and l are recalculated. In this way, the actual process, where pedestrians change their speed with a variable rate according to the area density, is realistically represented.

3.2   Simulator

Simulator is the tool responsible for model building, experimentation and output analysis. The model is automatically constructed based on the terminal description. Experimentation is consequently conducted according to simulation parameters provided by PEDSIM user. The graphical interface is implemented using SimGraphics (CACI 1998b). Experimentation encompasses the following activities:

1. Determining simulation parameters

2. Running experiments

3. Analyzing results

Determining parameters involves the experiment duration, warm up period, number of repetitions as well as if graphical representation is enabled. Simulation experiments are then executed under the various user-defined scenarios (concerning input load, etc). Simulator acquires automated model generation capabilities, transforming the original terminal description into simulation code through importing object-oriented, preconstructed models. Preconstructed models correspond to the terminal segment types and reside in model libraries. Model hierarchies are depicted in Figure 7. There are three basic object types (classes): Pedestrian, Segment and Generator. All segment types are derived as ancestors of the two latter types. Escalator Unit Generator is the most complex class, derived as ancestor of both Segment and Generator classes, using multiple inheritance. In this way, Escalator Unit Generator acquires the properties of both its predecessors (i.e. behaves both as a

segment and flow generator). Construction of customized segment models (e.g. for ticket barriers, which can be modeled as multiple-server/multiple-queue systems, as ancestors of Ticket Facility class) is supported through hierarchical layering, which enables the construction of complex models through extending the behavior of existing objects and ensures that models of a single entity, such as segment models, organized in a single class hierarchy can be accessed through a common interface (i.e. common object methods), using polymorphism (Zeigler 1995).
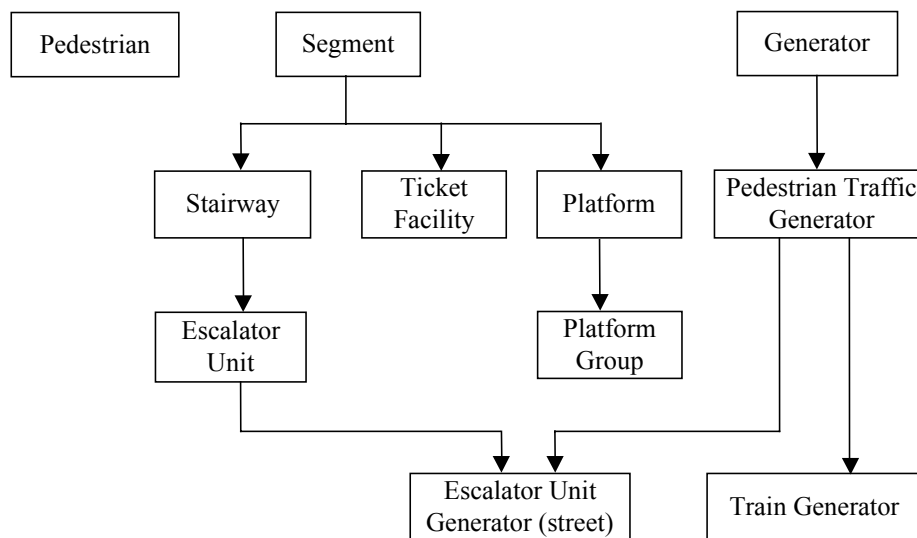
Figure 7: PEDSIM object class hierarchy

Each PEDSIM application (i.e. simulation experiment) is also modeled as an object instance. A single instance of this class corresponds to a simulation experiment. *Application* class can also be overridden so that either a textual or a graphical representation is provided. The latter is used for visualization and model validation purposes, whereas textual representation is preferable for faster model execution.

Pedestrian flow results involve a minimum/average/maximum walking speed analysis to determine the level of service provided within each segment. Analysis is oriented towards: i. terminal design, to reach conclusions for the use of terminal segments and the level of service provided, as well as to indicate potential design deficiencies, and ii. pedestrian routes, to obtain a clear view of

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pedestrian flows and indicate potential problems in specific routes. Simulation results for the predefined measures of interest are graphically presented to enable decision making.

4   Case Study of the Omonia Metro Station

PEDSIM was used to study pedestrian traffic in Omonia station, a major terminal of the lately redesigned and expanded Athens underground. Pedestrian flows were studied during the design and construction of the terminal, so that evaluation results could provide a feedback to these phases. Long-term estimates for pedestrian traffic were used for morning and evening peak hours. Omonia is a four-level interchange station between two lines of the underground. Line platforms reside in levels L2 and L4. L1 is the concourse level and L3 is the transfer level between lines. Pedestrians crossing the station without entering the restricted passenger area also use the concourse level (Figure 8).
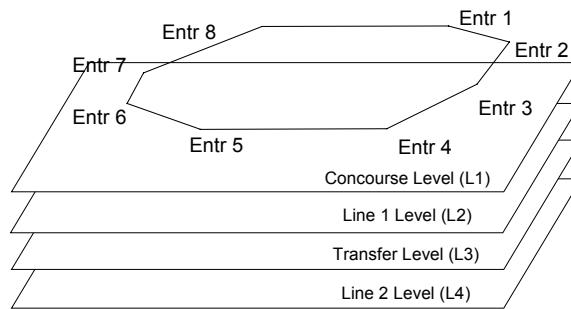

Figure 8: Abstract representation of Omonia station

The concourse level has 8 entry/exit points to street. There are 6 stairways and 2 escalator units between this level and L2, 3 escalator units between levels L2 and L3, and 4 escalators units between levels L3 and L4 (Figure 8). Each escalator unit includes two escalators and a stairway. Pedestrian flows within the terminal according to long term forecasts are depicted in Table 1. Trains of both lines arrive every 4 minutes and the mean embarking/disembarking time is 48 seconds. The concourse level does not include any ticket barriers. Elevators were not modeled due to their kind of use and capacity, as they actually have no practical impact on traffic load, especially during peak hours.

The terminal is divided into 78 discrete segments of all five types (walkways, escalators etc). A subset of them (22 segments) is also used as pedestrian traffic generators. These segments are either entries/exits to street or platforms. Corresponding to the acceptable entry/exit combinations, 153 discrete routes and the corresponding probability for each route were defined. Simulation provided statistical results for the above segments and routes, such as the walking speed and route delay, which are used to calculate the level of service within each of the 78 segments according to the LOS criteria for moving pedestrian streams (TRB 1994). Route-oriented results, as the number of pedestrians and the walking time statistics were also provided. The list of predefined statistics can also be extended through incorporating appropriate statistical objects for monitoring other measures of interest (CACI 1998a).

Morning Peak Hours		Destination				
		Street	Line 1 Central Platform	Line 2 northbound Platform 2	Line 2 southbound Platform 1	Total
Origin	Street	5000	600	50	350	6000
	Line 1 (northbound)	6800	0	125	1275	8200
	Line 1 (southbound)	3400	0	125	575	4100
	Line 2 (southbound)	9800	2100	0	0	11900
	Line 2 (northbound)	3100	700	0	0	3800
	Total	28100	3400	300	2200	34000

Table 1: Long-term forecasts

Experimentation with the simulation model was performed for the morning peak hours where most passengers arrive to the terminal by train. The simulation experiment covered a two-hour duration, from 7:00 am to 9:00 am. The results involve all routes from the trains to the street, and vice versa, as well as the pedestrians traversing the station without using the underground. An instance of the running experiment is presented in Figure 9. Graphical representation also includes the current number of pedestrians and the currently provided level of service within each segment, which is marked with a distinguishing color in order to enhance the usability of simulation results.

The measurements obtained indicated that the overall terminal operation appeared to be within acceptable boundaries, even though shorter times may have been expected for specific routes. A limited number of segments of the concourse level also appeared to be especially crowded, providing

a low level of service (E) for short, not longer than 10 seconds, time periods. Model calibration (involving modeling parameters m and σ of normal distribution) was accomplished for the specific terminal segments for which monitoring capabilities were enabled. Calibration was oriented towards the speed/density relationship, as pedestrian walking speeds were higher than expected for the morning peak hours, and the percentage of pedestrians using stairways instead of escalators, which was actually less than expected due to the increased stairway length. PEDSIM can also be customized to adopt alternative flow modeling approaches through extending the existing segment model behavior in the object hierarchies (Figure 7), in order to apply a case-specific approach for specific segments, if more appropriate.
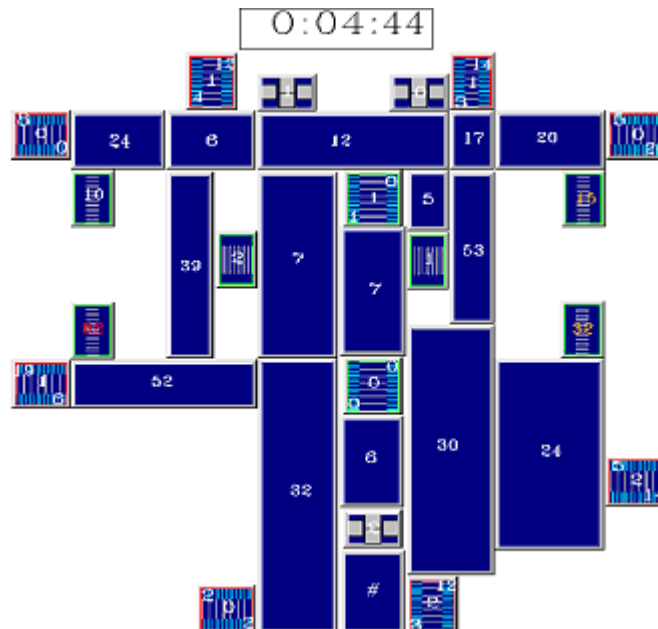

Figure 9: Instance of a running experiment (concourse level)

5   Conclusions

The simulation environment introduced has the following important characteristics: integration of the design and the experimentation phases, flexibility, automated model generation through the use of preconstructed, extendable models, efficient pedestrian flow modeling on the basis of standardized models, detailed description of input data (e.g. traffic generation data and pedestrian

routes) and experimentation parameters, and graphical representation of the level of service provided within individual segments.

Simulation of transport terminals is an efficient decision support tool for testing and evaluating different operation strategies and supporting the optimization of terminal operations. It also provides a well-structured concept of performance evaluation and comparison of terminal operations against standards that are based on quantitative measures of service. PEDSIM can also be oriented towards emergency response planning in order to evaluate reactions to potential emergency scenarios, and this is the objective of our current research. Except for dealing with specific traffic data and pedestrian routes, this also requires the terminal description to be modified according to the emergency planning conditions (concerning the direction of escalators, etc).

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