is not yet at hand, the process for reaching a politically acceptable and workable solution has been set in motion by MTC, armed with its authority to allocate discretionary funds for transit, with the cooperation of the transit agencies. With clearly defined objectives and the public interest well in mind, the goal of BART-bus service coordination may be within reach of the San Francisco Bay Area.

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Abridgment

Dade County's Experience with Urban Station Simulation (USS) Procedures

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One of the most important considerations in the design of rapid transit stations is the delay that passengers passing through the station will encounter. It is important that service facilities in the station (turnstiles, escalators, stairways, etc.) have sufficient capacity to process the maximum number of passengers arriving or departing at any given time. Sufficient capacity is mandatory to assure the safety of passengers. Further, ridership tends to increase as the delays passengers experience are reduced.

Urban Station Simulation (USS) is a transit station simulation computer program developed by the Urban Mass Transportation Administration (UMTA) to analyze the capacities of stations. Station planners provide as input to the program the geometric configuration of a proposed station and the proposed capacities of the various service facilities in the station. The USS program then simulates the movements of individual passengers through the station and records statistics on how they are distributed along alternate routes and on the delays they encounter in waiting lines (or queues) that develop at various points.

By reviewing USS reports of such statistics, the planner can evaluate the capabilities of a proposed station design before resources invested are in detailed design and construction. Capacity problems can be identified and dealt with during the early stages of design. Details of the capabilities of USS have been presented elsewhere (1).

As part of its analysis of transit stations in the Metropolitan Dade County Transportation Improvement Program, the Kaiser Transit Group (KTG) has applied the USS program to designs for the proposed Douglas Road, South Miami, and Dadeland North stations in the southern (Dixie Highway) corridor of the stage 1 Dade County Rapid Transit System. Figure 1 shows the USS model of one of the Douglas Road station configurations that was analyzed.

Links (pedestrian paths) and nodes (decision and delay points) of the model are superimposed on floor plans of the lower (concourse) and upper (platform) levels. Passengers boarding trains originate as walkers (zone 1), drivers who have used the park-and-ride (zone 2) or kiss-and-ride (zone 3) facilities, or transferring riders on one of the several bus lines serving the station (zones 6-10). They enter the station through turnstiles (nodes

Figure 1. Sample station layout and USS network.

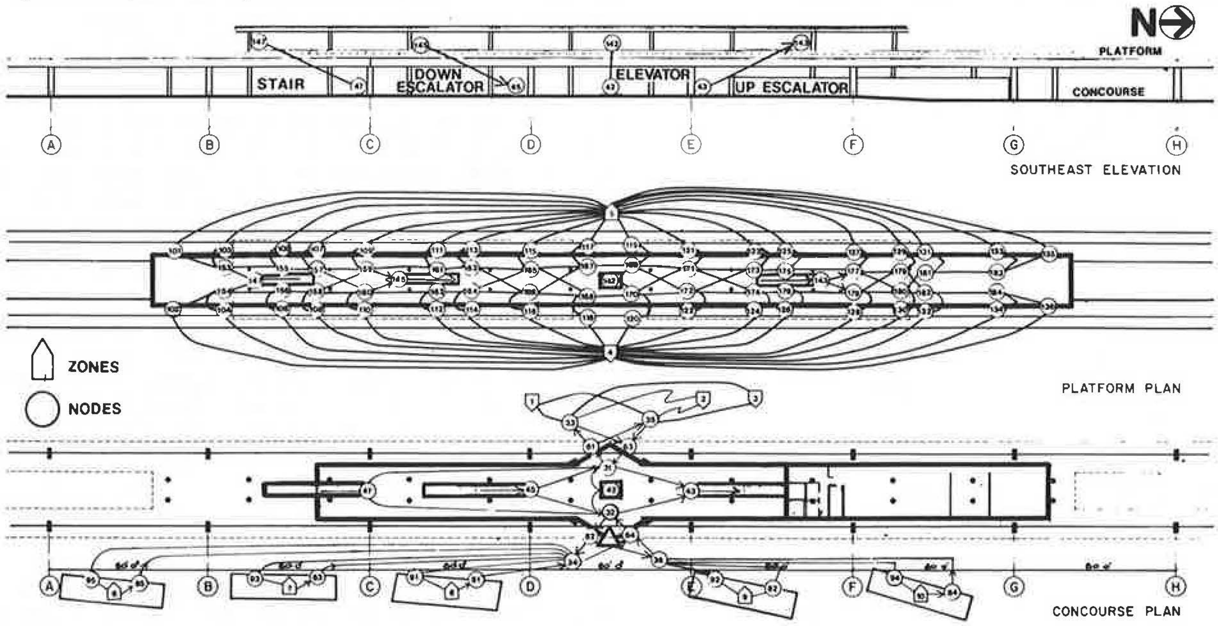
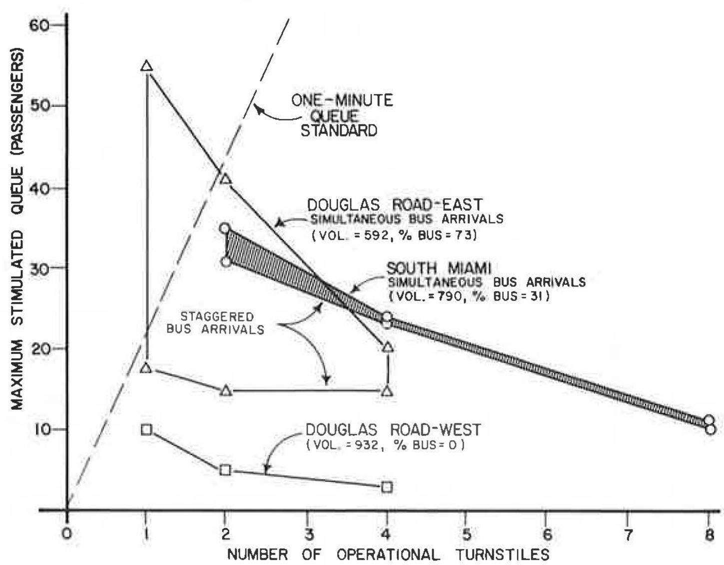


Figure 2. Maximum queues observed at access turnstiles.



63 and 64), move up to the platform level via stairs and escalators, wait for and enter a train by one of the several doors (such as node 122 for a northbound train or node 119 for a southbound train), and exit the model at the appropriate train zone (zones 4 and 5).

Passengers getting off trains follow reverse routes from train zones toward one of the other zones. Most links in the model permit flow in both directions. However, one-way links like the escalators are also considered appropriate and are identified in Figure 1 by arrows.

FARE-GATE REQUIREMENTS

KTG's use of USS has centered on a number of station-sizing issues (2). One such issue at the various rapid transit stations is the number of fare gates or turnstiles required to serve anticipated passenger volumes. The service level of a group of turnstiles is measured by the length of the queue that can develop. The guideline KTG designers have used is that such a queue should never exceed the volume of patrons that can pass through the turnstiles in a minute.

Simulation analyses of fare-gate requirements were performed at all three stations tested. It was assumed that fare gates provide one-way service, that people can exit from them at a rate of 40/min, and that people can enter them at a rate of 24/min.

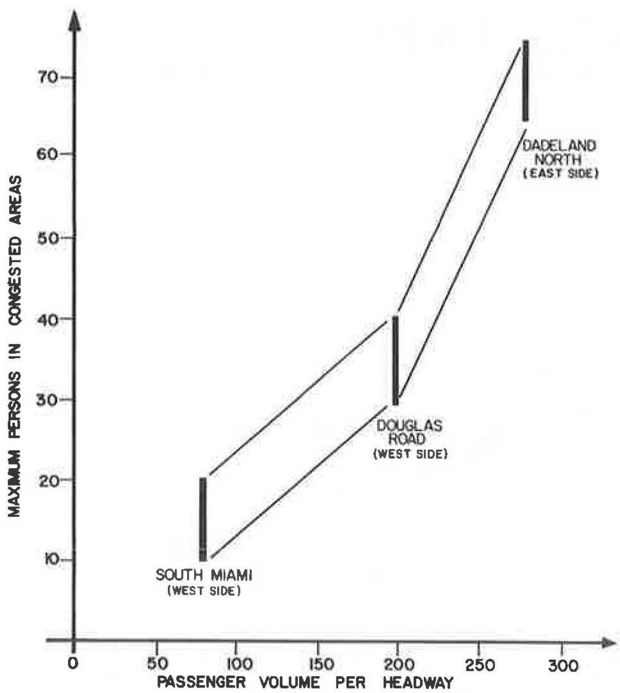
Figure 2 illustrates the results of queue simulation for turnstiles for the single bank of turnstiles planned at the South Miami station and for both the east (bus) and west (automobile) sides of the Douglas Road station. In each case, the hourly volume of passengers served and the percentage of patrons arriving on buses are indicated. The dashed line in Figure 2 shows the maximum allowable queue that can be cleared in a minute.

In general, the length of the queue observed for a given number of turnstiles increases as the volume of passengers does. However, the arrivals of buses com-

Table 1. Comparison of typical results for vertical-movement alternatives.

Category	Douglas Road	South Miami
Simulated morning peak-hour volume	3888	1578
Assumed service rate of stairway (min)	120	120
Maximum queue at top of stairway		
Case A	45	9
Case B	6	NA
Case C	6	1
Average passenger time in station (s)		
Case A	315	277
Case B	305	NA
Case C	300	272
Percentage of platform access by the south versus north vertical-movement devices		
Case A	27 versus 73	25 versus 75
Case B	100 versus 0	NA
Case C	7 versus 93	6 versus 94

Figure 3. Maximum simulated congestion in restricted areas beside vertical-movement devices.



plicate this matter, because bursts of passengers reach the turnstiles together and cause momentary overloading. This is accentuated when several buses arrive simultaneously. Staggering bus arrivals could minimize such bursts.

Figure 2 shows clearly how these factors will affect queues at access turnstiles at Dade County's transit stations. Although the west side of Douglas Road has the highest volume of those reported, it produces the smallest queues. Other areas have larger queues because substantial numbers of passengers arrive on buses. When this number becomes large, as in the case of the east side of Douglas Road, the difference between staggered and simultaneous bus arrivals becomes substantial. Actual experience should lie somewhere between these two limiting cases.

VERTICAL MOVEMENT

Another series of issues KTG has studied with USS centers on the number and orientation of vertical-movement devices (escalators, stairs, and elevators) along the centerline of the station. For example, one sequence of alternatives consisted of a case A (one stair, one escalator, and one elevator for vertical movement) versus cases B and C (stair at the center of the platform replaced by a second escalator and a stairway added at the south end of the platform). The latter two cases are distinguished by the orientation of the escalators: In case B the up escalator is on the south, and in case C the up escalator is on the north.

Table 1 illustrates the USS results used to compare the three cases at the stations where they were considered. The effect of cases B and C is illustrated by the percentage distribution of access volumes as passengers enter the Douglas Road platform. Under case B, all access flow is to the same end of the platform (100 percent south versus 0 percent north). By separating the up escalator and the stair in case C, flows can be distributed slightly more evenly on the platform (7 percent south versus 93 percent north). Thus, case C is preferred and was the only two-escalator approach tested at South Miami.

In a comparison of cases A and C, the principal results of interest are the queue at the top of the case A stair and the average amount of time passengers spend in the station. If the queue at the stairway is too large or delays too lengthy, the escalator is necessary. However, stairway queues for case A, as shown in Table 1, are not great enough to justify the additional escalator. The largest value—45 at Douglas Road—is well within the number that can be cleared within a minute. There is a slight (5-10 s) reduction in the time passengers spend in the station when an extra escalator is added, but that savings is not enough to justify the extra escalator.

CONGESTION ON PLATFORMS

At all stations, the spaces alongside the vertical-movement devices are the platform areas most likely to produce congestion. Thus, the occupancy of such areas was monitored in all results of the USS simulation.

Figure 3 illustrates the results observed by showing the maximum number of persons observed in potentially congested areas during KTG's simulations of the three south corridor stations. Values varied somewhat according to the specific assumptions of particular simulation runs, so a range of values is shown for each station. Thus, for example, the Douglas Road station had a maximum of 30 to 40 persons in the potentially congested areas. These values translate to minimum areas per patron of 0.5 m^2 (4-5 ft^2), which authorities such as Fruin (4) suggest is the minimum for patron convenience.

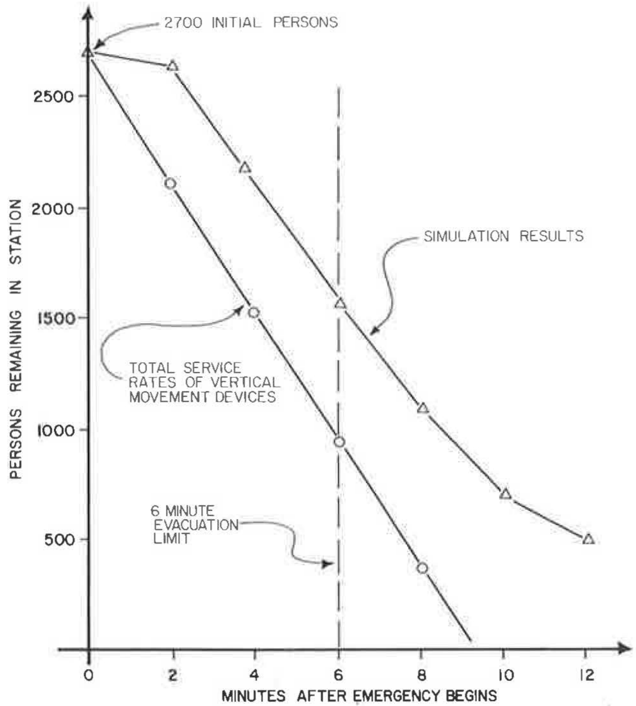
The values in Figure 3 may have been somewhat inflated by the internal logic of the USS program, but they showed clearly that congestion beside vertical-movement devices may be a concern in any of the stations at which volumes will be high.

EMERGENCY EXIT

KTG's main analysis of vertical-movement alternatives considered only the capacity required to serve patrons in the morning peak hour. However, the facilities for vertical movement must also allow evacuation of the platform in an emergency.

One series of KTG's simulation tests of the Douglas Road station addressed such requirements for emergency evacuation. The particular configuration tested has one stairway and two inoperative escalators that function as reduced-capacity stairs. The purpose of the test was to determine whether the 2700 people potentially on the platform and in two adjacent trains at the time of

Figure 4. Emergency exit routes for Douglas Road example.



an emergency could be cleared from the station in 6 min.

Figure 4 illustrates the observed results of the simulation. The number of people remaining in the station at each time interval simulated is compared to the number of people who could be cleared at the maximum capacities of the vertical-movement devices. Clearly, neither the observed simulation results nor the maximum vertical-movement capacities would permit all 2700 patrons to be cleared within 6 min. Additional vertical-movement capacity is required to meet the standard.

The parallel pattern of the two lines in Figure 4 indicates that vertical-movement capacity is the limiting consideration in emergency evacuation of all stations. Once an evacuation is under way, patrons are cleared from the station at about the capacity rate. However, actual evacuations lag behind maximum capacities because some time is lost in starting patrons toward the vertical-movement devices.

COMMENTS

The USS program has not been widely released by UMTA because of many known deficiencies [see KTG's critique (3)]. In fact, UMTA has taken the first steps to produce a new version. Still, this paper demonstrates that pedestrian simulations can provide many useful analyses of station design. KTG's simulation results have been well received by the architects who must use them, and more analyses have been requested. It is rarely possible to determine exactly which analysis caused a given change in design, but simulation results have certainly influenced KTG's decisions on fare gates, capacity for vertical movement, and emergency exits.

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