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A COMPUTER SIMULATION OF TAMPA
INTERNATIONAL AIRPORT'S LANDSIDE
TERMINAL AND SHUTTLES

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Acknowledgement

Abstract

TOPSIM, a terminal simulation package developed at M.I.T., was used to simulate Tampa's landside terminal and to study its capacity-congestion characteristics as traffic levels increase. Tampa has no congestion problems at present, processing 5 million passengers per year, but may in the future. TOPSIM indicates that congestion arises at the ticket counters and on the critical segments of the elevator cycle when annual traffic volumes reach 14+ million passengers.

TOPSIM's modular design has sufficient flexibility to handle a variety of airport layouts without major reprogramming effort. The package was previously used to simulate passenger flows for hypothetical "Metroport" terminals (handling passenger volumes similar to LaGuardia) and for Eastern Airlines' terminal at Logan. It produces performance statistics on passenger movements (such as total distance walked and time spent standing in queues), and on facilities (such as utilization of ticket booths).

TOPSIM's application to Tampa demonstrates its ability to handle other than "shuttle" oriented terminals. In fact, it can theoretically simulate any terminal regardless of trip type or mode, since the passenger processing routine is similar for most terminals.

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Tampa incorporates a hub-satellite design which divides passenger activities between the Landside and Airside terminals. Passenger processing occurs in the central Landside terminal while security checks, seat assignment, and boarding occurs in the Airside terminals. An automated shuttle system spans the 1000 feet between Landside and Airside with a 40 second ride in special shuttle cars departing every 70 seconds (see Figures 1 and 2).

This separation-of-function theme continues into the Landside terminal where each phase of passenger processing occurs on a different floor. Long escalators link the floors much as the shuttles link the terminals (see Figures 3 and 4).

The Landside terminal has six floors, three for passenger processing and three for parking. The first floor, or Baggage level, has baggage carousels and Rent-a-Car booths. Long escalators run directly from the Transfer level feeding Deplaning passengers to the Baggage level, and a roadway surrounding the floor expedites passenger flow out of the building. The second floor, or Ticket level, has airline check-in counters. An elevated roadway surrounding the floor feeds Enplaning passengers into the building and escalators speed passengers to the Transfer level. The third floor, or Transfer level, has shuttle lobbies for access to the Airside and numerous shops and other attractions for passenger convenience and airport revenue (see Figures 5-7).
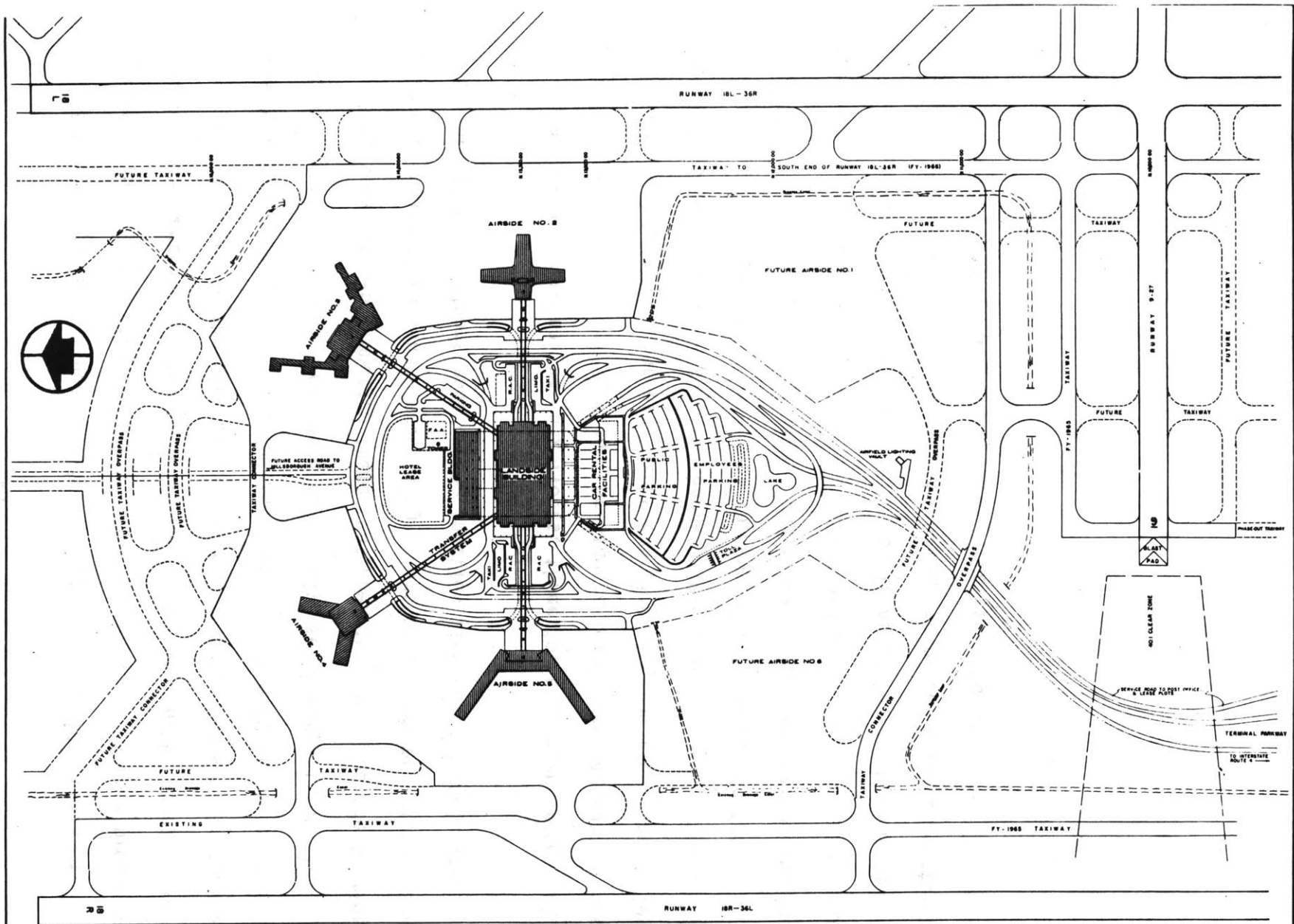
Figure 1: Tampa International Airport Site Plan
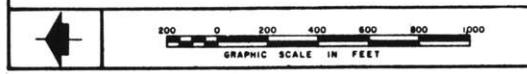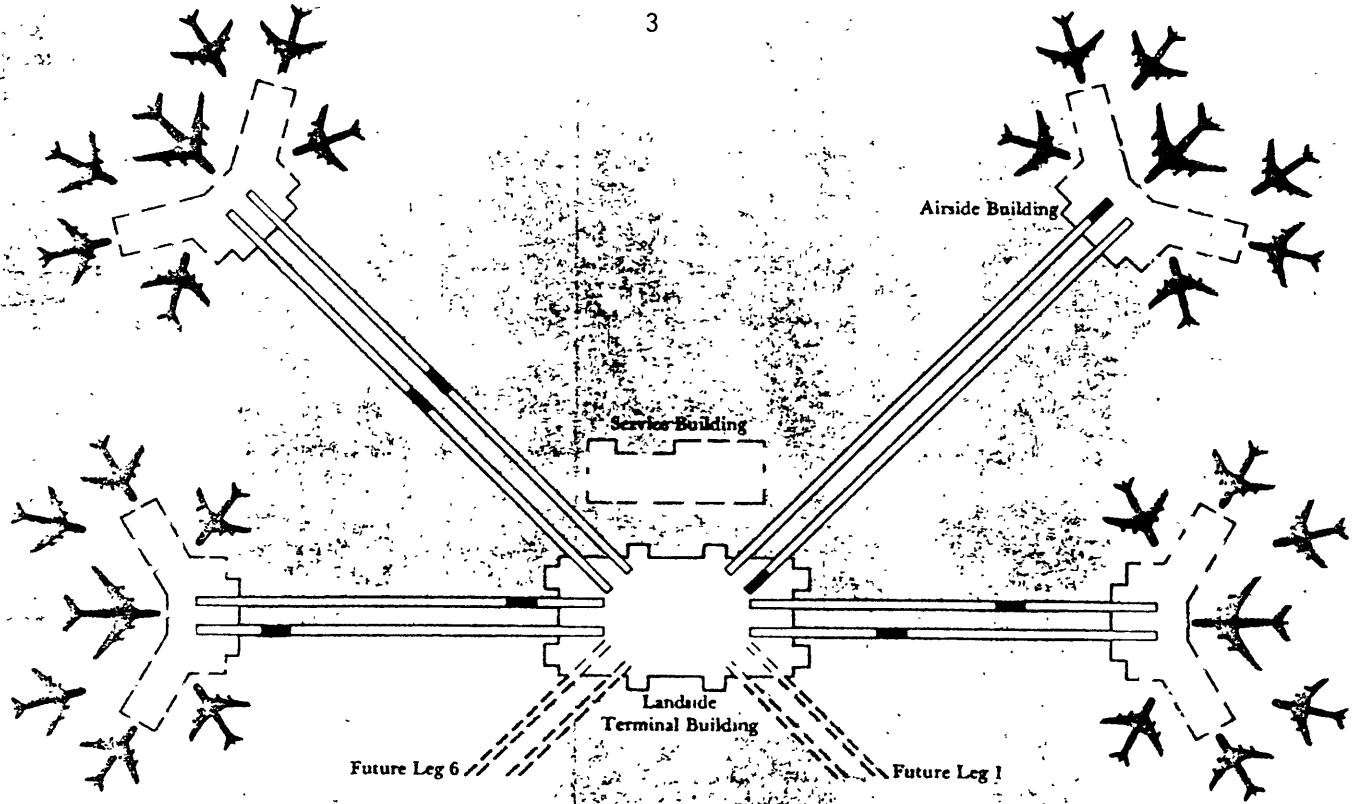
Figure 2:   The Simulation Includes the Landside Pax
            Terminal and Four Sets of Shuttles

Parking - 3
Parking - 2
Parking - 1
Transfer
Ticket
Baggage
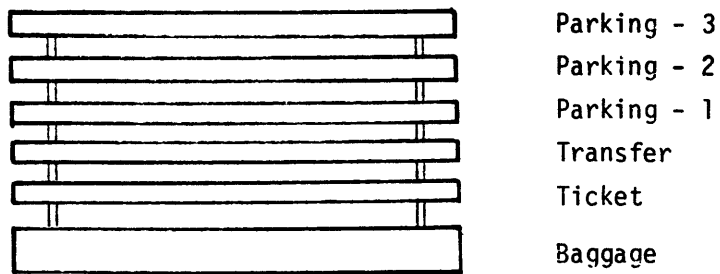
Figure 3:   The Landside Terminal's Six Levels
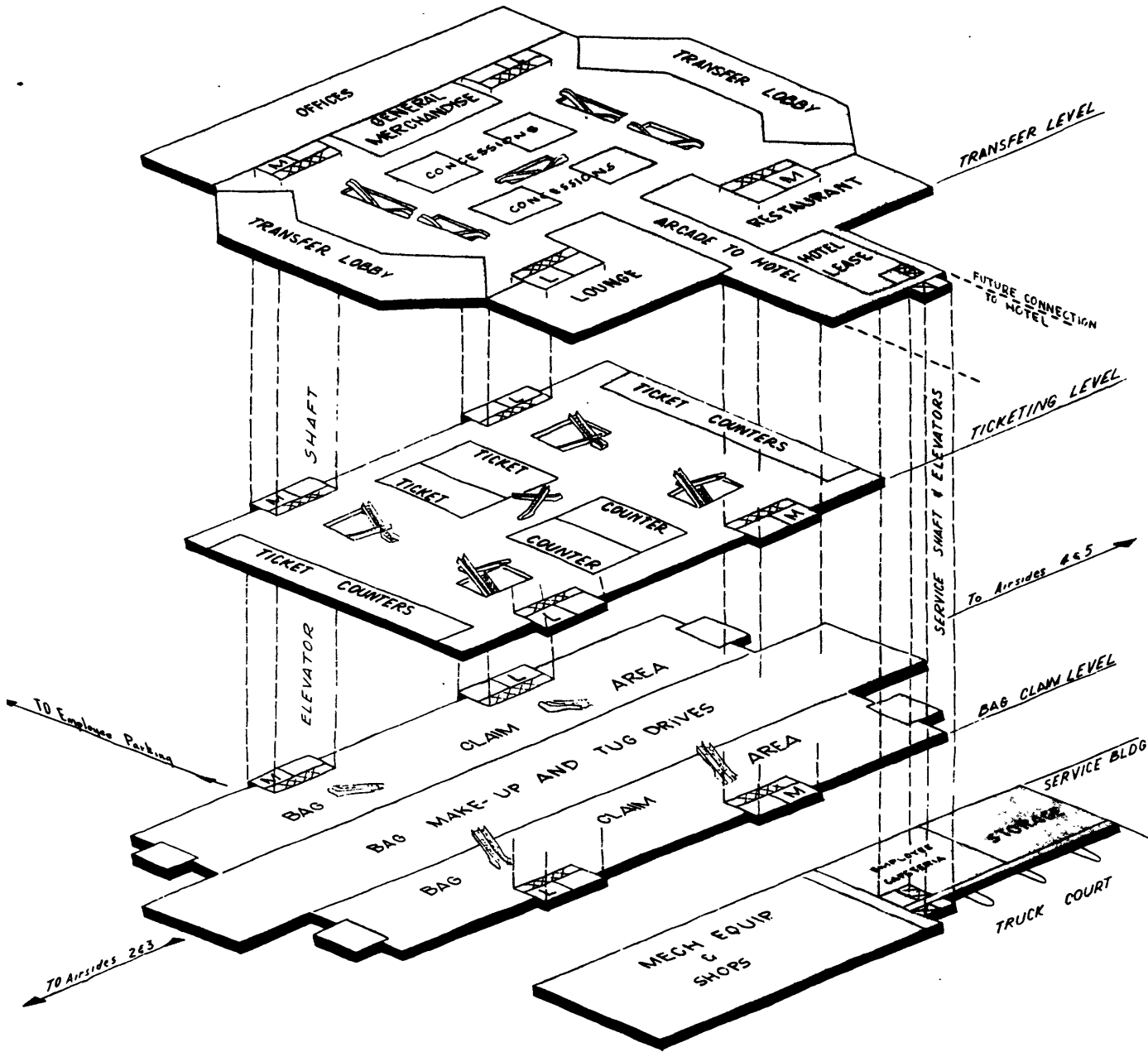
Figure 4: LANDSIDE BUILDING
ISOMETRIC SKETCH

Figure 5: Baggage Level

SERVICE BUILDING

TRUCK COURT

DOCK

TRANSFER MAINT

TRANSFORMERS

SER ELEV

ELEC EQUIP

MECHANICAL EQUIP

STORAGE

SHAFT

M W

FIRST AID

OFFICES

SHOPS & STORAGE

EMPLOYEE CAFETERIA

COMM

TELEPHONE EQUIP

STOR

DEPLANING ROADWAY

PLAZA

CAR RENTAL

M STOR

STOR L

CAR RENTAL

VAL AS

DAL

GT M L

BAG · CLAIM AREA

NAL

L M GT

NAL NAL NAL UAL AC DAL DAL

M

PLAZA

TUG DRIVE

NAL EXP NW

BAG UAL NE

MAKEUP AREA
TWA EXP PAA DAL AC EXP EAL

TUG DRIVE

L M GT

NW NE AS TWA

NE NW TWA EAL EAL EAL EAL

GT M L E AL

PLAZA

BAG CLAIM AREA

CAR RENTAL

STOR

STOR M

CAR RENTAL

PLAZA

DEPLANING ROADWAY

DEC 1968

GRAPHIC SCALE IN FEET
0 30 60 90 120 150

J. E. GREINER COMPANY
CONSULTING ENGINEERS
TAMPA FLORIDA

HILLSBOROUGH COUNTY AVIATION AUTHORITY
TAMPA INTERNATIONAL AIRPORT
TAMPA – FLORIDA

LANDSIDE BUILDING
BAG CLAIM LEVEL

5

Figure 6: Ticket Level

ROOF OF SERVICE BUILDING

SERV ELEV

ARCADE

ABOVE

ENPLANING ROADWAY

CIRCULATION DRIVE

PLAZA

EXPANSION

TICKET COUNTERS

NAL

NW

LOBBY

OPEN

OPEN

TICKET COUNTERS

UAL

DAL

NE

TWA PAA DAL

TICKET COUNTERS

OPEN

OPEN

LOBBY

TICKET COUNTERS

AC

EAL

EXPANSION

PLAZA

CIRCULATION DRIVE

LINE OF PARKING ABOVE

LINE OF PARKING ABOVE

ENPLANING ROADWAY

DEC. 1968

GRAPHIC SCALE IN FEET

J. E. GREINER COMPANY
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TAMPA FLORIDA

HILLSBOROUGH COUNTY AVIATION AUTHORITY
TAMPA INTERNATIONAL AIRPORT
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LANDSIDE BUILDING
TICKETING LEVEL

6

Figure 7: Transfer Level

FUTURE
CONNECTION TO HOTEL

ROOF   SERVICE   BUILDING

LINE OF PARKING ABOVE

HOTEL LEASE

ARCADE (TO HOTEL)

RESTAURANT

COCKTAIL   LOUNGE

TRANSFER SYSTEM NO 4 TO AIRSIDE

TRANSFER SYSTEM NO 3 TO AIRSIDE

M

L

DEPLANE

DEPLANE

PLAZA

PLAZA

ENPLANE

DEPLANE

ENPLANE

DEPLANE

CONCESSIONS

LOBBY

LOBBY

TRANSFER SYSTEM
TO AIRSIDE NO 5

TRANSFER SYSTEM
TO AIRSIDE NO 2

ENPLANE

ENPLANE

HELIX ABOVE

HELIX ABOVE

DEPLANE

DEPLANE

CONCESSIONS

LINE OF PARKING ABOVE

FUTURE

FUTURE

LINE OF PARKING ABOVE

PLAZA

PLAZA

GENERAL
MERCHANDISE

BARBER
SHOP

N

L

M

OFFICES OF
HILLSBOROUGH COUNTY
AVIATION AUTHORITY

PAA AC
NAL
UAL
UNAS
DAL

EAL

DEC. 1968

0 30 60 90 120 150
GRAPHIC SCALE IN FEET

J. E. GREINER COMPANY
CONSULTING   ENGINEERS
TAMPA   FLORIDA

HILLSBOROUGH COUNTY AVIATION AUTHORITY
TAMPA INTERNATIONAL AIRPORT
TAMPA - FLORIDA

LANDSIDE BUILDING
TRANSFER   LEVEL

II   THE SIMULATION

II-A   <u>Objective</u>

A model is a simplified description of a real world system. It should
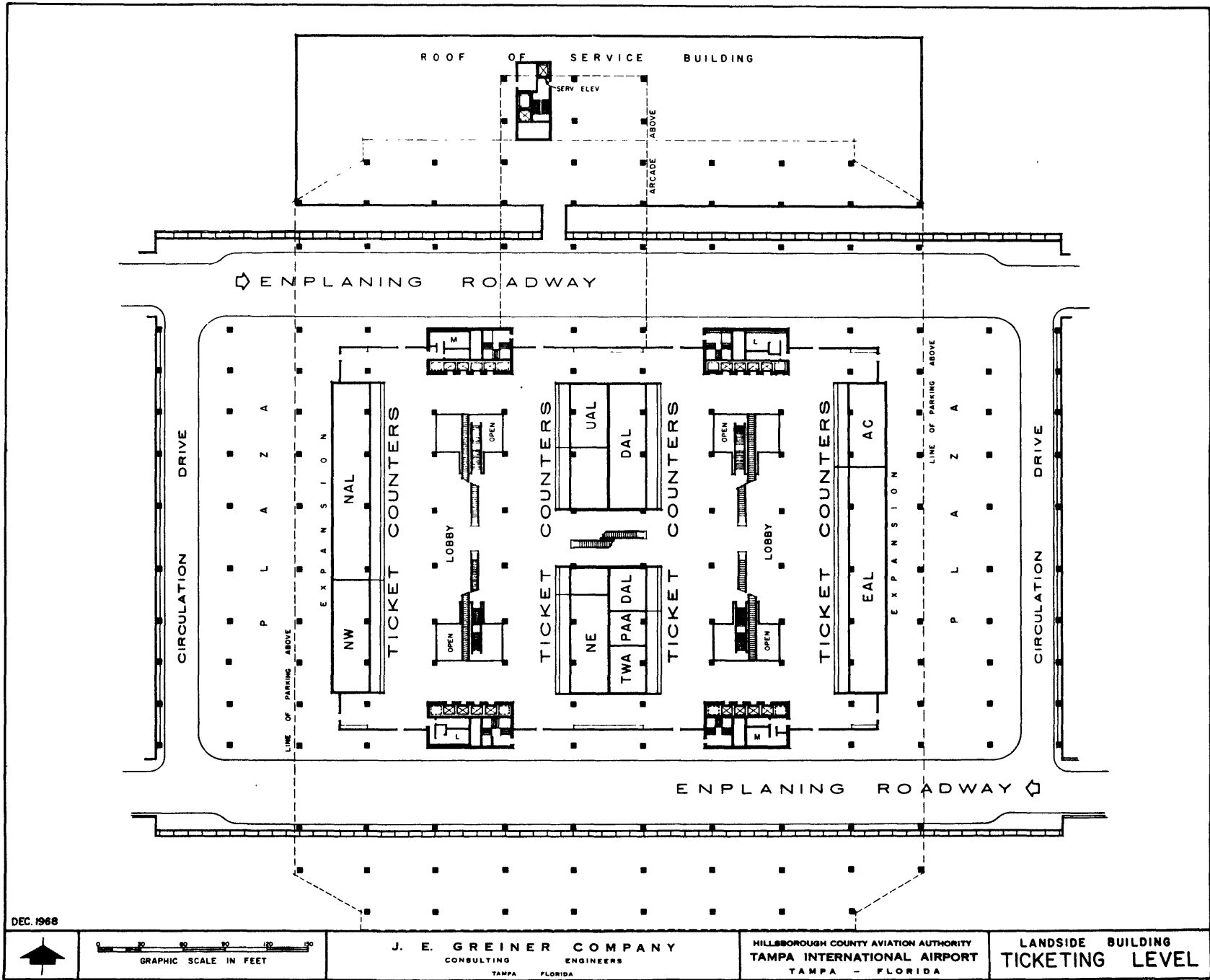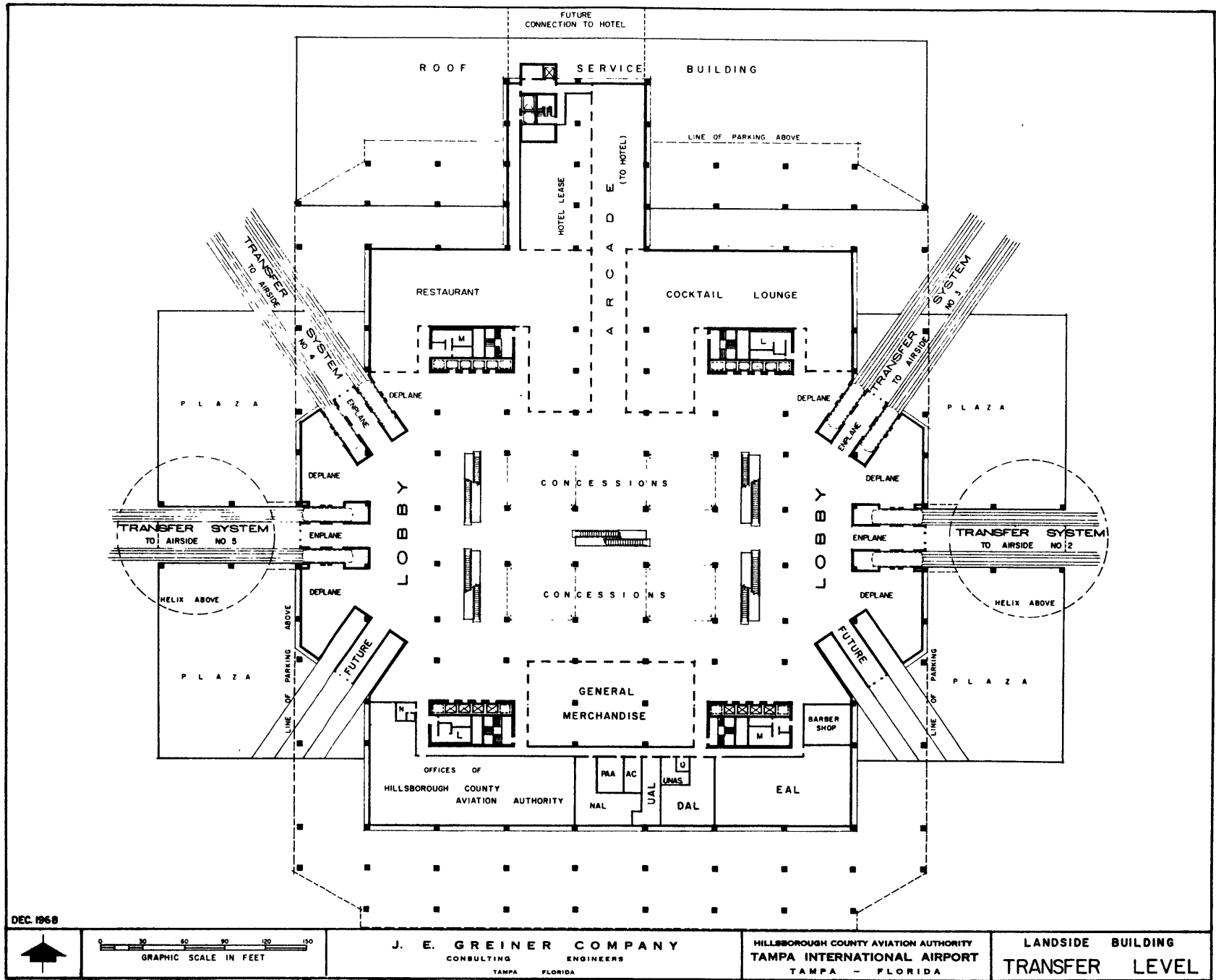retain the essence of that system, concentrating in detail on those parts
most relevant to the modeler's objectives. For example, the Landside
terminal includes a variety of facilities, activities, passengers, and passenger
flows. Those placed in the simulation depend upon the objectives of the
model.

The objective of this study was to measure the capacity-congestion
characteristics of the Landside terminal and shuttles. The emphasis,
therefore, was directed toward those facilities where congestion will most
likely occur, such as the ticket counters and escalators. In fact, any
facility that processes or transports passengers is a potential source
of congestion and delay. Four major facilities were analyzed; the results
are shown in section III.

II-B   <u>Facilities</u>

Figure 8 shows the facilities modeled on each floor, where a facility
either processes passengers as part of the flight service (such as a ticket
counter), or provides transportation within the terminal complex, such as
an escalator or a shuttle. These facilities account for a large portion of
the congestion and delay passengers experience.

Passengers

The simulation has four passenger flows (listed below, also see Figures 9 and 10) where each flow may have several routes through the Landside terminal, depending upon the access/egress mode used. Connecting passengers at Tampa are too few to justify in this simulation. (However, they should be considered if the Airside terminals are modeled.)

Passenger Flows

1) Enplaning passengers and Wellwishers to the Airside.

2) Wellwishers from the Airside.

3) Greeters to the Airside.

4) Deplaning passengers and Greeters from the Airside.

The model collects passengers into passenger groups, where a group contains a person or persons entering/leaving the airport together. For example, one group might contain a single passenger while another contains a family of five attended by fourteen Wellwishers (groups average 1.5 passengers). The model moves a group through the terminal as a single entity, only splitting it into individuals when encountering a facility that processes only individuals, e.g. a ticket agent. After processing, the members reassemble into a single group and continue moving through the terminal as before.

Every group has a set of attributes associated with it, such as: number of persons in the group, the airline it patronizes, and an index signifying an Enplaning or Deplaning passenger (see Table 1). These attributes identify the group and direct its flow through the terminal, besides collecting statistics needed to measure congestion and delay.

The simulation uses Poisson interarrival times to create passenger groups, which yields random arrivals but still results in the desired number of passengers per hour. All passengers are generated using identical Poisson functions, except Deplaning passengers which arrive in plane load batches and require a high volume Poisson function for within batch interarrival times and a separate linear probability function for between batch interarrival times.

Enplaning passengers, Greeters, and Wellwishers use one generator apiece. The Deplaning passengers use seven different generators, one for each trunk airline (PanAm and TWA are modeled as one airline for passenger generation due to their limited traffic volumes).

FACILITIES
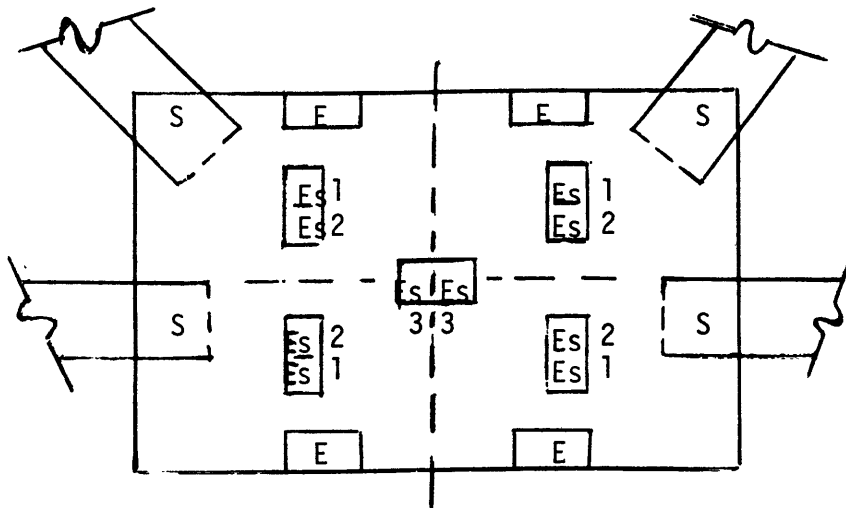
TRANSFER LEVEL

S - SHUTTLE
E - ELEVATOR
Es - ESCALATOR
1 - FROM TICKET LEVEL
2 - TO BAGGAGE LEVEL
3 - TO TICKET LEVEL
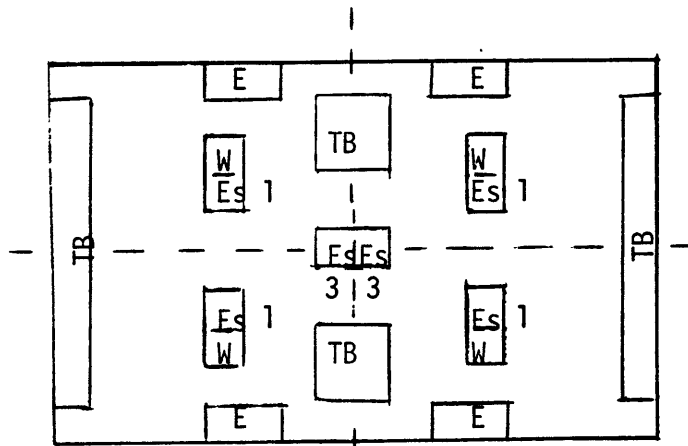
TICKET LEVEL

TB - TICKET BOOTHS
E - ELEVATOR
W - STAIRS
Es - ESCALATOR
1 - TO TRANSFER LEVEL
3 - FROM TRANSFER LEVEL
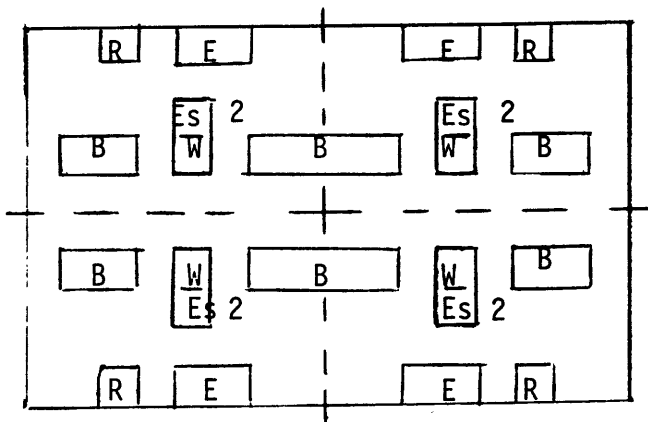
BAGGAGE LEVEL

B - BAGGAGE CONVEYORS
R - CAR RENTALS
E - ELEVATOR
W - STAIRS
Es - ESCALATORS
2 - FROM TRANSFER LEVEL

Figure 8:   The three lower floors contain both pax processing facilities
            and pax conveyance facilities. Note that the set of facilities
            in each quadrant on a floor are identical, though the shuttles
            differ in position.

PARKING
GARAGE

ELEVATOR

ELEVATOR

ELEVATOR

TRANSFER LEVEL

SHUTTLE

LOITER

AIRSIDE

ELEVATOR

ESCALATOR

TICKET LEVEL

ENPLANING
ROADWAY

TICKET
COUNTERS

STAIRS

ELEVATOR

BAGGAGE LEVEL
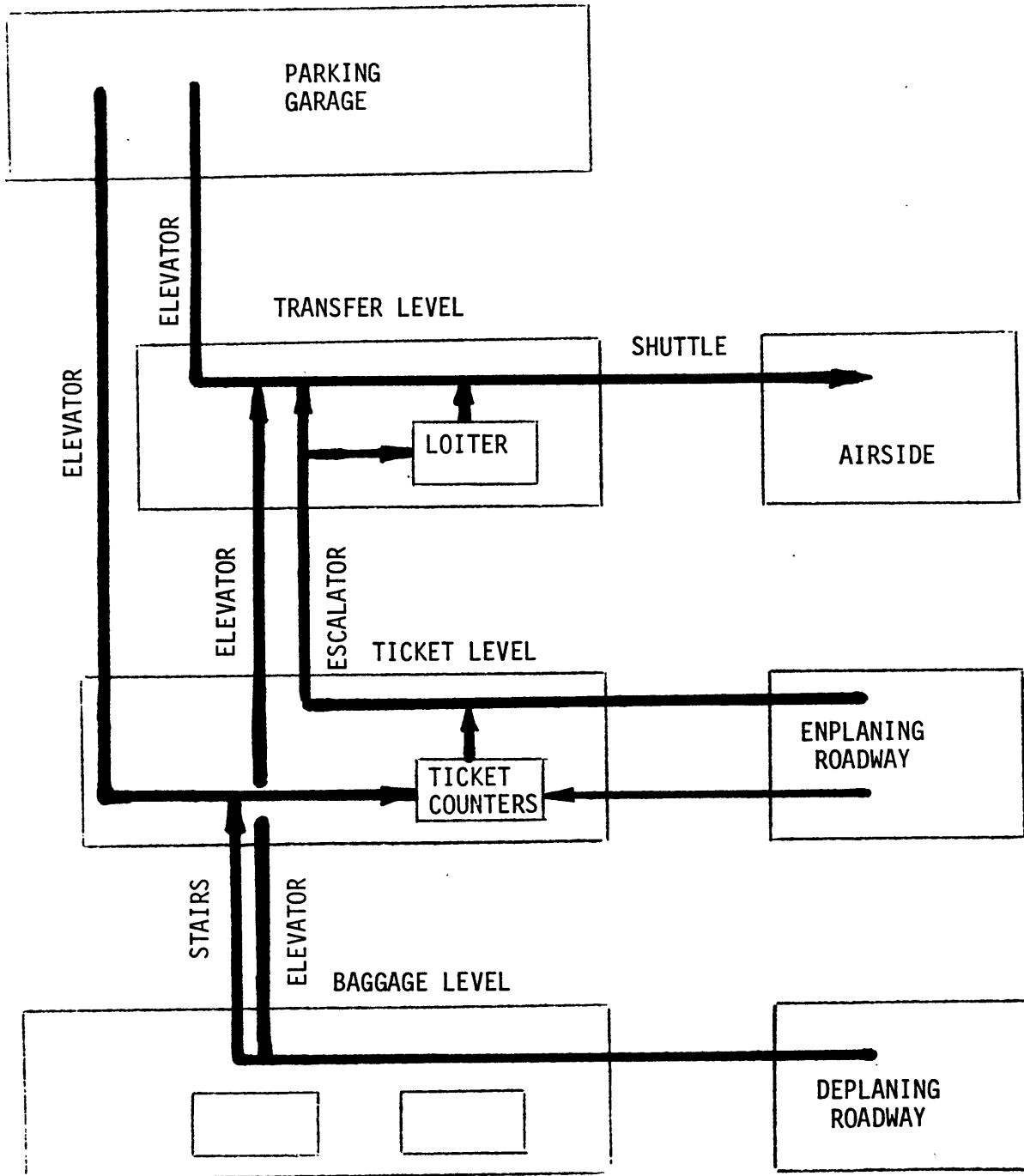
DEPLANING
ROADWAY

Figure 9A: Enplaning passenger flows
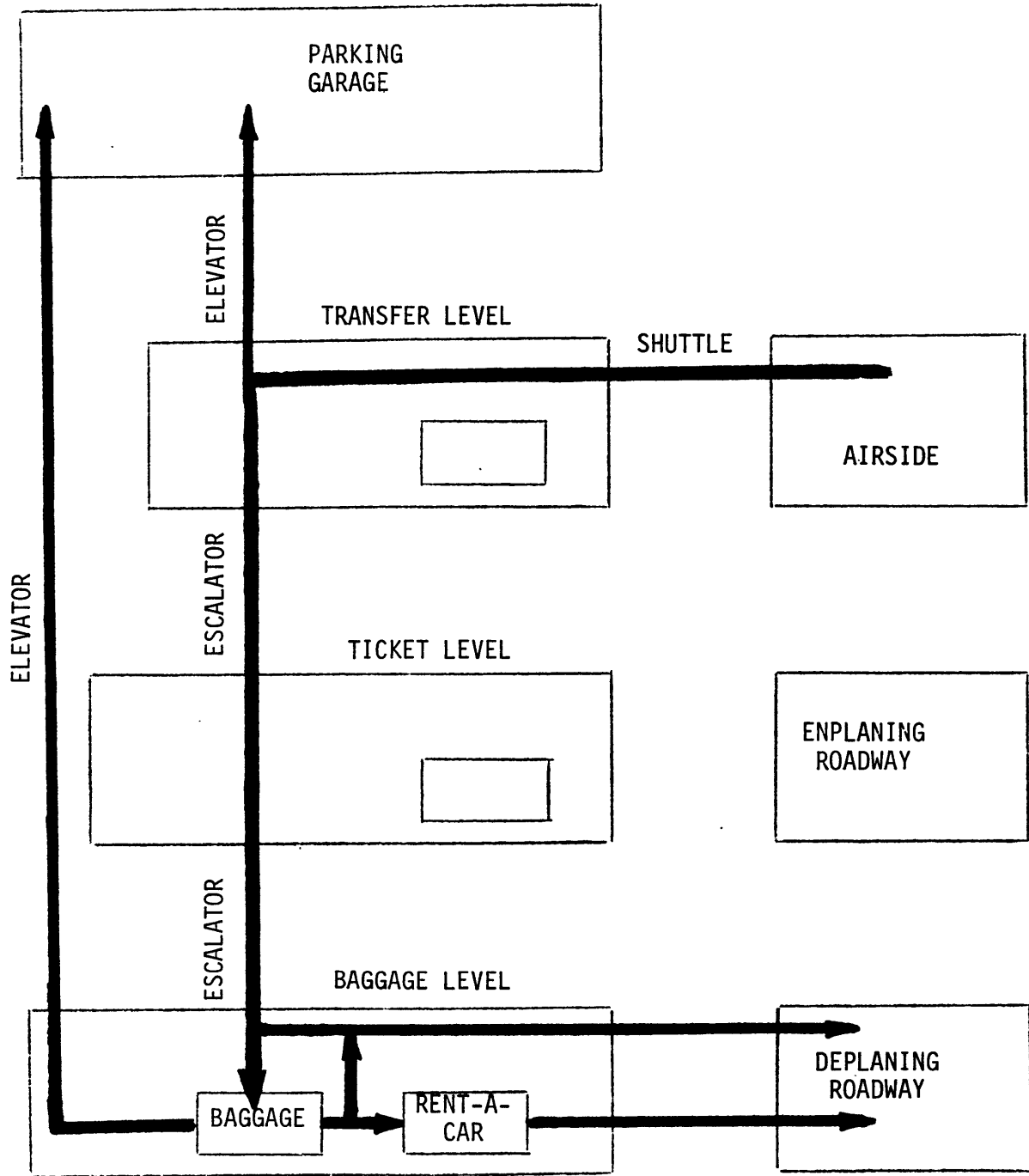
Figure 9B: Deplaning passenger flows

PARKING
GARAGE

TRANSFER   LEVEL

AIRSIDE
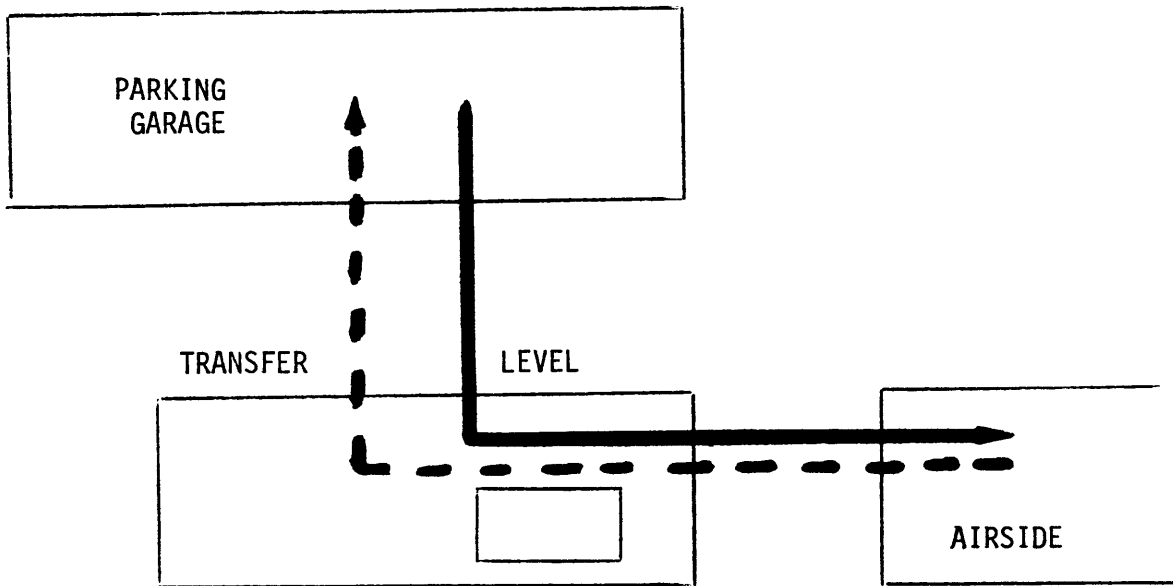
Figure 9C: Greeters   ————————

Wellwishers   — — — —

Figure 10A: Inbound Passenger
              Flow

```
                    ┌─────────────────┐
                    │    GENERATE     │
                    └────────┬────────┘
           ┌─────────────────┴─────────────────┐
           │                                   │
  ┌────────┴────────┐                 ┌────────┴────────┐
  │  WELL WISHERS   │                 │  ARRIVING PAX   │
  └────────┬────────┘                 └────────┬────────┘
           │                                   │
  ┌────────┴────────┐                 ┌────────┴────────┐
  │     ASSIGN      │                 │  GROUP PAX TO   │
  │   PARAMETERS    │                 │   ARRIVE IN     │
  └────────┬────────┘                 │  BATCHES FROM   │
           │                          │ EACH SATELLITE  │
  ┌────────┴────────┐                 └────────┬────────┘
  │    WAIT FOR     │◀────────┐                │
  │     SHUTTLE     │         │       ┌────────┴────────┐
  └────────┬────────┘         │       │     ASSIGN      │
           │                  └───────│   PARAMETERS    │
  ┌────────┴────────┐                 └─────────────────┘
  │     RIDE TO     │
  │ TRANSFER LEVEL  │
  └────────┬────────┘
```

NUMBER BAGS = 0 ?   — YES →   PARKED IN GARAGE ?

WALK TO ESCALATOR   ← NO

YES (PARKED IN GARAGE?) → WALK TO ELEVATOR → RIDE TO PARKING LEVEL → TERMINATE

RIDE ESCALATOR TO BAGGAGE LEVEL

NUMBER BAGS = 0 ?   — YES →

NO → WALK TO BAGGAGE BELT → PICK UP BAGGAGE → PARKED IN GARAGE ?

RENTING A CAR?   — NO →

YES → WALK TO RENT-A-CAR BOOTH → RENT CAR → WALK TO CURB → TERMINATE
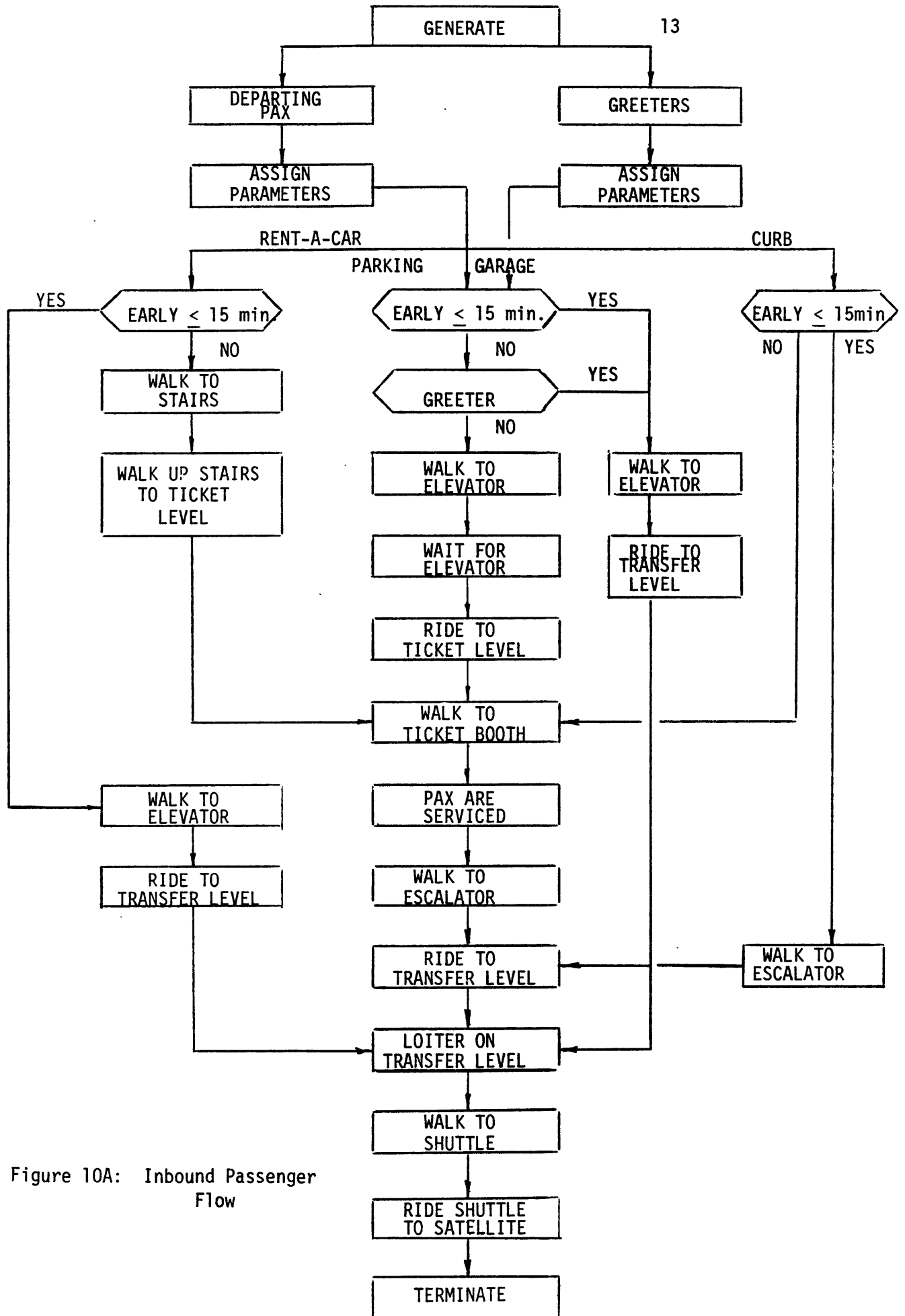
PARKED IN GARAGE ?   NO →

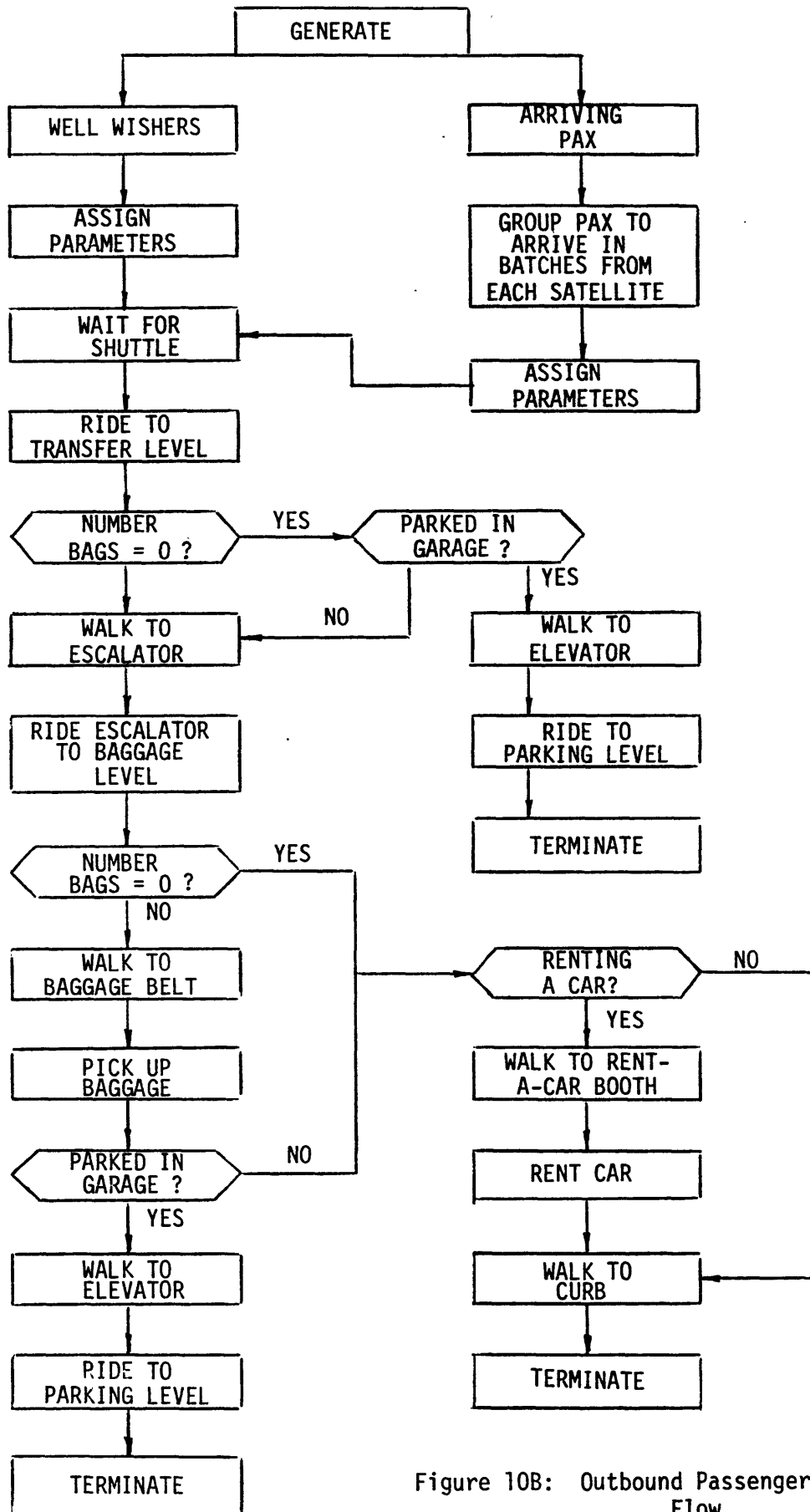YES → WALK TO ELEVATOR → RIDE TO PARKING LEVEL → TERMINATE

Figure 10B: Outbound Passenger
Flow

Table 1: Passenger Attributes

1) Airline

2) Time till Departure or Arrival of Flight

3) Current Position - Quadrant

4) Current Position - Storage Number of Quadrant

5) Mode of Access or Egress

6) Number of Passengers in Group

7) Number of Wellwishers and Greeters in Group

8) Total Number of Persons in Group

9) Number of Bags in Group

10) Time Spent in Landside Terminal and the Shuttle

12) Current Position - Storage Number of Level

14) Departure/Arrival

15) Distance being Walked (temporary)

16) Total Distance Walked

17) Walking Speed of Group

18) Time Spent Waiting in Queues

20) Parking Level

III   RESULTS

The simulation of Tampa's Landside terminal confirmed that the terminal

can handle its design capacity easily (14+ million passengers annually).

The goal, however, was not to check the adequacy of the design but to in-

vestigate the complex capacity-congestion relationships.

The simulation generated statistics covering the facilities and passenger

movements in the Landside terminal. These statistics were combined to produce

capacity-congestion graphs on four of the facilities (ticket counters,

elevators, escalators, and shuttles). The baggage conveyors were not included

due to a lack of data on baggage movements from aircraft to Landside

terminal. The conveyors are important to the flow of passengers and should

be included whenever detailed data on the baggage flow becomes available.

Peak hour activity is assumed for the simulation, where the number of

passengers entering the Landside temrinal during the peak hour equals

ten percent of the average daily passenger flow. The total annual passenger

$$\text{Peak Hour Traffic} = (10\%) \times \frac{\text{(Total Annual Passenger Traffic)}}{\text{(365 days per year)}}$$

traffic or "Passengers Annually" does not include connecting traffic. Only

12% of the passengers are connecting and only a fraction of those ever enter

the Landside terminal (off-line connections).

Each floor of the Landside terminal has four quadrants, each processing

some fraction of the total passenger flow to that floor. Since each quadrant

has equivalent facilities, the busiest quadrant will congest first and is

therefore the critical quadrant. The expected delay for a particular

annual traffic level depends upon what fraction of the total flow goes to

the busiest quadrant. That fraction cannot be predicted exactly, but a range of values can be used to bound the expected delay. For Tampa those values are 25% and 30%.

III-A   Ticket Counters

The average passenger delay increases exponentially with Tampa's total annual traffic volume, assuming a fixed number of ticket agents (see figure 11). The delay remains small up to 10 million passengers annually, but increases rapidly thereafter, passing three minutes average delay at 14+ million passengers annually.

The delay curve referenced above assumes maximum possible staffing at every counter for all levels of traffic. In practice, airlines will try holding costs down by employing just enough agents to give passengers a reasonable level of service. For example, if three minutes average delay is considered a reasonable level of service, as indicated by the dashed line in Figure 11, then the airlines cannot hold passenger delay to less than three minutes once traffic grows past 14+ million passengers annually, and 14+ million becomes the congestion point. However, that point is an average for the whole terminal. Individual airlines may experience significant delays at lower volumes, depending upon how closely the allotted counter space matches the volume of traffic for each airline.

The utilization rate (% of time an agent is busy) for a constant number of ticket agents grows linearly with the traffic volume, reaching 90% at 14+ million passengers annually. 90% may sound high, but it covers the peak hours only; the average daily utilization would be much lower.

These results assume one agent for every ten feet of ticket counter and an average service rate of 2.4 minutes. They also assume a distribution

of counter space producing equal delays for all airlines.

Actual delays will deviate from those predicted if changes from the base case above occur in the future (see Table 2). All of these changes affect either the service offered at the counter or the pattern of passenger arrivals.

Table 2:   Future deviations from the base case that would

affect the predicted ticket counter queuing delays.

A.   Deviations decreasing delays

1)   Squeeze more agents behind the counter. This solution is limited by growing passenger confusion in front of the counter.

2)   Use an agent in front of counter to aid passengers standing in line (a technique used at Washington National).

3)   Form separate queues defined by passenger needs, e.g. Information, Ticket Validation, and Ticket Purchase.

4)   Use curbside check-in extensively.

5)   Share counter space between airlines.

6)   Change airline schedules.

B.   Deviations increasing delays

1)   Introduce super-jumbo jets, causing sharp peaks in passenger acitivity.

2)   Distribute counter space inequitably, forcing large delays for one airline and few for another.
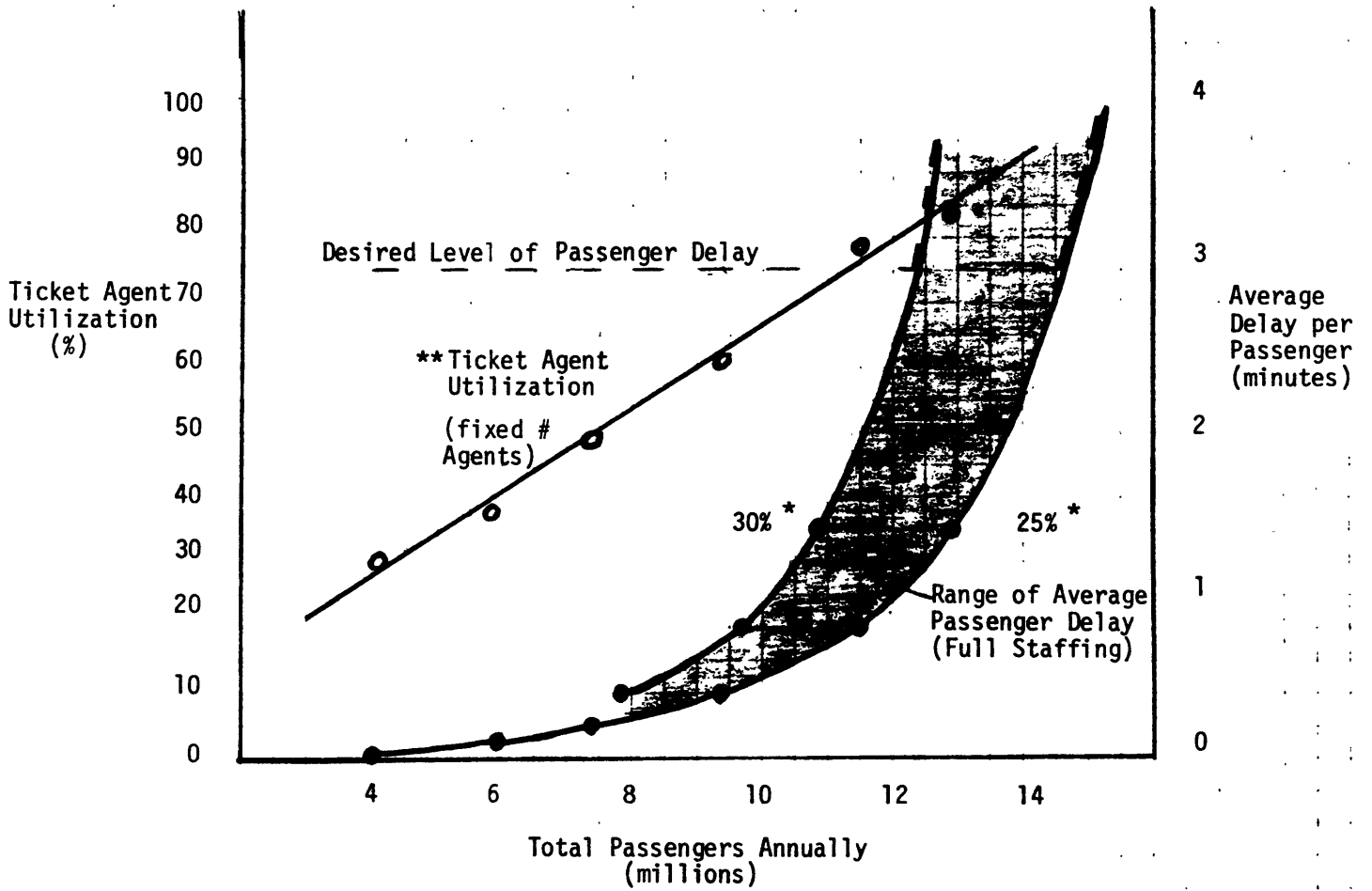
3)   Change airline schedules.

Figure 11: Ticket Counter delay graph
*25 and 30% refer to the percentage of traffic flowing through
the busiest quadrant of the Ticket level.

**Ticket agent utilization equals the average percentage of
time that an agent is busy.

III-B   Elevators

   The elevators run a fixed cycle traveling from the Baggage level to the third floor of the Parking Garage and back again, stopping at every floor (a good approximation at higher traffic volumes). The floor dwell time and the between floor travel time take almost ten seconds each, yielding a total cycle time of 192 seconds. A 48 second interval separates individual elevators.

Park 3
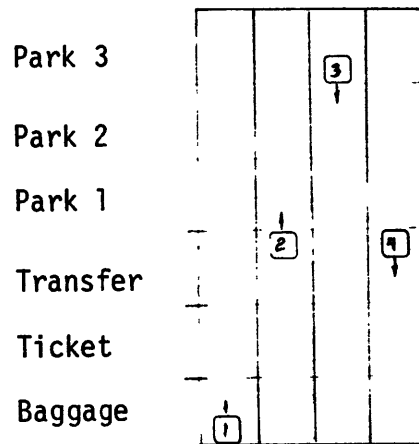
Park 2

Park 1

Transfer

Ticket

Baggage

Figure 12: Each quadrant of the terminal has a bank of four elevators. The elevators run a fixed cycle, following one another by 48 seconds or 2 1/2 floors.

Due to the complex pattern of traffic on the elevators, the typical aggregate measures of congestion, e.g. average elevator load per cycle, are inappropriate. Instead, the most heavily traveled or "critical" segment of the elevator cycle was found and analyzed to determine the percentage of time that the demand could not be met (congest frequency). When the critical segment congests, the elevators as a system are considered congested.

As shown in Figure 13, the critical segment lies between the transfer level and the Parking Garage. This result confirms intuitive expectations, since most elevator traffic moves between the Garage and the passenger levels and loses them on the lower floors, while an elevator traveling up gains passengers on the lower floors and loses them on the parking levels. In both cases, the maximum loads occur on the segment between the Transfer level and Parking Garage.

Figure 13: Elevator flows. The busiest or critical segment is between the Transfer level and the first floor of the Parking Garage.
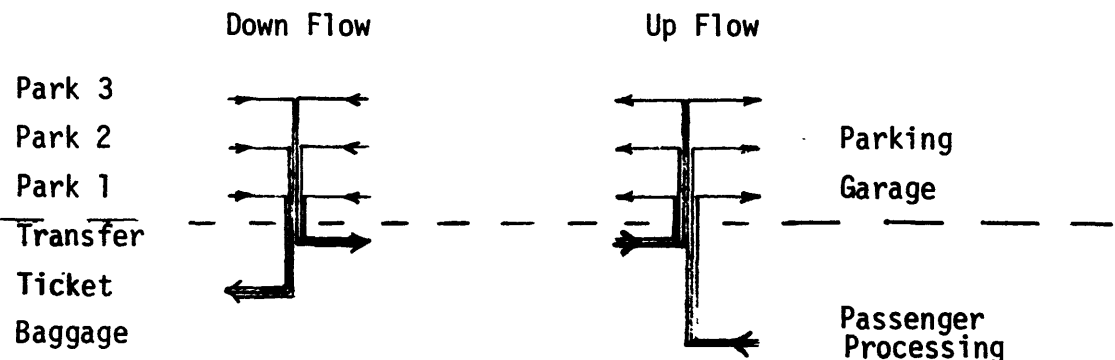
a. Greeters travel to the Transfer level and most Enplaning passengers travel to the Ticket level.

b. Wellwishers travel from the Transfer level and most Deplaning passengers from the Baggage level.

On the critical segment the average passenger load grows linearly with the volume of traffic, but the percentage of times the elevator cannot carry the total demand (the congestion frequency) increases exponentially. The congestion frequency falls just short of 3% at 12 million passengers, rises to over 4% at 13 million passengers, and explodes to approximately 7% at 14 million passengers (see Figure 14).

The congestion frequency does not give the passenger rejection rate, only the percentage of times more people wanted to use the elevator than room was available. The passenger rejection rate is but a fraction of the congestion frequency, albeit a fraction that grows as congestion frequency grows. (The congestion referred to here applies only to the critical segment; overall, the elevators will have no problem carrying the demand.)

The Deplaning passenger batching problems so prevalent for escalators and shuttles do not weigh heavily here. By the time a batch of passengers has filtered to the Baggage level and picked up their luggage, the batch has crumbled and stretched out. Therefore, little of the delay on the elevators is attributable to batching.

The prediction above assumes passenger behavior continues as it exists today; a change would of course affect the results. Some possible changes and their effects are listed below.

1) Change mode split, fewer people driving means fewer cars in the garage and fewer persons using the elevators. A rapid transit line from the city of Tampa or improved bus service would reduce the percentage of persons driving. In fact, any change affecting the mode split will affect the elevator performance.

2) The addition of a fourth floor of parking would aggravate elevator delays.
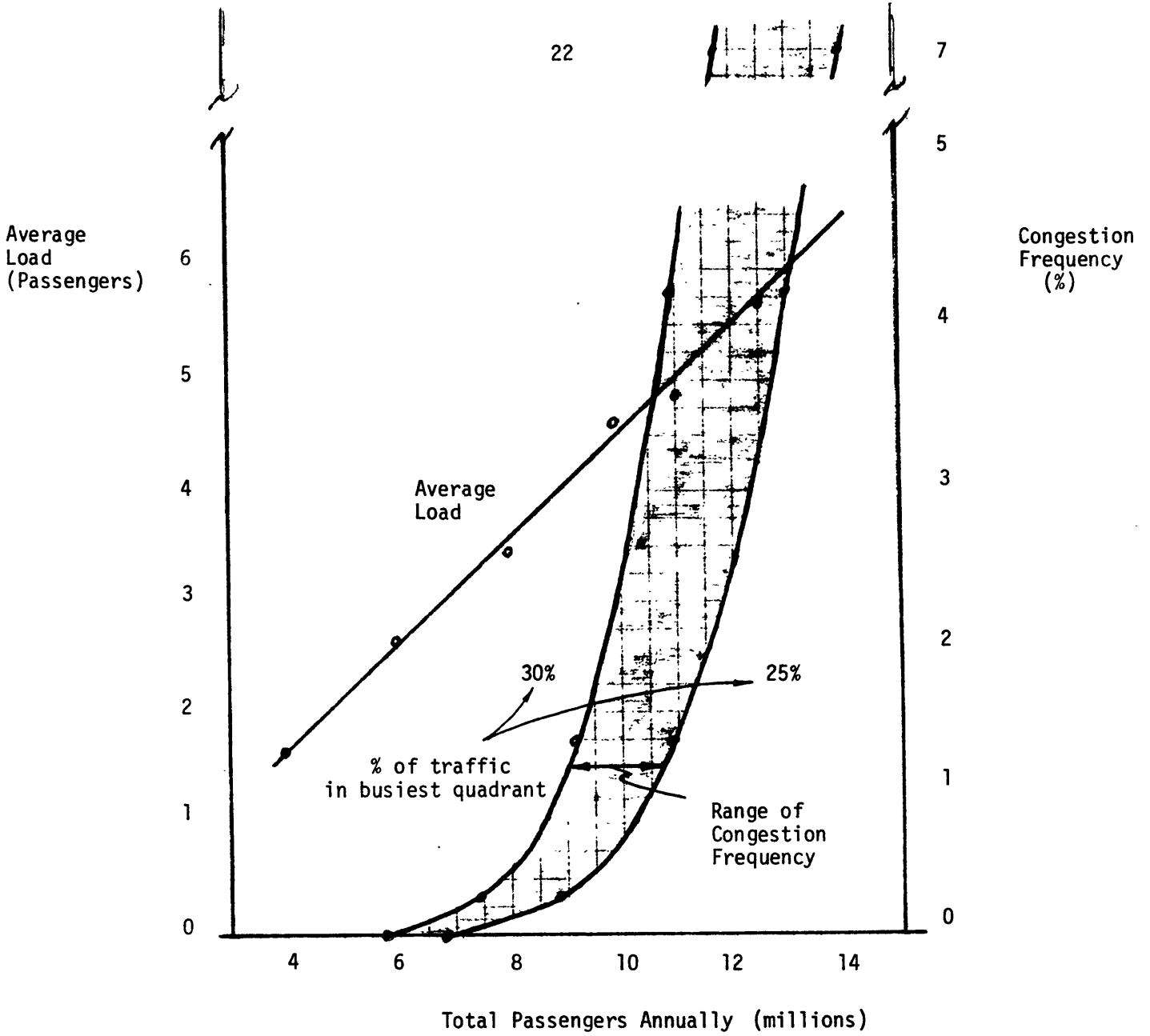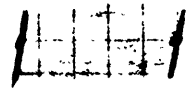
Figure 14:   Congestion Frequency and Average Load on the
             Critical Elevator Segment

III-C   Escalators

Two groups of escalators provide service in the Landside terminal,
those carrying Enplaning passengers from the Ticket level up to the Transfer
level and those carrying Deplaning passengers from the Transfer level down
to the Baggage level. Of the two groups, the latter experiences the only
significant delays, a result stemming from passenger batching. Consequently,
this section refers only to the down escalators between the Transfer and
Baggage levels.

Passengers perceive escalator congestion in two stages. The first
is being delayed versus not being delayed, and the second is being delayed
for a significant length of time. The distinction is important; a passenger
has expectations about the service he receives. Few persons expect to
be delayed at an escalator, therefore any delay will cause irritation.
A significant delay (30 seconds or more) may cause extreme irritation.
Thirty seconds may seem short, but an individual expecting no delay views
it as long. If the passenger was at a ticket booth, however, thirty seconds would
be short because a delay is expected there.

Congestion at the escalators is measured by the percentage of passengers
experiencing a delay and by the average amount of delay experienced.
The percentage of passengers delayed grows steadily, reaching almost 50%
at 15 million passengers annually (see Figure 15). The average delay for
passengers experiencing delay grows very slowly, presumably because the
delay depends more on the batch size than on the number of batches. The
average delay among all passengers, however, grows more rapidly because
both the average delay and the percentage of persons delayed grows.

The simulation shows the escalators causing only minor
delays. However, should passenger habits, airline procedures, or airport
policies change, the escalator delays could change. Note particularly the
shuttle-escalator relationship. A shuttle meters the passenger flow to an
escalator by carrying a maximum of 86 persons per minute, while an escalator
can carry up to 115 persons per minute. Thus, the shuttles protect the escalators
from overly large passenger flows. Two shuttles arriving simultaneously
from different Airsides and feeding the same escalator could cause problems,
but by carefully positioning airlines on the Baggage level, this effect
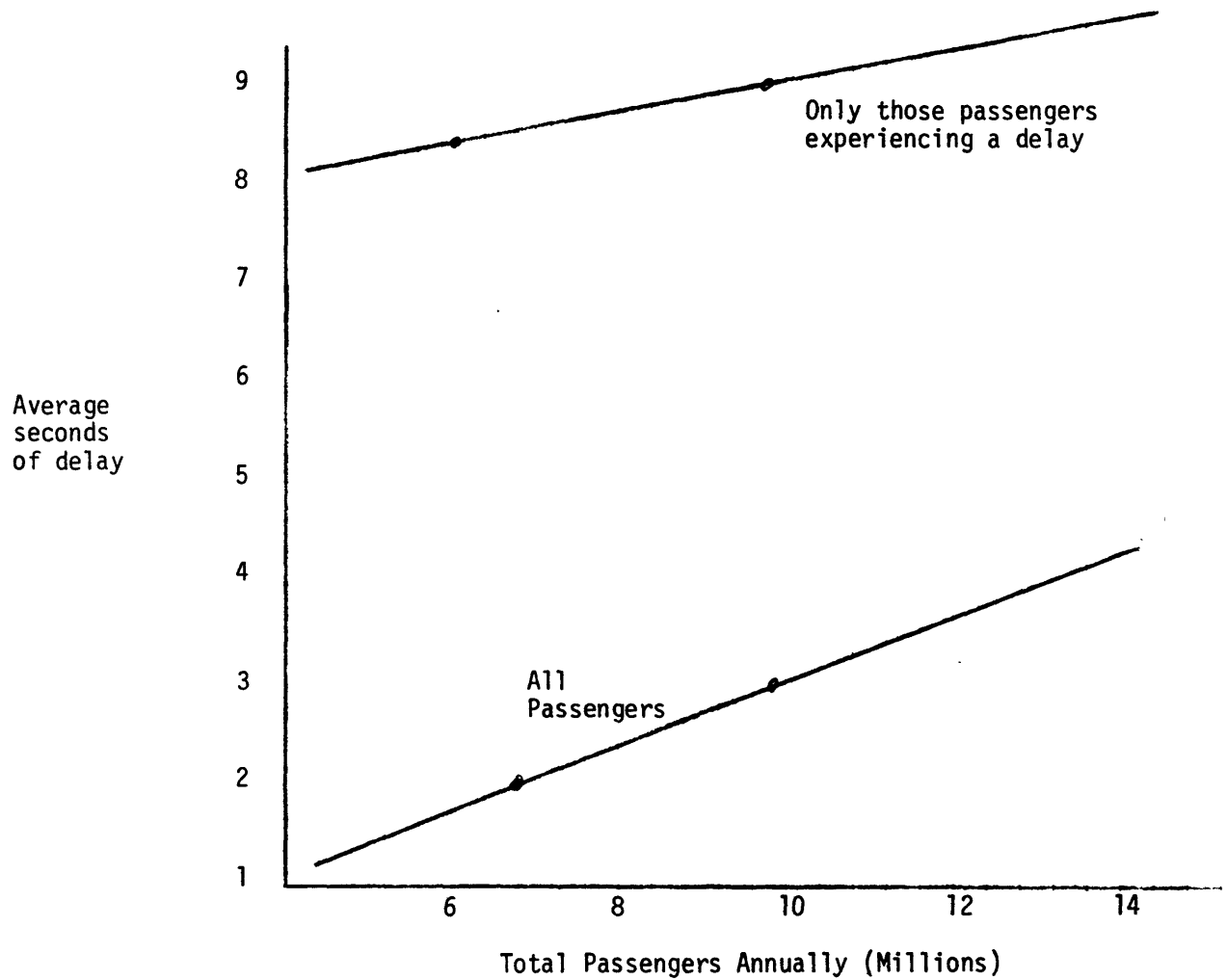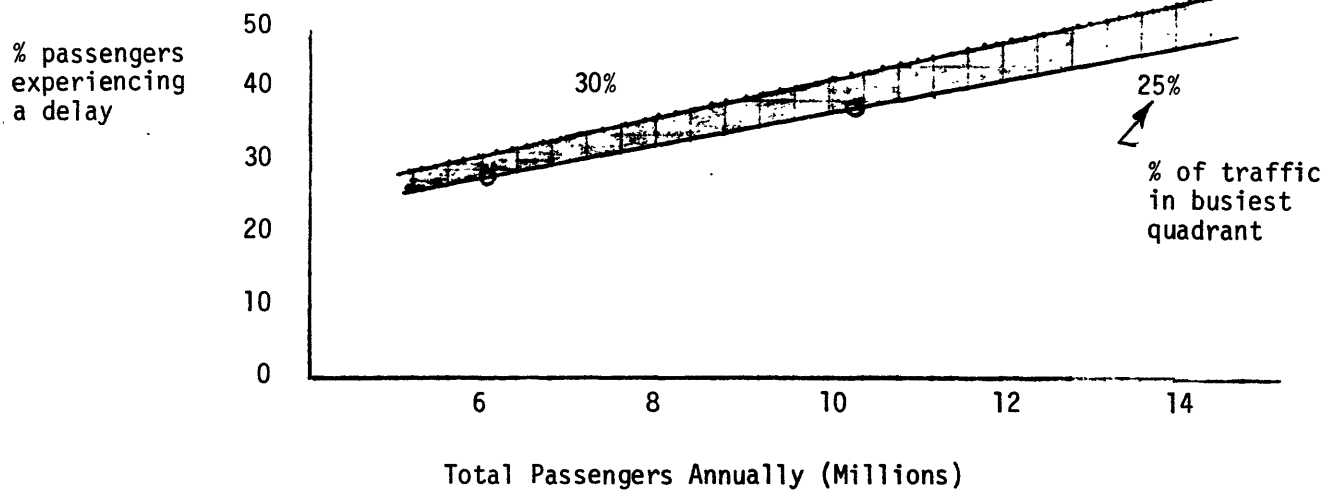is negligible (see 3, in Table 3).

% passengers
experiencing
a delay

Total Passengers Annually (Millions)

Average
seconds
of delay

Total Passengers Annually (Millions)

Figure 15: Congestion graphs for escalators connecting Tranfer
level to the Baggage level.

Table 3:   Factors affecting delay at the Transfer level to Baggage level

escalators

Increase delays

1. Larger shuttle cars allowing larger batches of passengers.

2. Faster shuttle cycle time, decreasing time between batches.

3. Two shuttles feeding the same escalator simultaneously.

This can now occur for NA-UA, TWA-EA, TWA-BN. However, in each case the probability of a simultaneous arrival is extremely low due to the low frequqency of flights for TWA and UA.

The probability of simultaneous arrivals at one escalator can increase dramatically if the airline positions on the Baggage level are changed without careful consideration. For example: If EA moved to the northwest quadrant of the Baggage level, then the two shuttles on the east side of the terminal would feed EA and DL traffic to the one escalator in the northeast quadrant (both airlines have baggage facilities on the north side of the terminal), making the probability of simultaneous arrival of batches very high (see Appendix IV-C).

Decrease delays

1. An increase in the percentage of passengers carrying baggage aboard the aircraft, thereby requiring fewer passengers parked in the garage to go to the Baggage level.

2. Decrease batch sizes or string the planeload of passengers out.
For example, an interesting display on the Transfer level might divert some of the passengers long enough to relieve the pileup at the down escalator.

3. Baggage claim at Airside terminal.

4. Ground level shuttle from Airside terminal to the Baggage level of the Landside terminal.

5. Careful positioning of airlines on Baggage level.

6. Divert part of the traffic to the elevators.

III-D   Shuttle

The shuttle never approaches congested levels. With cars carrying 100 passengers at 70 second headways, two filled 747's can unload simultaneously without noticeable strain on the system. Even at 14+ million passengers annually, the shuttles carry an average load of only 20 passengers (see Figure 16).

Only the arrival of super-jumbo jets carrying more than 500 passengers could congest the shuttles, but only momentarily and only if two jets unload simultaneously. Even here there will not be a problem unless special arrangements are made to unload passengers quickly.
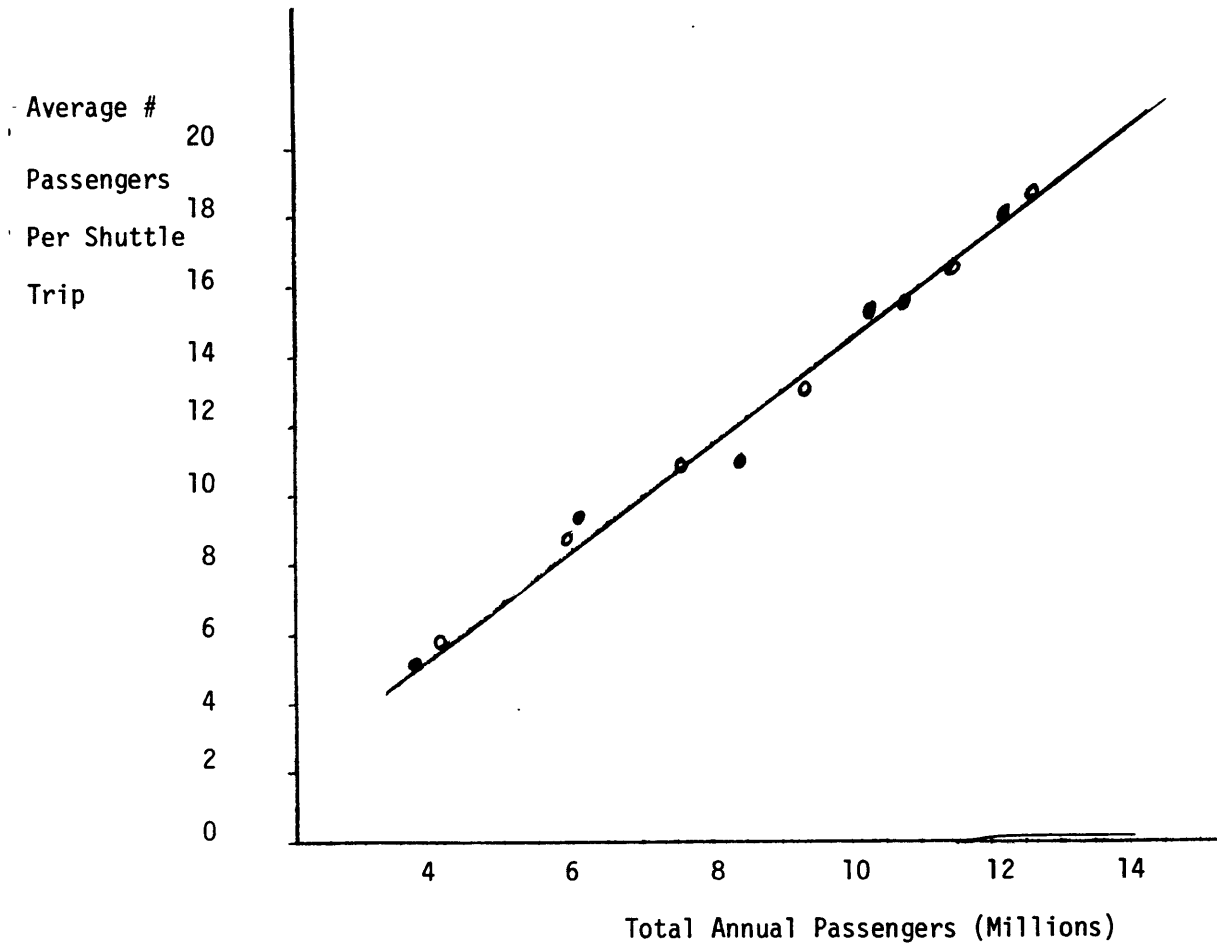
Shuttle Utility

Figure 16: Average passenger load on the shuttles. The shuttle
capacity is 100 persons; obviously, that capacity
is never approached. All eight shuttles are assumed
to be running continuously.

III-E   Discussion of Results

Conclusions

The ticket counters and elevators will be the first facilities to
experience delays, both at annual volumes of 14+ million passengers. The
ticket counters are amenable to a large spectrum of actions that could
relieve the delays. The elevators, however, are less flexible. For them
few actions exist to relieve critical segment congestion; fortunately, however,
the number of passengers delayed·will be small.

The escalators feeding the Transfer level from the ticket level
and the shuttle to the Airside terminals experience no significant congestion.
Both have capacities far beyond expected traffic volumes and are blessed
with a smooth flow of passengers, i.e.
the ticket counters act as a valve on traffic to the escalators, metering
the volume and smoothing any batches.

The shuttle to the Landside also has a capacity far above the expected
flows and even handles the planeload batches with ease.

The escalators from the Transfer level to the Baggage level will
experience minor delays, in that passengers often will not be able to walk
onto the escalator unimpeded. However, no major delays ($\geq$ 30 sec. avg.)
are expected. Problems could arise if the airline positions on the Baggage
level are not carefully matched to airline positions on the Transfer level.
This will be particularly important when the two additional terminals are
added. The shuttle meters passenger flow to the escalators, limiting
batch size to 100 persons. No problem will exist as long as two shuttles
at one end of the terminal do not feed the same escalator, or at least do
so only rarely.

Limitations

The validity of a model's output depends strongly upon the accuracy
of its input. A number of estimates and data from other airports were
used for the Tampa simulation, which give a reasonable representation of
airport and passenger bahavior but lack any qualities unique to Tampa.
The output, therefore, gives a fair representation of Tampa airport and shows
trends and approximate delays but cannot claim extraordinary accuracy for
the predictions.

For greater confidence in the results, a detailed passenger survey at
Tampa should be run to collect airport specific statistics for input to
the simulation. The improvement in accuracy will be important only if Tampa
passengers and facilities behave significantly differently than passengers
and facilities elsewhere. Since no reason exists to believe Tampa behaves
in a unique manner, the estimates used in this case should be sufficient.
A survey, however, could confirm this assumption and contribute valuable
information at the same time.

TOPSIM Potential

TOPSIM has both long- and short-range planning potential. The current
study was a long-range analysis limited in both scope and objective,
modeling only the Landside terminal and shuttles for a single scenario.

A full study would perform a detailed sensitivity analysis, incorporating
other key structures and testing a variety of possible scenarios (see
Table 4). This approach would aid an airport planner or operator in their
long-range planning by determining the impact of events likely to occur in
the future.

Table 4: Areas of Further Research

Other structures to include in the simulation:

1) Baggage Movements

2) Airside Terminals

3) Parking Facilities

4) Roadways and Curbs

5) Rent-a-Car facility

Some alternate scenarios:

1) Change access/egress modal split

2) Introduce a rapid transit line from city of Tampa

3) Introduce ticket machines on curbs and in Parking garage

4) Introduce extensive curbside and garage baggage check-in

5) Change service procedures at ticket counters

6) Change number of passengers per passenger group

7) Change number of greeters/wellwishers per passenger

8) Introduce larger aircraft

9) Speed unloading of aircraft

10) Manipulate the positions of airlines on the Baggage level

In the short term, TOPSIM can test operating policies under consideration by the airport manager and changes proposed by airlines. Through frequent use of the model, an airport operator would learn the terminal behavior intimately and in time would require the model only for novel situations.

TOPSIM

TOPSIM is written in GPSS (General Purpose Simulation System), a language designed for writing simulations and one that greatly simplifies the task of building a model. The TOPSIM-Tampa program was run in the batch mode on an IBM 370 model 165 computer at MIT's Computation Center. A typical run simulating three traffic levels cost $100 and consumed 5 minutes of CPU time. For each traffic level the model was warmed up for two hours of simulated time to reach the steady state and then run for two more hours of simulated time.

IV   APPENDICES

IV-A Data Sources and Assumptions for Passenger Flows

A1. Assignment of Parameters

1) The percentage of peak hour passengers assigned to an airline equals
    the percentage of total traffic an airline carried in the year ending
    June 1974.

2) Eight trunk airlines are modeled: Braniff, Delta, Eastern, National,
    Northwest, Pan Am, TWA, and United.

3) The minutes before departure an Enplaning pax arrives at the terminal,
    source: United Airlines' National Airport Statistics, given in a
    letter to Professor R.W. Simpson, July 31, 1969.

4) The distribution of access modes, source: Tampa International
    Airport "Origin and Destination Study", November, 1973, by the
    St. Petersburg Times.

5) Number of passengers per group, source: Tampa International Airport
    "Origin and Destination Study", November, 1973, by the St. Petersburg
    Times.

6) Number of wellwishers/greeters per passenger, source: Washington
    Baltimore Survey, Volume II, May 1968, by the Abt Associates.

7) Number of bags per passenger by access mode, source: <u>Ground Transport to Philadelphia International Airport</u>, Simpson and Curtin, July 31, 1968.

8) Average walking speed, source: <u>The Use of Queuing Models - At Airports</u>, Walter A. Barbo, institute of Transportation and Traffic Engineering, University of California, September 1, 1967.

A2. <u>Enplaning Passenger Flow</u>

1) An Enplaning passenger entering the terminal with less than 30 minutes till flight departure will proceed directly to the shuttle, bypassing the ticket booths.

2) Greeters go directly to shuttle, never loitering on the Transfer level.

3) Enplaning passengers using the garage park in the quadrant marked for their airline, which corresponds to the airline's position on the Ticket level.

4) Enplaning passengers arriving in rent-a-cars enter Baggage level from south side of building.

5) They then use stairs to access Ticket level, and elevators to access Transfer level from Baggage level.

6) Enplaning passengers entering terminal from the curb on Ticket level, access that part of curb marked for their airline, which presumably lies adjacent to that airline's ticket booth inside.

7) From ticket booth, walk to nearest escalator for ride to Transfer level.

8) Loiter time on Transfer level, FTL estimate.

A3. Deplaning Passengers

1) The time between batches varies randomly, using a linear distribution.

2) Deplaning passengers arrive in planeload batches where the average batch has 50 passengers arriving within a three minute span. The model utilizes a Poisson process to create passengers, i.e. the interarrival time is random with a mean of 3.6 seconds. Therefore, group sizes are random, but over many groups average 50 passengers.

3) Once on the Transfer level, a passenger walks directly to the escalator to reach the Baggage level or directly to the elevator to reach the parking garage (if no baggage).

4) Waiting time for baggage is a function of the number of bags, an FTL estimate. Since no data was available on baggage wait times, this estimate was gross at best.

5) Walk to nearest door for rides waiting at the curb and to the nearest elevator, if parked in a garage.

6) Walk to south side of building, if renting a car.

IV-B Facilities

Each facility was modeled as indicated below.

B1. Passenger Processing

1) Ticket Booths

Each airline uses maximum staffing and a single waiting line or queue located in one of the four quadrants. Passengers enter the queue of their airline, wait until the front is reached, and then engage the first available agent. This multiserver, FIFO queue has the same expected waiting time as a multiserver, random access queue, where the latter closely approximates the behavior of multiple queues with passengers free to switch lines. The variance, however, is somewhat larger.

Single Queue
(FIFO)
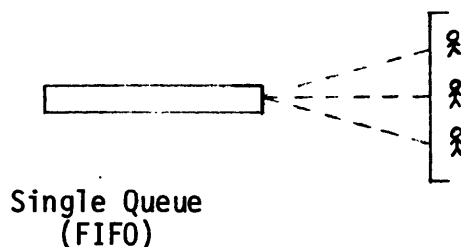
Ticket agents - a passenger leaves queue only when an agent becomes free

The service time varies randomly about a mean of 2.4 minutes, source: D.O.T. videotape, April 23, 1968.

2) Rent-a-Car Booths

These operate similar to ticket booths, only passengers do not associate particular booths with particular airlines. The average service time varies randomly about a mean of four minutes.

B2. Passenger Transport

1) Shuttle

The shuttle runs on a fixed cycle, 42 seconds for transit and 30 seconds for station dwell time. With two shuttles running concurrently and on opposite cycles, the headway spans only 72 seconds. The passengers enter a single queue while waiting for the next car, then enter simultaneously. Shuttle cars hold a maximum of 100 persons.

FIFO Queue
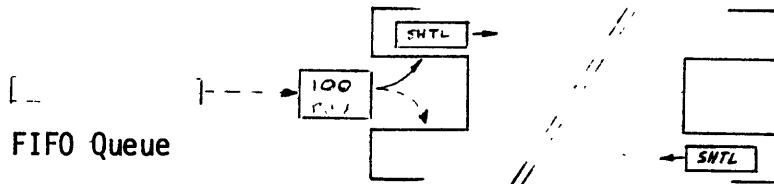
2) Escalators

Passengers queue at the entrance and enter one at a time with a maximum service rate of ten passengers every six seconds. The escalators spanning one floor have a passenger travel time of 30 seconds, those spanning two floors take 54 seconds (FTL estimate, based on timing escalators in Boston).

| FIFO Queue | 10 pax
6 sec. | Escalator
30/54 sec. ride |
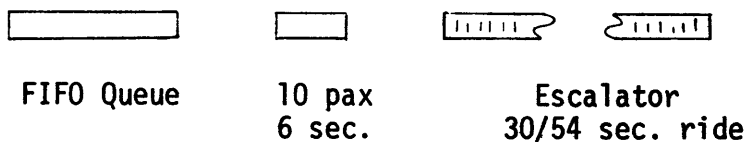
3) Elevators

The four banks of four elevators each run identical, continuous cycles, the cars spaced 48 seconds or 2 1/2 floors apart, for a 24 second average waiting time. Passengers queue at each bank of elevators and enter the next car simultaneously. Cars hold a maximum of ten persons (see Section III-B).

4) Stairs

Operate similar to escalators where passengers enter at a maximum rate of eight persons every six seconds. Since climbing requires more effort than level walking - the stairs equal 100' of walking in both distance and time.
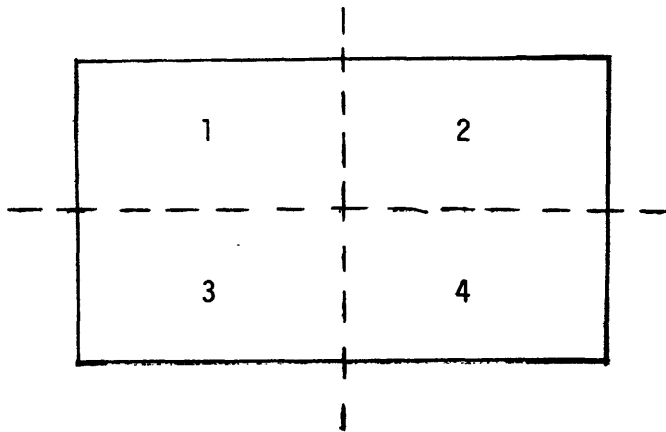
FIFO Queue   8 pax
6 sec.

Stairs
equivalent to 100' of
level ground

1	2
3	4
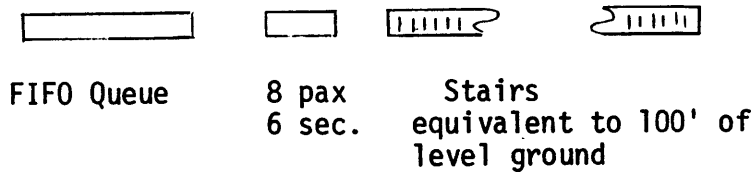
Figure 17: Each level is divided into quadrants, with each airline being assigned to a quadrant according to its location on that floor.

1	2
NW UA	TWA DL PA
NA	EA BN
3	4

TRANSFER LEVEL

1	2
NA UA BN	DL
NW	TWA PA EA
3	4

TICKET LEVEL

1	2
NA UA	DL PA
NW TWA BN	EA
3	4

BAGGAGE LEVEL