PC-Based Pedestrian Flow Simulation Model for Grand Central Terminal

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ABSTRACT

A pedestrian flow simulation model was developed to test and evaluate the proposed underground pedestrian network for Grand Central Terminal's North End Access Improvements. The simulation model runs on a personal computer (PC) using the LOTUS 1-2-3 spreadsheet program. Based on the results of the simulation, planners modified the design to increase the capacities of certain passageways and to develop a more cost-effective design solution. Also, the model was used to test nearly a dozen construction-phasing options to respond to capital funding availability and passenger flow needs. The model, although not as sophisticated as some previous simulation programs, proved to be a useful and cost-effective tool in the design process. It uses widely available, inexpensive personal computer hardware and software. The pedestrian flow simulation model, its essential components, and how it was used as a design tool are described in this paper. The advantages and disadvantages of this type of approach are discussed in the conclusion.

The design of a new underground pedestrian passageway system is underway for historic Grand Central Terminal in New York City. Metro-North Commuter Railroad Corporation of the Metropolitan Transportation Authority is planning the North End Access Improvements to shorten the travel time for commuters and to reduce pedestrian congestion within and around the terminal. More than 150,000 rail commuters and subway riders will benefit from the improvements each day. A pedestrian flow simulation model that was developed to test and evaluate the proposed facilities is described in this paper. The simulation model runs on a personal computer (PC) using the LOTUS 1-2-3 spreadsheet program. Based on the results of the simulation, planners modified the design to increase capacities of passageways and to develop more cost-effective design solutions. The model also was used to test nearly a dozen construction-phasing options to respond to capital funding availability and passenger flow needs.

The model, although not as sophisticated as some previous simulation programs, proved to be a useful and cost-effective tool in the design process. It uses widely available, inexpensive personal computer hardware and software.

The pedestrian flow simulation model, its essential components, and how it was used as a design tool are described in this paper. The advantages and disadvantages of this type of approach are discussed in the conclusion.

BACKGROUND OF THE PROJECT

Grand Central Terminal is located in Midtown Manhattan at 42nd Street and Park Avenue (see Figure 1). It serves as a "stub end" terminal for trains arriving from the north. The terminal is the southernmost point on Metro-North's Harlem, Hudson, and New Haven lines, and it also serves long distance Amtrak service to upper New York State and the midwest. The only way for pedestrians to reach the train platforms is by walking through the main concourse at the south (downtown) end of the platforms, as shown in Figure 2.

When Grand Central Terminal was opened in 1913, the southern orientation of its exits served its commuters well because virtually all of Manhattan's development was south of the terminal. However, over the past 70 years, dense office building development has occurred to the north of the terminal. This shift in land use means that 57 percent of all morning peak-hour Metro-North riders are headed for destinations north of the terminal--between 42nd and 60th Streets in Midtown Manhattan. Most (94 percent) of those riders walk to their destinations (1).

The terminal was designed to handle southbound pedestrian flows out of the terminal, but the majority of the people are now headed northbound. This shift has created several problems. One problem is backtracking--northbound passengers exiting trains must first walk south off the platforms and into the main concourse before they can reverse direction and walk north (see Figure 3). Another problem is the congestion and delay created at the exits, corridors, and vertical circulation facilities used by these northbound passengers.

A solution to these problems is to build new exits leading from the north ends of the underground train platforms directly to the street. The North End Access Improvements will provide this direct access (see Figure 4). Conceptually, the North End Access Improvements will superimpose a grid of two north-south and two east-west walkways over the existing platforms, allowing most passengers to reach the new northern exits.

Two nonrevenue tracks will be covered over and converted into north-south walkways, or spines, that will run from the main concourse of Grand Central Terminal at 43rd Street northward to 47th and 48th Streets. The new north-south spines will replace tracks 22 and 31, currently used for maintenance, on the upper level. (Grand Central Terminal's tracks and platforms occupy two underground levels. The upper level tracks are numbered 11 through 42, and the lower level tracks are numbered 101 through 116.)

Two east-west cross passageways will tie into the north-south spines to allow passengers from virtually all platforms to reach the spines. The two cross passageways will be constructed at a new level be-

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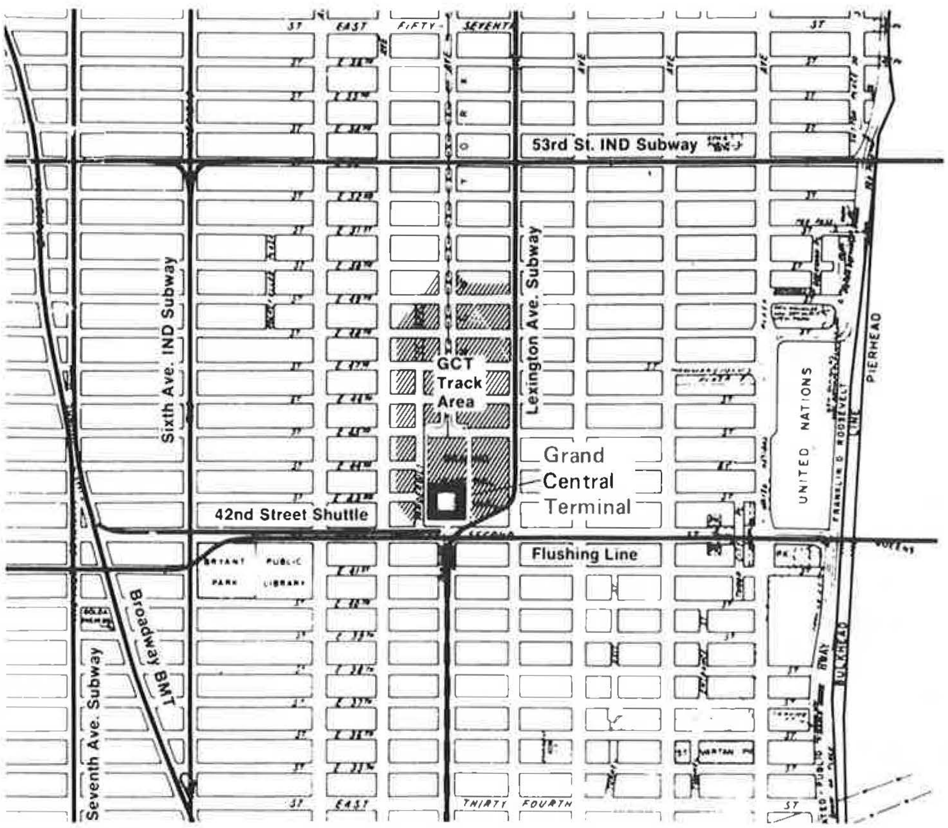

FIGURE 1 Grand Central Terminal and environs.

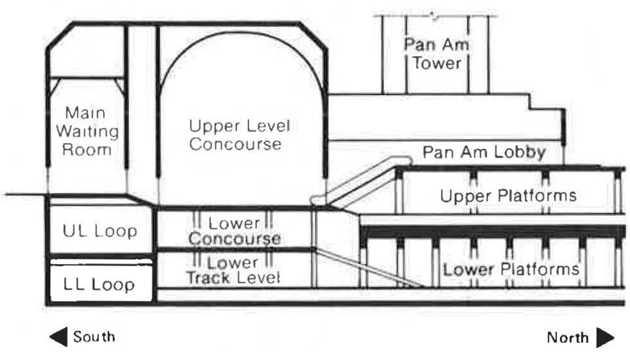

FIGURE 2 Section of Grand Central Terminal. All passengers presently must walk south to the concourses.

tween the upper and lower train levels--one under 45th Street and a second one under 47th Street. The 45th Street cross passageway will serve the lower level platforms by new stairs. The 47th Street cross passageway will serve the upper level platforms. The cross passageways range in width from 25 to 33 ft whereas each of the north-south spines is approximately 25 ft wide. There are eight proposed surface connections for north end access--four along 45th Street and four along 47th Street. In addition, two additional surface connections are possible as parts of proposed development projects.

The North End Access Improvements were originally proposed and recommended in 1975 when the New York Metropolitan Transportation Authority issued the Grand Central Terminal Improvements Technical Study (2). In that study, the need, feasibility, and desirability of the improvements were established. For a variety of reasons--primarily the lack of funding--the North End Access Improvements were not advanced beyond the 1975 feasibility study. In 1984 Metro-North contracted with Parsons Brinckerhoff Quade & Douglas, Inc., to prepare the necessary planning, architectural, and engineering analyses and documents to implement the proposed North End Access Improvements.

The work program for the North End Access Improvements project was undertaken in two phases. The first phase reexamined the 1975 concept in terms of need, effectiveness, costs and benefits, and implementability. These analyses provided Metro-North the information and materials it needed to gain approval and funding for the improvements. In the second phase, the architectural and engineering documents needed to implement the project are being prepared.

As part of the work program, a means of examining peak passenger loads in the proposed pedestrian facilities was needed. Because the proposed facilities are to be built within the confines of existing structures while maintaining peak-period train capacity, the sizes and configurations of new elements, and therefore their capacities, are physically constrained. Therefore, the key to the design process was to determine the performance and adequacy of the various elements of the North End Access Improvements--corridors, vertical circulation, and waiting areas--given their physical and operational constraints. The expected peak volumes within portions of proposed facilities were to be compared to the available capacities at a design standard level of service.

No existing pedestrian flow simulation computer program was found to fulfill the requirements of the study scope and design process, particularly one that would meet the project's tight budget and schedule. Therefore, the study team decided to develop a passenger flow simulation model geared specifically to the needs of this study, based on readily available personal computer hardware and

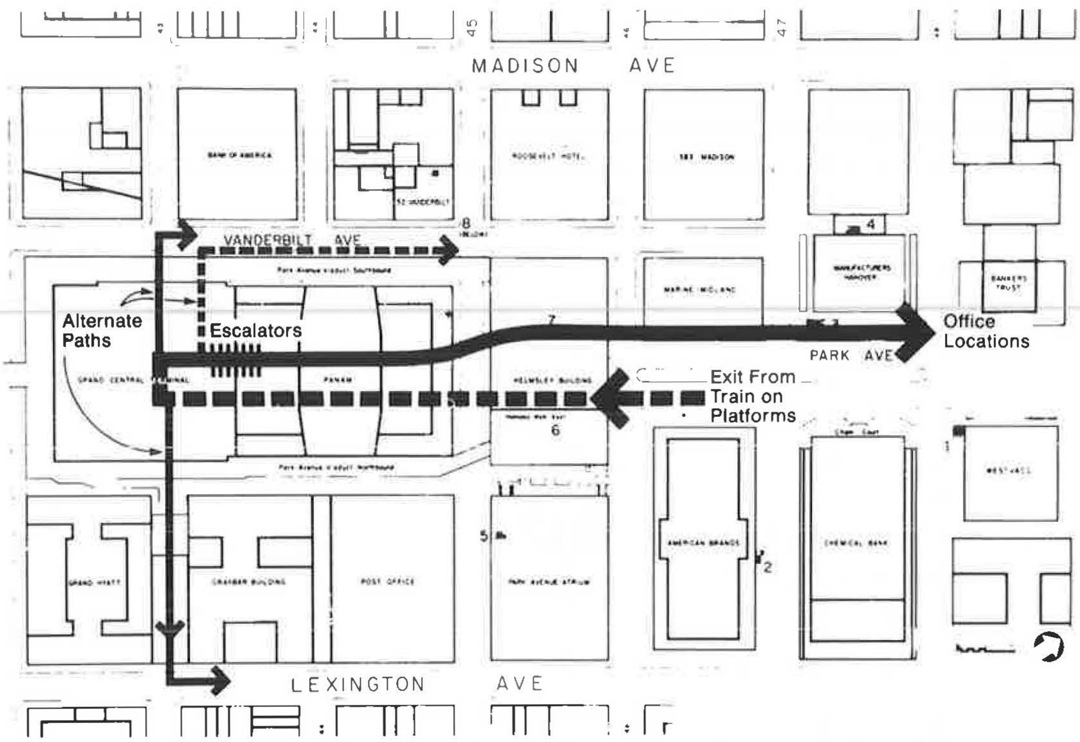

FIGURE 3 Path of typical Metro-North commuter from midpoint of platform to northward destination.

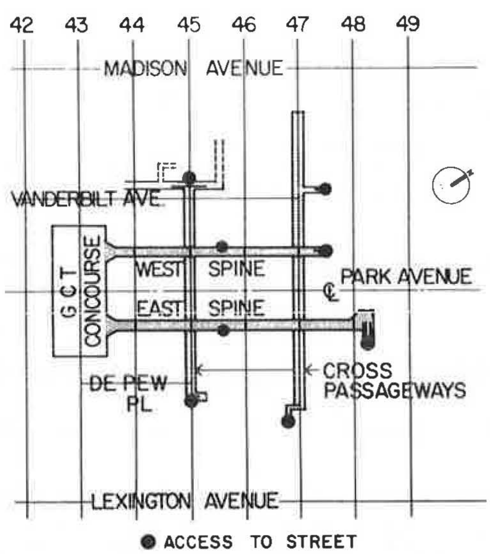

FIGURE 4 North End Access concept.

software. The program operates on an IBM PC using the LOTUS 1-2-3 spreadsheet program. This program is a simplified model that traces its origin to the UMTA Transit Station Simulation (USS) model (3).

MODEL DESCRIPTION

The basic components of the pedestrian flow simulation model are network definition, trip generation, trip distribution, trip assignment, assessment of congestion levels, and sensitivity analysis (see Figure 5). Each component is discussed in the paragraphs that follow.

Network Definition

The first step in the process is to define a pedestrian network in terms of links, nodes, sources, and sinks, as shown in Figure 6. Each link represents a portion of a pedestrian path such as a corridor or stair. The proposed Grand Central Terminal Improvement network is modeled by 44 links. Each node represents either a point of intersection between links or a "source" or "sink." A source node defines a place where people enter the network system; a sink node is where they leave the system. The network has 12 source nodes and 13 sink nodes.

In the model, the primary sources of pedestrians are the train platforms where Metro-North riders leave their trains and begin walking toward their destinations. Grand Central Terminal actually contains 13 lower level platforms and 15 upper level platforms, but for modeling purposes, groups of adjacent platforms were aggregated, forming five source nodes on each level. Two additional sources represent entrances where pedestrians enter the system from the street or adjacent subway stations by way of the main concourse of the terminal.

There are 13 sinks or exits by which pedestrians can leave the North End Access pedestrian system. Ten of the exits are new ones created by the project (including the two potential connections with new development projects), and three represent existing exits through the main concourse itself.

Trip Generation

The number of pedestrians arriving at each source was estimated from train arrival schedules and passenger loadings for a typical Metro-North weekday. Using Lotus 1-2-3 as a database manager, train movements for an entire day were entered onto a spreadsheet. The database contains for each train information about train arrival time, platform and track

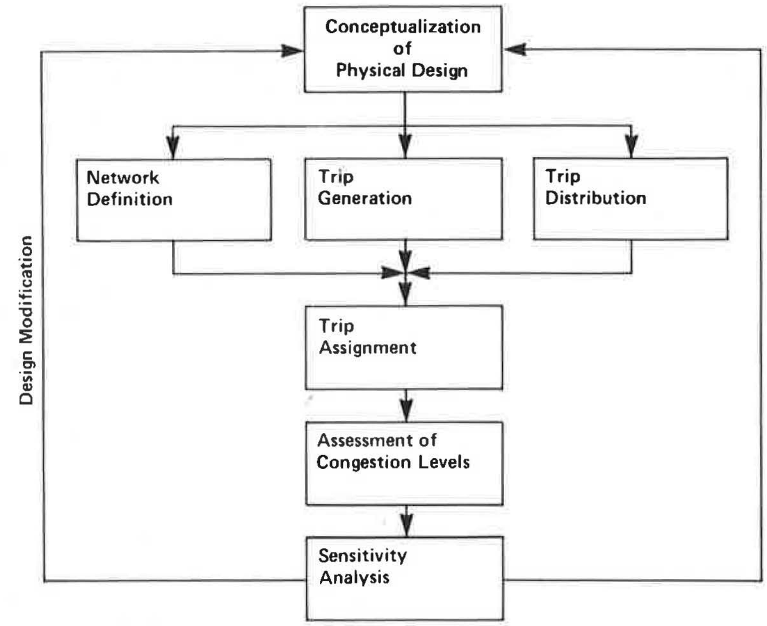

FIGURE 5 Pedestrian flow simulation methodology.

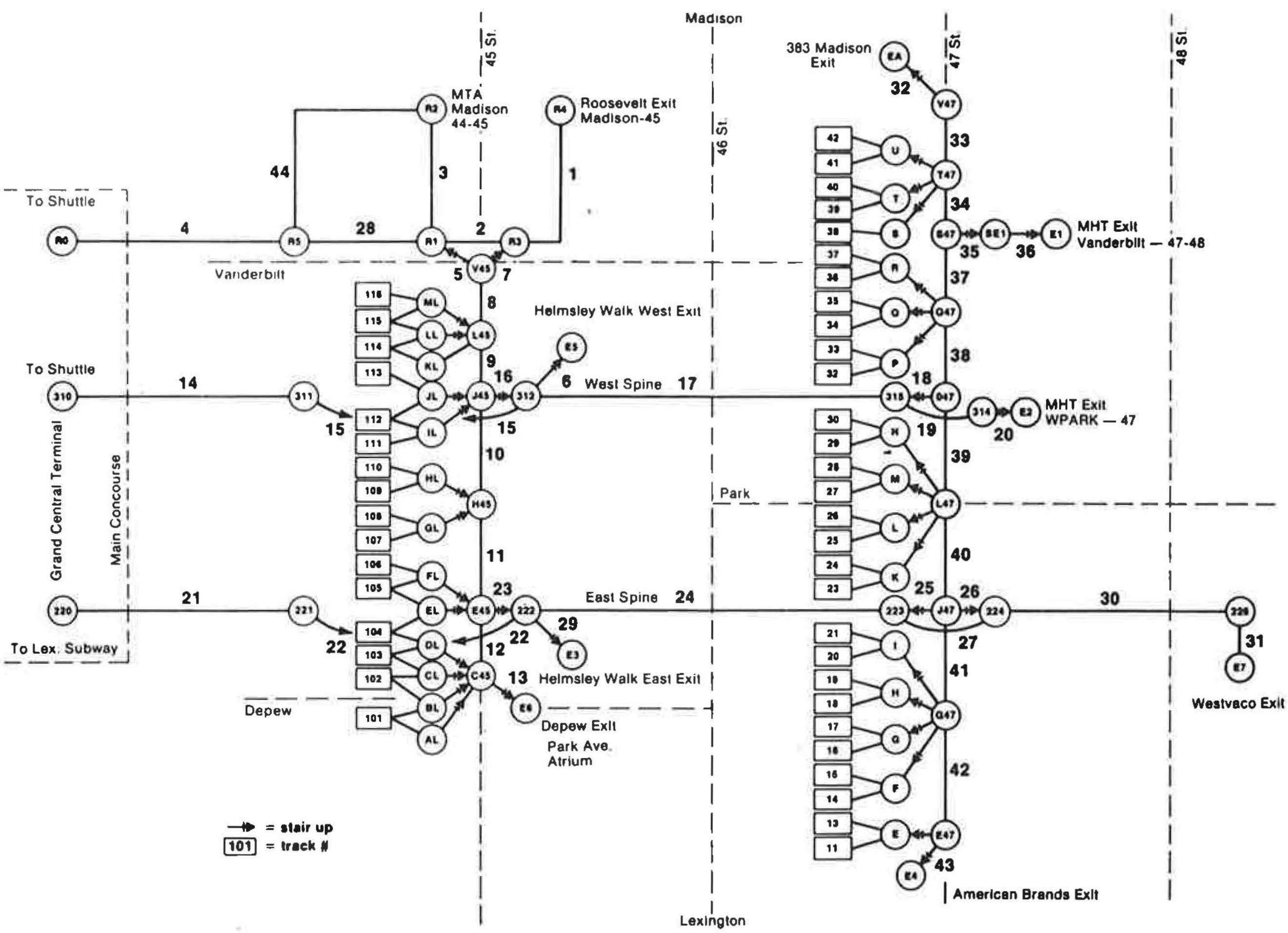

FIGURE 6 Schematic Plan of North End Access flow network shows upper and lower level tracks (sources), passageways (links), transfer points (nodes), and exits (sinks).

location, the number of cars, the typical number of passengers, and the branch of the rail network where the train picked up passengers.

The database of arriving trains was sorted by time of arrival and track location. For each 15-min period of the day the number of arriving passengers was aggregated in order to find the peak 15-min and 1-hr periods in the morning and afternoon. Once the peak time periods were chosen, the passenger arrivals were aggregated by platform groupings making up each source in the network. Trip generation for future years was accomplished by applying various demographic growth rates representing growth in rail ridership and in Manhattan employment.

In addition to peak direction Metro-North commuters, three other groups of potential users of the proposed system were included in the simulation model:

- "Reverse" direction Metro-North commuters.
- Non-Metro-North users walking in a north-to-south direction.
- Non-Metro-North users walking in a south-to-north direction.

Trip Distribution

For the purposes of the pedestrian flow simulation model, Manhattan was divided into 24 geographic zones surrounding Grand Central Terminal. The arriving train passengers were distributed to these destination zones according to a passenger origin-destination survey completed for this project.

The distribution of passengers walking to each zone was calculated by multiplying the number of arriving passengers headed for each zone by the percentage of passengers walking to that zone. The percentage walking was also determined from the ridership survey. Trip distribution for future years was determined by applying employment growth factors that were specific to each geographic zone of Manhattan.

Once the passengers were distributed into the geographic zones, they were distributed to North End Access exits. Passengers headed for each zone were assigned the exit offering the most direct walking path to that zone. Statistical analysis of the Metro-North ridership origin-destination survey shows that on the current Grand Central Terminal pedestrian facilities, virtually all morning peak riders use the exit that provides the shortest path to their ultimate destination. Currently, these commuters walk through the exit best oriented toward their destinations. It was assumed, then, that given new North End Access facilities, riders would choose the new exit that is along the shortest path.

Trip Assignment

The trip assignment was undertaken in two steps--the determination of a probable path for each source-to-exit pair, and the assignment of a number of pedestrians to the probable paths. For each source-to-exit pair, a shortest path through the network passageways was assigned, based on survey results that showed that commuters overwhelmingly choose the most direct path to their destinations. The path assignments were completed manually by inspecting the network, and they took into account distance and ease of passage. Many paths require walking up or down stairs to get to another level. When there was a choice between two paths of roughly equal distance, but one path required traversing more flights of stairs, the path with fewer level changes was chosen. In no case did the chosen path involve more than two level changes. The path was coded into the simulation program as a probability that trips between a source and exit would use a particular link.

A table of probable paths was coded for each of the 13 exits. In order to simplify the coding process and to visualize the paths more clearly, one network diagram was drawn for each exit. Each diagram highlighted all the links that a pedestrian would walk through to reach that exit from each of the 12 sources (train platforms). In cases where two or more paths were equally desirable, the pedestrians were assigned proportionally to those paths.

The pedestrian assignment model was completed using the Lotus 1-2-3 spreadsheet. The entire network was represented on the spreadsheet in tabular form with 44 rows representing links and 12 columns representing sources. One such table, or base assignment matrix, was set up for each of the 13 exits (see Figure 7).

The network tables were used to represent the probable pedestrian paths to each exit. Using the probable path diagrams created above as a guide, the tables were filled in with ones and zeros; a 1.0 in a spreadsheet cell represents a link traveled on the probable path for the source-exit pair, and a zero represents an untraveled link. In cases in which there were two equally likely paths, a factor of 0.5 was used for each of the two links involved.

The second step of the trip assignment is to assign a number of pedestrians to the probable paths. Pedestrians are assigned to the links by multiplying the base assignment matrices by two factors--the number of pedestrians coming from each source, and the percentage of all pedestrians headed for each exit. This matrix multiplication process results in one table for each of the 13 exits. Each exit table contains link volumes headed toward that exit, with 44 rows of links and 12 columns of sources. These 13 tables were summed together cell by cell, according to the rules of matrix addition, which resulted in one table of link volumes for all exits. The resulting link volumes for the various morning and afternoon period simulation scenarios were plotted on diagrams of the proposed facilities. An example is shown in Figure 8.

Assessment of Congestion Levels

The pedestrian assignment model simulated pedestrian flow volumes on each link. The volumes were for 15-min and 1-hr intervals, depending on whether 15-min or 1-hr source volumes were used in the assignment process. Pedestrian level of service (LOS) guidelines were used to determine the carrying capacity of each link at LOS C (4). The ratio of volume-to-capacity (V/C) on each link is used as a measure of congestion. The V/C ratios are calculated by the model for both 15-min and 1 hr intervals. The resulting V/C levels were then used to determine the ability of particular North End Access facilities to handle the expected peak pedestrian volumes at LOS C. A V/C of 1.0 indicates that during the period simulated, the links operated at full capacity at level of service C-D. A ratio greater than 1.0 means that the level of service degrades below the design standard, possibly resulting in some delays or queuing, which may be acceptable if they are of short duration. A V/C of less than 1.0 means that the facility is functioning at a level of service better than C-D and has capacity available for additional flow volume.

Figure 9 shows an example of the simulation program summary table output that provides information on each link: (a) facility type and characteristics, (b) capacity, (c) flow volumes, and (d) V/C.

Matrix describing paths through links from a given origin (source) to a given destination (exit).
1 signifies that the link is on the Origin - Destination pair

EXIT NODE #EA (383 Madison)

S o u r c e N u m b e r (Platform letter, Platform group, and Source number)

Source ID Link #	Location	Nodes A to B	E E47 1	FGHI G47 2	KLMN L47 3	PQR Q47 4	STU T47 5	ABCDE C45 6	EF E45 7	GH H45 8	IJ J45 9	JKL L45 10	Lex Sbwy 220 11	Shuttle Subway 310 12	
1	Roos Pas	R4 -R3													1
2	Roos Pas	R3 -R1													2
3	Roos Pas	R1 -R2													3
4	Roos Pas	R0 -R5													4
5	Stair to Pas	R1-V45													5
6	Helmsley Wlk.W	E5 -312													6
7	45 Xpass	R3-V45													7
8	45 Xpass	V45-L45													8
9	45 Xpass	L45-J45										1			9
10	45 Xpass	J45-H45						0.5	0.5	1					10
11	45 Xpass	H45-E45						0.5	0.5						11
12	45 Xpass	E45-C45						1							12
13	Depew Str	C45-E6													13
14	Spine 31 GCT	310-311												1	14
15	Spine 31	311-312												1	15
16	SpineStr-45Xp	J45-312						0.5	0.5	1	1	1			16
17	Spine 31	312-313						0.5	0.5	1	1	1		1	17
18	SpineStr-47Xp	313-047						0.5	0.5	1	1	1		1	18
19	Spine 31	313-314													19
20	MfrHan Str-Park	314-E2													20
21	Spine 22 GCT	220-221											1		21
22	Spine 22	221-222											1		22
23	Str to 45Xpas	E45-222						0.5	0.5						23
24	Spine 22	222-223						0.5	0.5				1		24
25	Str to 47Xpas	223-J47						0.5	0.5				1		25
26	Str to 47Xpas	J47-224													26
27	Spine 22	223-224													27
28	Roos Pas	R1-R5													28
29	Helmsley Wlk.E	222-E3													29
30	Spine 22	224-226													30
31	Westvaco Stair	226-E7													31
32	383 Madison	EA -V47	1	1	1	1	1	1	1	1	1	1	1	1	32
33	47 XPassage	V47-T47	1	1	1	1	1	1	1	1	1	1	1	1	33
34	47 XPassage	T47-S47	1	1	1	1		1	1	1	1	1	1	1	34
35	MfrHan Pass	S47-SE1													35
36	MfrHan-Vand Str	SE1-E1													36
37	47 XPassage	S47-Q47	1	1	1	1		1	1	1	1	1	1	1	37
38	47 XPassage	Q47-O47	1	1	1			1	1	1	1	1	1	1	38
39	47 XPassage	O47-L47	1	1	1			0.5	0.5				1		39
40	47 XPassage	L47-J47	1	1				0.5	0.5				1		40
41	47 XPassage	J47-G47	1	1											41
42	47 XPassage	G47-E47	1												42
43	AmerBrand Stair	E47-E4													43
44	Roos Pas	R5-R2													44

FIGURE 7 Base assignment matrix.

Sensitivity Analysis

The simulation model was used repeatedly for sensitivity analyses. "What if" testing was performed to examine the effects on V/C ratios of eliminating or adding links, sources, and exits. This was done by changing the factors in particular rows and columns of the spreadsheet. For instance, if a link was to be removed from the network, the network diagram was inspected to determine if any probable paths would change as a result of the elimination. The base assignment matrices of probabilities (ones and zeros) were then modified to reflect the new probable paths. The rest of the analysis process was then repeated. It was also easy to examine the effects of building narrower passageways or of increasing demographic growth factors by changing the appropriate cell values.

ROLE IN DESIGN PROCESS

The simulation model results were used to evaluate the adequacy of the proposed facility to handle the anticipated flow volumes at several stages of the design process. In the planning concept stage, the overall system was tested and found to work well. Several components were found to require additional capacity. Among these components were certain vertical circulation areas where the available corridor width is divided between stairs and/or escalators and corridor space. During the definitive design phase, the widths of several stairs and corridors within the total width available were adjusted to balance the relative capacities with the flow volumes. Escalators were added or removed. As detail design and engineering of the North End Access Improvements proceeded, several modifications were

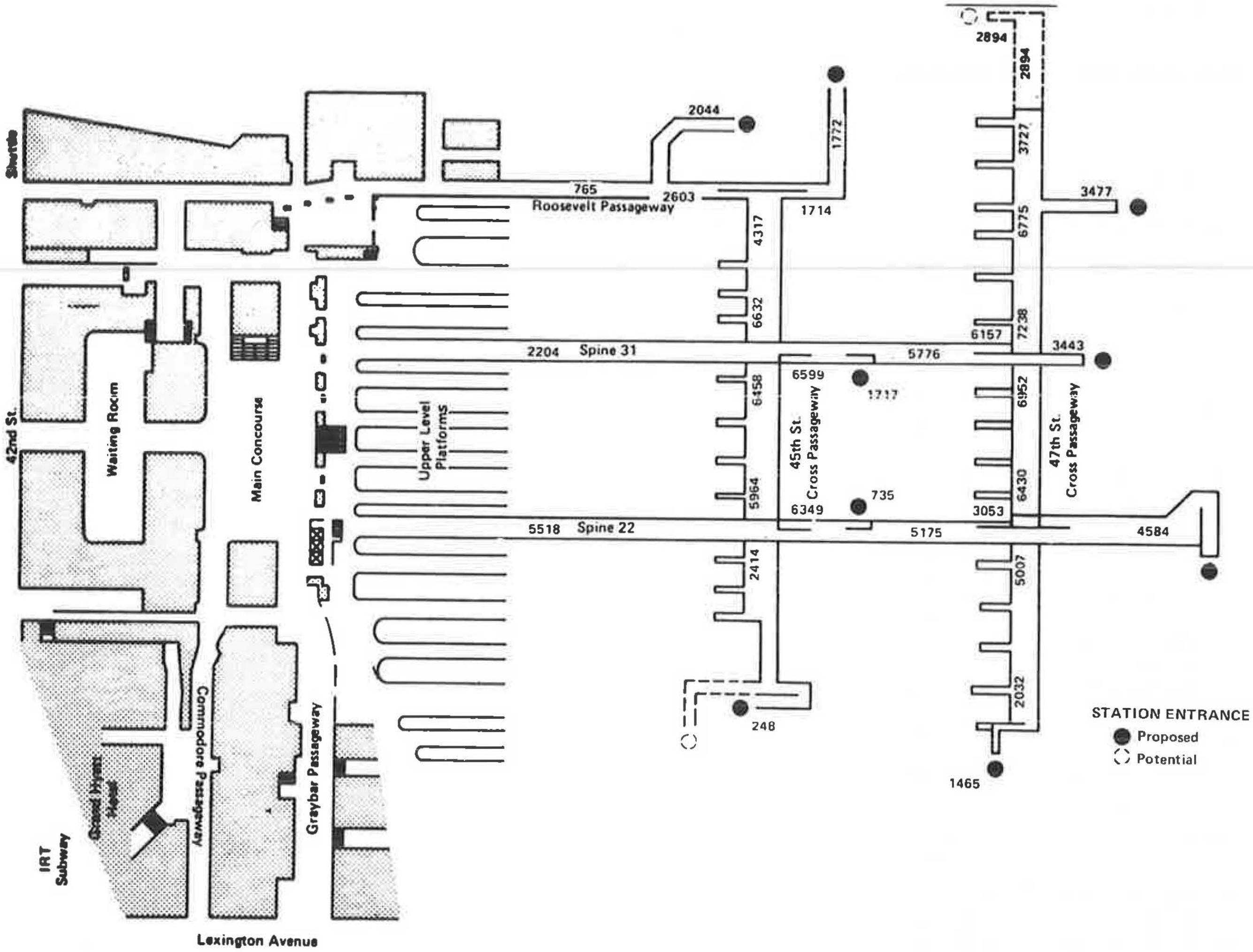

FIGURE 8 Pedestrian flow volumes through North End Access passageways and exits in the year 2000, 8:00 to 9:00 a.m.

required by structural or operational constraints, and the changes were tested using the simulation model.

Phasing plans were developed in the event that the total capital funds required to build the entire project suddenly do not become available. More than a dozen different options were simulated to test their ability to handle the anticipated pedestrian volumes in future years. Several options proved to be unworkable based on the results of the passenger flow program and were eliminated from consideration.

CONCLUSION

The approach to analyzing pedestrian flows for Grand Central Terminal North End Access was to take a rather sophisticated pedestrian flow model framework and simplify it. The simplified model provided a means for evaluating and comparing many alternatives within a tight budget and schedule that precluded the use of a more detailed simulation model approach. As such, the microcomputer model was shown to be quite flexible and applicable to a variety of pedestrian planning and design problems. It is easy to use and is relatively portable because of its reliance on Lotus 1-2-3 or similar common spreadsheet packages.

In the design process, therefore, the model was used as an evaluation tool, functioning in a "what if..." mode. Analysts could vary the input train schedule and aggregate passenger volumes, the network (by inserting and removing links and exits), and the capacities of network elements.

In the Grand Central project, the new access passageways had to be shoehorned into a very tight existing infrastructure between beams and columns carrying streets above while maintaining clearance for trains below. Consequently, the ability to evaluate the impact of dimensional changes on the capacity of the pedestrian system was of prime importance. The flexibility and ease of use of the program allowed it to be used as schemes were being developed and as design constraints were being discovered. For example, 12 variations of construction phasing were analyzed. The model thus became a key element in the design process.

The simplified approach of this model has several disadvantages when compared to a more sophisticated model, such as the UMTA Transit Station Simulation (USS) program. First, the stochastic element of the real-time simulation is not available. The simplified model is purely deterministic, allowing no random flow variations that would be expected in real life. Second, the paths are determined manually. Although the manual path assignment process probably requires less time for a simple network than coding for use by a computer algorithm, it would be cumbersome for a large network. Nevertheless, in spite of these shortcomings, the PC-based flow simulation

Link ID #	Location	Loc Node A-B	Total Vol 1 Hour Peak	Nominal Width (feet)	Effective Width (feet)	Length (feet)	Facility Type	Total Vol 15 Min. Peak	Capacity 15 Min.	Vol/Cap	
1	Roos Pas	R4 -R3	1777	10	8		S	553	1200	0.46	1
2	Roos Pas	R3 -R1	62	7	5		C	13	1125	0.01	2
3	Roos Pas	R1 -R2	1022	12	10		S	318	1500	0.21	3
4	Roos Pas	R0 -R5	765	13	11		C	222	2475	0.09	4
5	Stair to Pas	R1-V45	2603	6	5		S	816	750	1.09	5
6	Helmsley Wlk.W	E5 -312	1717	1/6	1/5		E/S	540	2250	0.24	6
7	45 Xpass	R3-V45	1714	4	1		E	540	1500	0.36	7
8	45 Xpass	V45-L45	4317	34	30	90	C	1356	6750	0.20	8
9	45 Xpass	L45-J45	6632	34	30	60	C	1980	6750	0.29	9
10	45 Xpass	J45-H45	6458	34	30	95	C	1568	6750	0.23	10
11	45 Xpass	H45-E45	5964	34	30	95	C	1484	6750	0.22	11
12	45 Xpass	E45-C45	2414	34	30	70	C	233	6750	0.03	12
13	Depew Str	C45-E6	748	8	7		S	233	1050	0.22	13
14	Spine 31 GCT	310-311	2204	27'6"	20	430	C	698	4500	0.16	14
15	Spine 31	311-312	2410	13	8	95	C	793	1800	0.44	15
16	SpineStr-45Xp	J45-312	6599	1/6	1/5		S	1966	2250	0.87	16
17	Spine 31	312-313	5776	27'6"	20	360	C	1717	4500	0.38	17
18	SpineStr-47Xp	313-047	6157	10	9		S	2026	1350	1.50	18
19	Spine 31	313-314	3443	10'6"	9		C	1077	2025	0.53	19
20	MfrHan Str-Park	314-E2	3443	1/6	1/5		E/S	1077	2250	0.48	20
21	Spine 22 GCT	220-221	5518	28	19	430	C	1312	4275	0.31	21
22	Spine 22	221-222	5518	10	6	95	C	1312	1350	0.97	22
23	Str to 45Xpas	E45-222	6349	1/6	1/5		S	1592	2250	0.71	23
24	Spine 22	222-223	5175	28	19	350	C	1222	4275	0.29	24
25	Str to 47Xpas	223-J47	3053	11	10		S	739	1500	0.49	25
26	Str to 47Xpas	J47-224	2463	11	10		S	941	1500	0.63	26
27	Spine 22	223-224	2121	10	9		C	483	2025	0.24	27
28	Roos Pas	R1-R5	1715	9	7		C	526	1575	0.33	28
29	Helmsley Wlk.E	222-E3	735	6	5		S	231	750	0.31	29
30	Spine 22	224-226	4584	15'6"	14		C	1425	3150	0.45	30
31	Westvaco Stair	226-E7	4584	1/1/6	1/1/5		E/E/S	1425	3750	0.38	31
32	383 Madison	EA -V47	2894	1/8	1/7		E/S	896	2250	0.40	32
33	47 XPassage	V47-T47	2894	28'8"	25	45	C	896	5625	0.16	33
34	47 XPassage	T47-S47	3727	28'8"	25	60	C	1438	5625	0.26	34
35	MfrHan Pass	S47-SE1	3447	11'8"	10		S	1066	1500	0.71	35
36	MfrHan-Vand Str	SE1-E1	3447	1/5'8"	1/5		E/S	1066	2250	0.47	36
37	47 XPassage	S47-Q47	6775	28'8"	25	70	C	2244	5625	0.40	37
38	47 XPassage	Q47-O47	7238	28'8"	25	70	C	2425	5625	0.43	38
39	47 XPassage	O47-L47	6952	28'8"	25	95	C	2332	5625	0.41	39
40	47 XPassage	L47-J47	6430	28'8"	24	95	C	2075	5400	0.38	40
41	47 XPassage	J47-G47	5007	28'8"	25	100	C	1555	5625	0.28	41
42	47 XPassage	G47-E47	2032	28'8"	25	65	C	454	5625	0.08	42
43	AmerBrand Stair	E47-E4	1465	5'4"	5		S	454	750	0.61	43
44	Roos Pas	R5-R2	1022	9	7		R	318	1215	0.26	44

FIGURE 9 Spreadsheet showing pedestrian flow volumes through North End Access passageways and exits in the year 2000, 8:00 to 9:00 a.m.

model produced good results in a short time and fulfilled the needs of the designers.

On balance, the model documented here provided many of the advantages of more sophisticated pedestrian simulation models while offering added flexibility of analysis, simplicity of spreadsheet programming, and quick response associated with personal computing. It is expected that the software and methodology described here will be refined and used on further projects.

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Application of the Time-Space Concept to a Transportation Terminal Waiting and Circulation Area

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ABSTRACT

Demonstrated in this paper is the application of the time-space concept to the analysis of pedestrian activities in the waiting and circulation area of a transportation terminal. It is intended to show how this approach can address situations and problems not adequately handled by the use of other methods. The time-space concept is described first. It is a new procedure for analyzing pedestrian activities (especially those associated with transportation facilities and dense urban centers) in which the following factors are taken into account: (a) the total amount of space required for the various activities of people within an area, (b) the amount of time they require that space, (c) the amount of available space, and (d) the amount of time that space is available. Following the discussion of the time-space concept, a case study is presented to demonstrate some of its capabilities and features. The problem is analyzed first by using the traditional flow rate approach and second by using the new time-space method. Finally, the two analyses are compared and the situations in which the new approach would be advantageous are pointed out.

The time-space concept is a new approach to analyzing and evaluating facilities for handling pedestrian activities, especially those associated with transportation terminals, transit stations, and dense urban centers. The time-space concept, first introduced as a method for examining sidewalk corners and crosswalks (1-2), can be applied to any facility where pedestrian activities--walking, waiting or queuing, and processing--occur. This approach can address many situations and problems that cannot be adequately addressed using other methods.

Basically, the time-space concept considers the total amount of space required by the people involved in various activities within an area, and the amount of time that they require that space. At the same time, it considers the amount of space available for these activities and the amount of time that the space is available.

Demonstrated in this paper is the application of the time-space concept to the analysis of pedestrian activities within a proposed facility for a transportation terminal. The time-space concept is described first. Then, a case study is presented that demonstrates some of the capabilities and features of the time-space concept. The same problem is analyzed using the more traditional flow rate technique and the two approaches are compared.

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PEDESTRIAN PLANNING AND DESIGN FUNDAMENTALS

Most of the material presented here is based on three sources (2-4). It is readily recognized that people