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Enhancing Transit Facility Design

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ABSTRACT

The use of simulation as an integral element of transit facility design has become increasingly popular with the development of new software in a transportation engineer's toolbox. Beyond the most basic operational assessments, these tools have the ability to demonstrate people movements, frequently traveled paths, and separately, levels of service. Of particular interest to architects and designers, the simulations provide improved and, at times, more realistic results that better clarify and illustrate the "effectiveness" of their work in a dynamic manner.

Furthermore, gone are the days of only relying on spreadsheets and bringing to the public a few rudimentary tables listing analysis results. It is now commonplace for public interest groups to frequently expect consultants to have such a dynamic graphical tool at the ready for them to examine.

STV is involved in a number of projects that require input as to how transportation terminals and stations will function well before design alternatives have been finalized. In fact, the provision for simulation efforts has been a required evaluation criterion for the acceptance of specific conceptual and preliminary design schemes.

Given today's heightened security concerns, accounting for rapid emergency egress is of paramount interest to designers. Pedestrian simulation modeling allows for the relatively quick analysis of multiple pedestrian scenarios including emergency evacuation and normal circulation possibilities, which realistically assigns people to the nearest exits, measures egress times, identifies points of congestion, and requires minimum preparation time.

The capabilities and advantages of pedestrian simulation modeling will be demonstrated based on analyses performed for projects such as the design of the Port Authority of New York and New Jersey's World Trade Center Transportation Hub and the reconstruction of New York City Transit's Cortlandt Street 1 Train station within WTC Site. Both projects are intermodal in nature, and involve the complex "mixing" of people from many origins and destinations.

The images and videos provided by the simulation, and included with this paper, have proven to serve as powerful and conclusive input to designs that provide for the smooth and efficient movement of people through stations and terminals.

INTRODUCTION

Almost two decades ago, the onset of Long Island Rail Road's attempt to bring commuter rail service into Manhattan's Upper East Side brought focus to the agency's desire to provide more-than-adequate operations for its customers as they were to ascend from their deep-tunnel platforms. Of course, earlier strides were made to detail pedestrian movements with Fruin's groundbreaking studies in the 1960s (Fruin 1971, 1987), and later with Benz' time-space methodologies (Benz 1985), but these were static analyses requiring reviewers and the public to

look at abstract results as being adequately representative. Such “leaps of faith” were largely dependant on analysts’ communicative skills.

Complicating this work was the advent of the National Fire Protection Association’s 1982 guidelines (NFPA 1987) to assess transit station pedestrian clearance abilities from emergency scenarios. These guidelines, too, presented more calculation arcana for engineers to potentially mystify others with.

Then, basic analyses were acceptable to STV clients since these assessments were well conducted and detailed in reports. And now, such work with the basic building blocks of pedestrian analyses is still well received. Yet, tools have become available to make our analyses and products better.

As transit systems were planned and constructed in foreign cities in the late 1990s, so grew the appetites of architects and engineers to examine the effects of their designs on pedestrian flows *before* such plans were constructed. And designers could ill afford to construct inadequately designed terminals and stations. These concerns, in turn, was the genesis to using powerful computers and mathematical advances to create visual simulations of people movements as an overlay onto proposed layouts.

Today, our latest marquee project, one of the country’s most visible, involves planning and designing the new transportation hub at New York City’s World Trade Center site. Our use of static *and* dynamic tools is a requirement of our client to demonstrate that the agreed upon basis of designs will be achieved.

The paper focuses on three concerns. First, how is a model developed? Second, once functional, what will the analyst see and is it telling a “realistic story”? Finally, what benefits accrue from the work involved to construct such a model?

MODEL DEVELOPMENT

STV uses the STEPS (Simulation of *T*ransient *E*vacuation and *P*edestrian movement*S*) (Mott MacDonald 2005) simulation software modeling program that simulates pedestrian movements under both normal and emergency conditions, and provides easily understandable, real-time 3D simulations that graphically presents pedestrian movements, level of service, and usage.

The development of the pedestrian model can be organized into two categories, the building of the physical background elements and the creation of pedestrian movements. The physical background elements of the model consist of floor levels, walls, escalators, stairs, turnstiles, elevators, and train movements in to and out of a station/terminal – in essence, all the physical elements that compose a “working structure.” Throughout the modeling process, various physical background items are adjusted in order to realistically simulate pedestrian conditions and control/shape pedestrian maneuvers, such as walking speeds on stairs/escalators, turnstile/doorway processing rates, and pedestrian movement restrictions adjacent to platform edges.

The pedestrian events identify the characteristics of the people who will be modeled in the simulation; specifically, the number of people (i.e., groupings), their origins and destinations, walking speeds, composition (i.e., tourist vs. commuter), assigned routes, physical size, and patience levels.

MODEL OUTPUTS

Following is a sample of three of the advantageous simulation outputs provided by the STEPS model that could assist an analyst examining a station. First, a real-time simulation output of pedestrians walking and queuing within corridors, ascending/descending VCEs, boarding/alighting trains, and traversing through turnstiles is provided to give the viewer a sense of scale for the project in terms of the size of the facility and the volume of people. For example, a stakeholder can visually understand the difference between 500 versus 5,000 people per hour walking through a 10-foot-wide corridor.

Figure 1 is a sample simulation image of a station platform as alighting train passengers surge toward the vertical circulation elements. The simulation realistically models pedestrian behaviors on a platform as people move to the nearest VCE bank, as compared to walking on the platform, in order to alight a platform sooner.

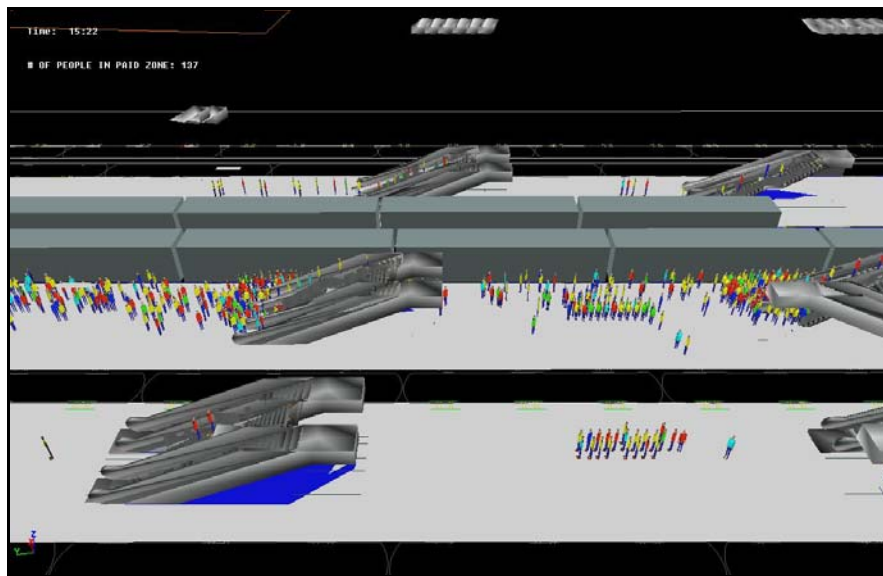


Figure 1: Platform Clearance Conditions during Train Alighting Surge

The sample image presented in Figure 2 focuses on pedestrian queuing near the base of a VCE bank. Again, the model appropriately simulates pedestrian flow behaviors as the passengers tend to walk along the shortest path between origin and destination and, consequently, tend to select a vertical circulation element closest to their origin.

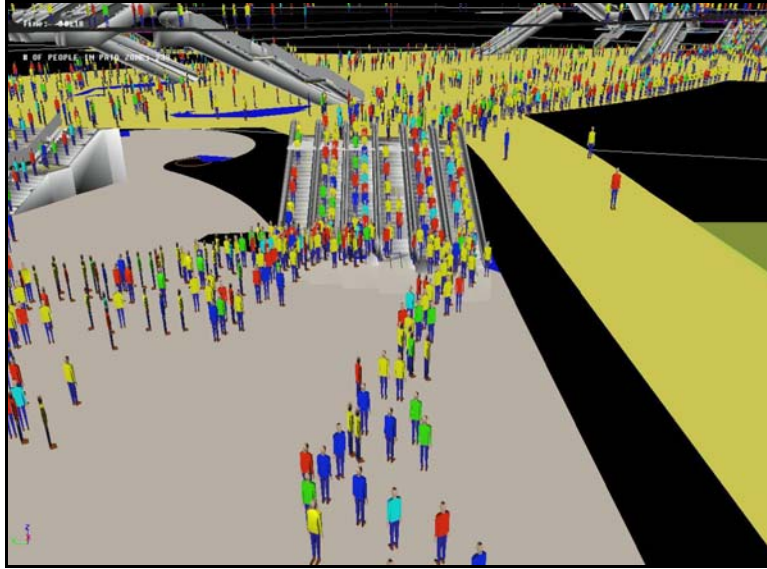


Figure 2: Pedestrian Queuing at Escalators during Train Alighting Surge

Second, the simulation identifies “hot spots,” locations that exhibit a high pedestrian density and possibly operate at poor levels of service. These images are similar to Doppler radar pictures, which identify locations of intense precipitation; in STEPS, deep red signifies dense pedestrian activity operating at a poor level of service.

The procedures for estimating and evaluating pedestrian capacity and level of service (LOS) are based on criteria established by Fruin and recommended within the Transportation Research Board’s *Transit Capacity and Quality of Service Manual* (TRB 2003). Pedestrian LOS thresholds related to walking are based on the freedom to select desired walking speeds and the ability to bypass slower-moving pedestrians.

The images presented in Figures 3 and 4 highlight the use of the level-of-service simulation for the images presented in Figures 1 and 2, respectively. Notice the deep red colors at the base of the VCE banks, indicating pedestrian queuing and poor LOS conditions. The green shades indicate moderate pedestrian flow at an acceptable LOS condition, and the cool blue colors highlight areas of low pedestrian activity.

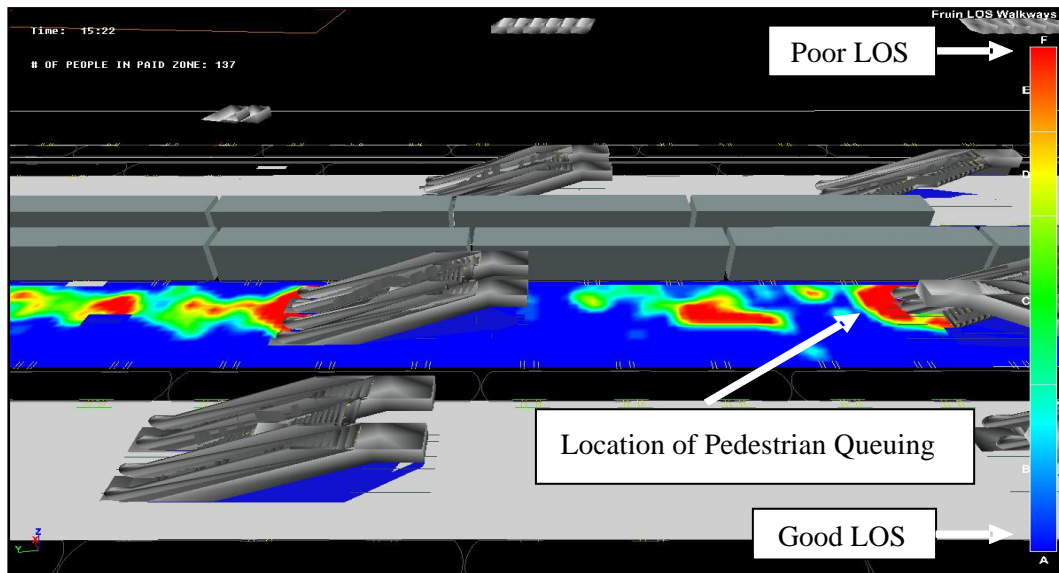


Figure 3: Platform Clearance LOS Conditions during Train Alighting Surge

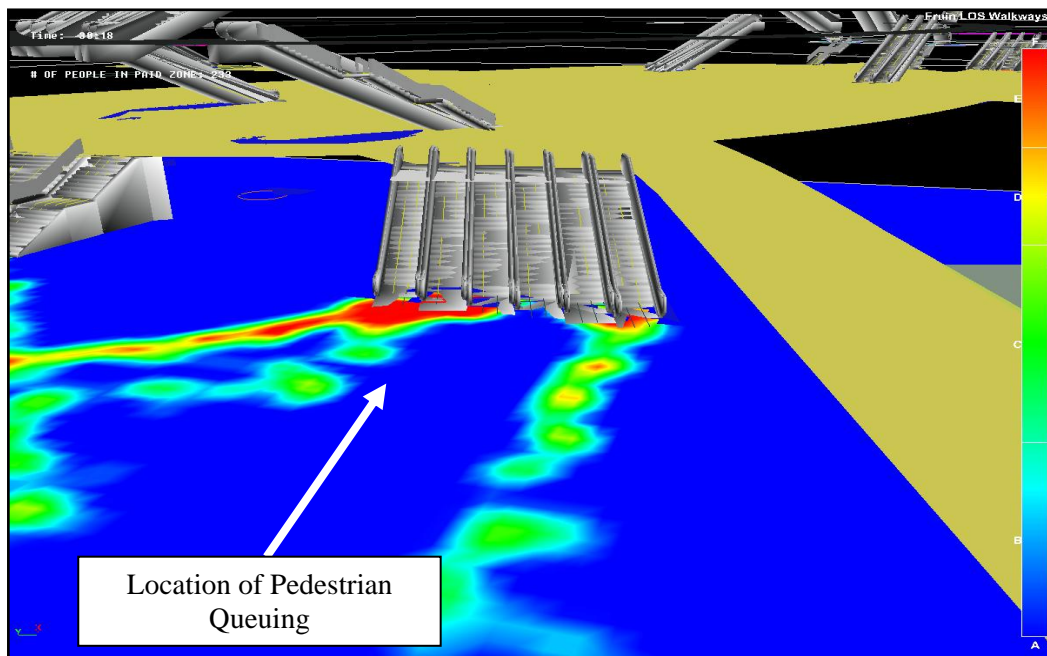


Figure 4: Pedestrian Queuing LOS Conditions during Train Alighting Surge

Third, the simulation can highlight high-usage walking paths through a terminal/station (see Figure 5). The easy identification of desired pedestrian routes can guide designers to properly locate wayfinding signage, VCEs, and retail kiosks so as not to obstruct preferred pedestrian paths. Obstructions within these desire lines create pedestrian turbulence, a reduction in pedestrian walking speeds, and a deterioration in pedestrian LOS.

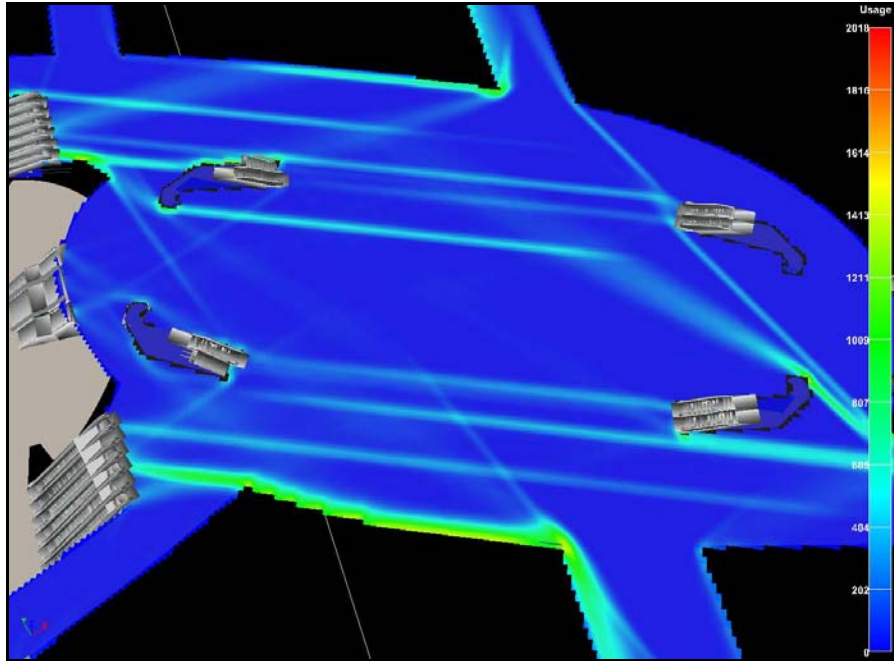


Figure 5: Plan View of a Concourse Showing Pedestrian Travel Paths

Here is where the value of dynamic pedestrian modeling bears fruit in that as different designs are created, we can see their effectiveness relative to each other and thus help winnow down multiple design choices to a select few.

In addition to the simulation outputs, the model can provide statistical, spreadsheet-type outputs, such as the number of people in the model per time increment, number of people in a particular area (i.e., pedestrian occupancy/density), pedestrian egress times, and pedestrian flow volumes at specific checkpoints.

MODEL BENEFITS

Several pedestrian simulation benefits have already been highlighted, but more detailed discussions of specific model advantages worth noting follow. One valued feature of pedestrian simulation is that transit-surge effects can be seen, rather than simply read as shown right in the sample output table listing waiting times and person densities over time to pass through individual turnstiles. Such a table is informative to the analyst for comparison with independent static analyses, but can be visually complicated to the public.

Time Interval	Density at Turnstile Entrance (m ² /person)	Exit Wait Time at Specific Turnstiles (seconds)					
		1	2	3	4	5	6
1:25	10.0	0.3	0.5	1.1	0.0	0.5	0.1
1:30	13.3	0.3	0.6	1.0	0.3	0.4	0.1
1:35	10.0	0.2	0.7	1.4	0.8	0.4	0.1
1:40	10.0	0.3	0.6	1.2	1.0	0.4	0.1
1:45	13.3	0.4	0.7	1.1	0.8	0.3	0.2
1:50	13.3	0.4	0.7	0.8	0.9	0.3	0.2
1:55	5.7			0.8	0.8	0.3	0.2

More information and tools are needed for our work because standard planning procedures for calculating the number of turnstiles needed to process passengers at a station are based on average peak period passenger arrival rates. Passengers truly exit a station in groups based on

the train arrivals. A dynamic simulation model allows users to see the effects of transit surges at the turnstile array, measure the maximum queue length, and calculate passenger egress times, certainly more comprehensible than such a table shown above. This feature becomes increasingly more useful at terminal stations where the transit surge volume could be highest and at stations with several transit lines where multiple transit surges may converge.

The model has been used to demonstrate the influence of various design alternatives on pedestrian movements and flows. Alternative station support-column configurations have been examined to evaluate their pedestrian impedance. Similarly, a convex versus concave configuration of a set of doors has been modeled to determine the pedestrian door-use distribution across an entry/exit.

Given today's heightened security concerns, accounting for rapid emergency egress during chance events such as escalator failures is of paramount interest to designers. Once a base model has been created, relatively quick analysis of multiple pedestrian scenarios including emergency evacuation and normal circulation possibilities can be examined. Conditions such as "downed" escalators or closed/untenable exits can be developed to measure egress times and identify congestion.

CONCLUSIONS

The use of simulation as an integral element of transit facility design has become increasingly popular with the development of new software in the transportation engineer's toolbox. Beyond the most basic operational assessments, these tools have the ability to demonstrate people movements, frequently traveled paths, and separately, levels of service. Of particular interest to architects and designers, the simulations provide improved and, at times, more realistic results that better clarify and illustrate the "effectiveness" of their work in a dynamic manner. That is, know where bottlenecks could happen during the virtual assessment, and modify plans to prevent such design shortcomings.

The sampling of the benefits and features of pedestrian simulation modeling highlighted in this paper provide a glimpse into the resources and capabilities of using this tool to serve as powerful and conclusive input to designs that provide for the smooth and efficient movement of people through stations and terminals.

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STEPS software version 2.1 was designed by Mott MacDonald, and is used under a license agreement dated May 18, 2005.

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