BUS TERMINAL PERFORMANCE MEASURED WITH TIME STAMPING

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Previously, the terminal planner faced with the task of evaluating the overall performance of a facility, has had available only disjointed pieces of information concerning parts of the problem. This lack of comprehensive, quantitative data lead to the analysis of separate pieces of the terminal, under different loading conditions, resulting in a piecemeal assessment of the terminal's performance. The research described in this paper was aimed at correcting these problems, through the application of a new survey technique called "time-stamping". After its initial application in an air terminal, this study was undertaken to expand the technique to bus terminals. The time-stamping technique was applied to the intercity bus terminal in Ottawa, Canada. Analysis of the data showed that no capacity related problems existed at present. The future location, magnitude and approximate timing of capacity problems were determined. Specifically, the following information was provided: 1. The amount of area in the terminal used over the survey period (at a given level of service) and its distribution both temporally and spatially 2. average length of stay and its distribution 3. average distance walked 4. desire line mappings indicating layout problems 5. average occupancy curves of terminal facilities, by busload. The processing capacity of the facility was determined, plus the expected impacts of scheduling revisions on increasing the useful lifespan of the terminal. Also, impacts of terminal layout revisions on reducing walking distances was predicted.

In recent years, there has been increasing interest in terminal planning, design and analysis, owing to the realization among transport planners of the importance of this facet of the intercity trip. Experience has indicated that new designs have better served both the traveller and the terminal owner/manager, but quantification of terminal performance remains largely unexplored.

The terminal planner faced with the task of evaluating the overall performance of a facility, previously had only disjointed pieces of information concerning parts of the problem. This lack of comprehensive quantitative data lead to the analysis of separate pieces of the terminal, under different loading conditions: resulting in a piecemeal assessment of the terminal's performance. The need for further work in the area is summarized by Hoel and Rozner (1):

Until very recently, little attention has been paid to methods for evaluating the performance of transition points between modes such as . . . transitions between intercity and interurban transportation networks . . . there is a pressing need for systematic procedures and analytical methods of facility design and evaluation.

Purpose and Scope of Study

Before attempting to optimize terminal design, the objectives of such a transfer facility should be delineated. The passenger is interested in effecting the modal transfer with a minimum amount of delay, a maximum degree of comfort and safety and at the preferred time. The owner/manager wishes to satisfy all demand, but must be concerned with return on investment through cost minimization and revenue maximization.

A search of the literature relevant to the state of the art in terminal evaluation/planning indicated that various parts of the terminal have been investigated separately. There remains the need for quantitatively examining the combination and interaction of these elements on a broader scale. This would be of more use to the practicing planner in ascertaining a facility's adequacy. Bits and pieces, which comprise the total, do not act in isolation; and so to analyse them as if they did, cannot be realistic.

Design standards and rules-of-thumb are available for rough "sizing out" of platform lengths, recommended area square footages etc. (2). These are usually based on gross yearly flow figures only and are derived from generalized past experience. Fruin (3) has defined pedestrian levels of service for walkways, stairways and queueing/waiting areas. These have been used extensively in the following analysis.

Computer simulations of terminal facilities have also been prepared (4). But none of the efforts surveyed have specifically addressed the problem of complete terminal performance evaluation. It is felt that one of the main reasons for this deficit has been the lack of data collection techniques suited to the task.

This paper presents the work of Johnson (5) who attempted to quantify as many of the stated design objectives as possible, measure these for a facility in operation and subsequently use these measures to evaluate the performance of a complete terminal.

This paper will therefore deal only with those design objectives which are readily quantifiable and measurable. Revenues and costs will not be dealt with directly. Table 1 specifies those areas that will be investigated and the measures to be used for each.

Physically the scope of the study is confined primarily to the terminal building itself, i.e. from the time the pedestrian enters until he leaves it.

Field Work

The intercity bus terminal in Ottawa, Canada, owned by Voyageur-Colonial Ltd. was selected as the example for analysis owing to its proximity, manageable size, relatively heavy usage (in peak periods), and newness of design.

The measures of performance sought were quantitative and detailed in nature and so the data base had to be the same. Basic elements such as occupancy counts, flow volumes, flow patterns and processing rates within the terminal had to be accurately provided. With these as a basis more complex measures could then be calculated.

The survey techniques considered were:
1. Personal interviewing.
2. Self administered questionnaires i) collected by survey personnel ii) mailed back.
3. Counts and observations.
4. Videotape and time lapse photography.
5. Inference from existing sources.
6. Tailing.
7. Time-stamping.

For detailed descriptions of the first 6 techniques see the Airport Travel Survey Manual (6).

The last one, time-stamping, was chosen as the most appropriate in terms of data quality and content, total terminal coverage, cost and ease of execution and analysis.

Time-stamping is premised on the fact that virtually all quantitative data can be derived for a terminal, if a time-space trace of each of its occupants can be made. A simple objective, but previously not possible using data from other survey techniques.

In this method, each person upon entering the building is given a card to carry (illustrated in Figure 1) which contains a coded time and location stamp. As the pedestrian proceeds through the facility, his card is further stamped by surveyors at the entrance/exit (called checkpoints) of each part of the terminal to be examined. Examples of these checkpoints are entrances/exits to ticket lobbies and queues, waiting areas, baggage claim areas, restaurants etc. When the traveller prepares to leave the terminal, his card is stamped and collected. The completed card is, in fact, exactly the required time-space trace. For further details on this method, see Braaksma (7).

Figure 2 shows the layout of the bus terminal, along with the location of checkpoints and surveyors. The survey was carried out during the weekly peak period of Friday, 14:00-19:00 H., on January 23, 1976.

University students were hired as surveyors and required approximately one hour to be briefed and trained.

Entrants to the terminal were asked if they were passengers or visitors, with the cards of the former being marked with a large "P" by the surveyors.

Problems in executing this survey were minimal with a few of the stamping clocks requiring replacing and there being insufficient surveyors available to permit coffee breaks. It was felt that surveyors were visible enough that participants could readily locate them, but did not interfere with or influence normal flows or activities.

The acceptance-completion rate was 45% of terminal users, giving a return of 1199 cards in 5 hours of survey time. It should be noted that determining the exact acceptance rate is vital to allow expansion of the data to simulate actual conditions.

Table 1. Terminal design objectives.

Terminal Design Objectives	Measure(s) Used
User-Related	
minimize time spent in terminal	. length of stay distribution . mean, median length of stay . length of stay variation with time
minimize distance walked	. average distance walked . desire line map (trip tables)
minimize crowding	. load to capacity ratios using appropriate levels of service
maximize available "extra" services	. remaining excess capacity
maximize convenience of arrival and departure times	. scheduling impact information; standard accupancy figures
Owner-Related	
maximize revenue . maximize use of existing facility	. area usage ratios . load to capacity ratios
. maximize scheduling efficiency	. scheduling impact information: standard occupancy figures
minimize service disruption	. problem prediction using expected growth and load to capacity ratios

Figure 1. Pedestrian traffic flow survey card.

Performance Measures

Data processing was done manually, owing to the relatively small number of cards. Since the completion of this work, the Airports Services and Security Branch of Transport Canada has developed computer programs for the calculation of most of the following data.

Occupancy Counts

The number of occupants in each part of the terminal over time was determined. This is shown in Figure 3. Peak occupancy for the whole terminal was 411 people at 5:10 P.M.. Figure 3 also illustrates relative values of occupancies in each part of the terminal.

Load to Capacity Ratios

More significant to the planner than simple occupancies is the ratio of what an area is holding to what it can/should hold, at a specified level of service, i.e. load to capacity ratios (L/C).

Many authors feel that 15 minute peaks should be planned for, and so, 15 minute average occupancies are used throughout. This means that if an area has a load/capacity ratio greater than 1.0, then, on the average, the desired level of service is not being met for this period.

To carry out a comprehensive analysis of the terminal, all of its elements must be included. This includes the static holding areas such as the restaurant, bar, botique, and waiting areas, the processors such as ticket wickets and lobby and bus bays; and links such as corridors.

Examples of load to capacity ratios over time are presented in Table 2 for the two processors in this terminal, the main waiting area and the ticket lobby as well as the "auxiliary" services. These have all made use of Fruin's (4) level of service in determining the capacity.

An off-shoot of the load to capacity ratios is the consideration of what percentage of available space is used for what part of the time over the survey period. This is expressed by the formula:

$$\frac{\text{space used x time it is used x 100}}{\text{total available space x total time available}}$$

These area-temporal utilization ratios differ from simple L/C's, in that time is included, plus it covers the complete survey period. In fact, differing distributions of L/C's, over this period could result in the same area-temporal utilization. Examples of this are shown in Figure 4 with the distance between horizontal lines representing the facility's capacity. When these are expanded until one of the "bars" reaches the capacity line, the resulting utilization ratio will indicate how much of the area will be used when the facility reaches its capacity at the daily peak. Of course, a flatter curve is more desirable as the loads are then more evenly spread over time, and the effects of efforts to achieve this (such as differential fares) will be made evident here.

Table 2. Load to capacity ratios, %.

Time	Main Waiting Area	Ticket Lobby	Restaurant	Bar	Boutique
14:15-14:29	16	9	2	2	12
14:30-14:44	28	13	22	7	16
14:45-14:59	26	5	13	4	16
15:00-15:14	24	9	11	7	20
15:15-15:29	23	8	26	22	24
15:30-15:44	20	13	27	42	24
15:45-15:59	27	18	39	49	36
16:00-16:14	41	28	63	44	48
16:15-16:29	67	41	71	42	44
16:30-16:44	61	46	56	49	20
16:45-16:59	53	35	69	40	48
17:00-17:14	59	31	61	31	32
17:15-17:29	70	42	55	42	40
17:30-17:44	61	41	57	64	48
17:45-17:59	53	39	39	49	12
18:00-18:14	41	22	36	20	20
18:15-18:29	29	13	11	9	4
18:30-18:44	9	4	0	4	0

Occupancy Curves

To help determine the effects of each busload on the terminal's facilities, the occupancy in the terminal of outbound and inbound passengers was broken down into individual busloads. These curves

were then superimposed and averaged for inbound, outbound "local" and outbound "express" bus passengers. An example is shown in Figure 5. These curves, in effect, indicate at any time relative to the scheduled departure or arrival, what portion of the bus-load can be expected to be in any part of the terminal. They also show graphically the impact scheduling can have on the terminal and surges that occur in loading are made evident. Similar curves have been developed for the waiting area, ticket lobby and combined auxiliary services. Through the superimposition of these curves, schedule revisions have been simulated. This indicated that such changes can have significant impact on extending the life of the facility.

Volume to Capacity Ratios

The processors and links are the dynamic elements of the terminal system. For these, the flow volume-to-capacity ratios have been calculated, again using Fruin's recommended levels of service (see Table 3).

Processing Capacity of Terminal

The facilities that are needed to complete the intermodal transfer, are the ticket wickets, ticket lobby, main waiting area and outbound bus bays. In order to determine the capacity of the terminal as a whole these are the parts that must be given priority. Table 4 contains the list of the daily peak L/C or V/C ratios:

Thus, the main waiting area should be the first essential part of the terminal to encounter capacity problems. When present loads are increased by roughly 50%, its capacity will be reached, at the specified level of service. For the hour surrounding this peak, there were 525 outbound passengers and 856 persons who moved through the terminal. Thus, one would expect that if more than approximately 800 outbound passengers or 1300 persons were to move through the terminal in one hour, there would be capacity problems. This is at a "peak hour factor" of .70 (see Highway Capacity Manual (8)). This has been defined as the terminal's processing capacity -- 800 outbound passengers per hour or 1300 persons per hour.

Table 4. Daily peak L/C or V/C ratios.

Terminal Element	Daily Peak L/C or V/C (%)
Restaurant	71
Waiting area	70
Bar	64
Ticket wickets	61
Boutique	48
Ticket lobby	46
Outbound bus bays	25

When combined with the expected growth rate in patronage, the capacity of the terminal can give the expected life of the facility. It was found here to be roughly 10 years. That is, the demand for use of the terminal will have increased by 50% in this time, and without modifications to the layout or operation, there will be capacity problems.

However, problems will not wait for 10 years to surface because the volume of demand and the resulting service provided are not linearly related in transportation facilities, as stated by de Neufville (9).

When the arrival rate approaches the maximum rate of service, delays increase disproportionately faster than the rate of arrivals . . . Extraordinary delays result, therefore, from any service system operating near its capacity . . . This behaviour is characteristic of all manner of service systems: check-in counters for passengers; conveyors and sorters for baggage; corridors for pedestrians; runways serving arriving and departing aircraft; and so on.

Trip Tables

From the survey data trip tables were prepared between pairs of checkpoints. These were prepared for inbound and outbound passengers, visitors, and total persons.

When the O-D trip table is presented graphically, the result is a desire line mapping as shown in Figure 6. This can be used to reorganize the layout

Table 3. Volume to Capacity ratios, %.

Time	Door #16	Restaurant Doors	Bar Doors	Boutique Door	Inbound Bus Bays	Ticket Wickets	Outbound Bus Bays
14:15-14:29	2.1	4.1	0.1	4.0	11.1	21.0	0.8
14:30-14:44	1.6	3.1	0.2	5.1	3.6	40.0	8.0
14:45-14:59	1.5	1.6	0.4	3.3	2.8	28.0	16.0
15:00-15:14	2.8	1.3	0.4	2.6	15.0	12.0	3.0
15:15-15:29	2.1	3.1	0.7	5.6	4.0	16.0	5.0
15:30-15:44	1.8	3.0	0.6	3.5	2.8	22.0	4.0
15:45-15:59	2.2	5.3	0.7	6.7	13.8	33.0	5.0
16:00-16:14	3.1	6.9	1.2	10.0	2.8	34.0	3.0
16:15-16:29	3.4	8.4	1.7	9.2	6.7	51.0	7.0
16:30-16:44	3.5	9.1	2.1	7.2	13.8	61.0	25.0
16:45-16:59	3.7	5.8	2.0	7.9	7.1	48.0	17.0
17:00-17:14	3.0	5.4	1.0	8.9	4.4	43.0	7.0
17:15-17:29	3.8	8.1	1.6	10.2	12.3	54.0	16.0
17:30-17:44	3.5	5.3	2.3	7.9	5.2	57.0	13.0
17:45-17:59	2.0	2.8	0.6	5.9	2.0	43.0	12.0
18:00-18:14	1.3	2.8	0.6	5.6	5.2	28.0	13.0
18:15-18:29	1.4	1.8	0.1	3.0	3.2	17.0	11.0
18:30-18:44	0.9	0.0	0.0	0.2	0.0	6.0	4.0

Figure 2. Voyageur-Colonial bus terminal layout, Ottawa

SCALE :

0   20'   40'   60'

LEGEND :

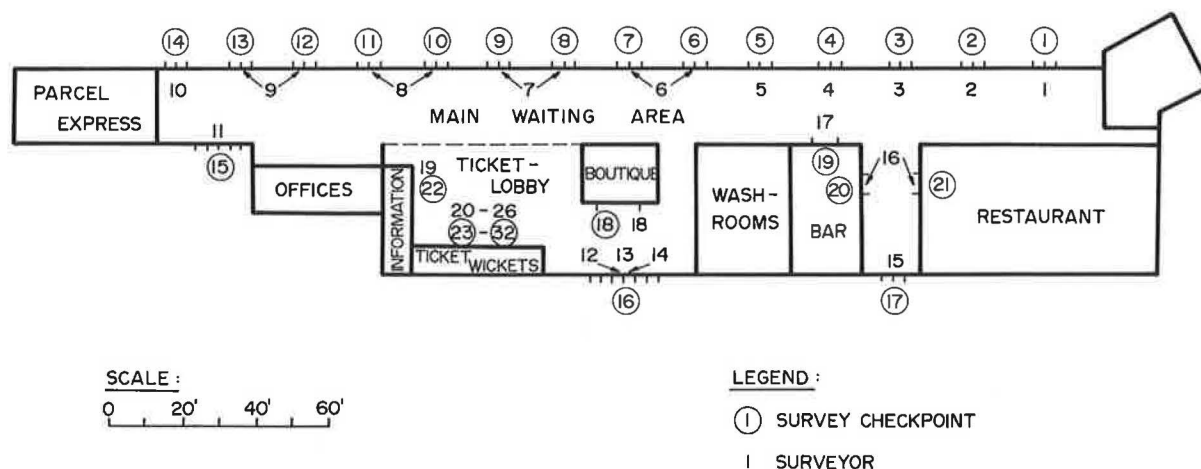(1) SURVEY CHECKPOINT

I   SURVEYOR
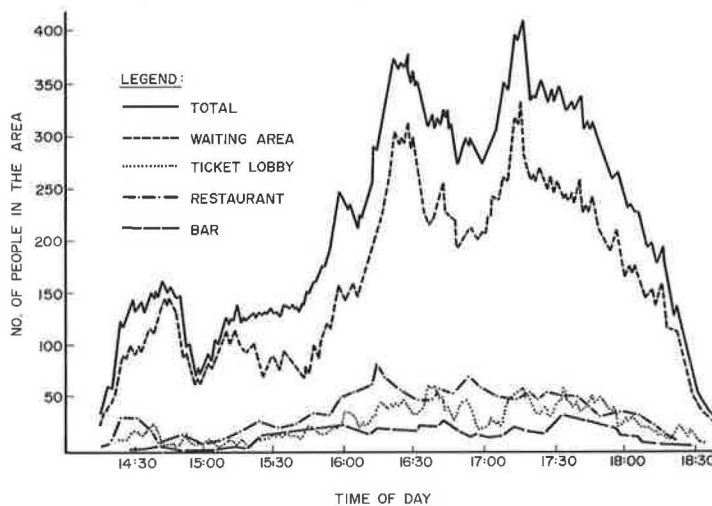
Figure 3. Area occupancies over time.
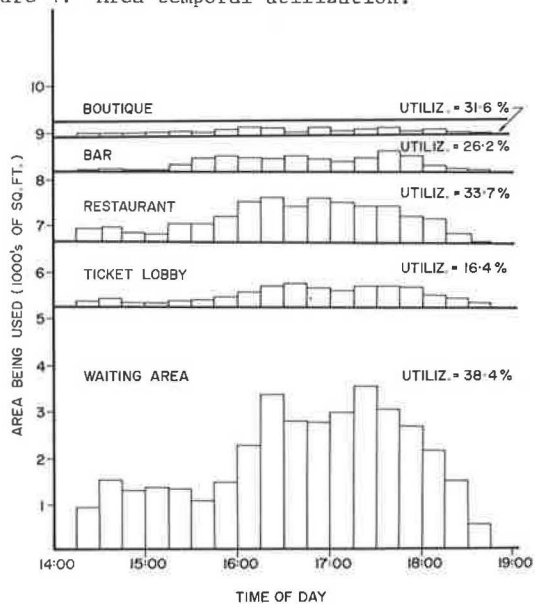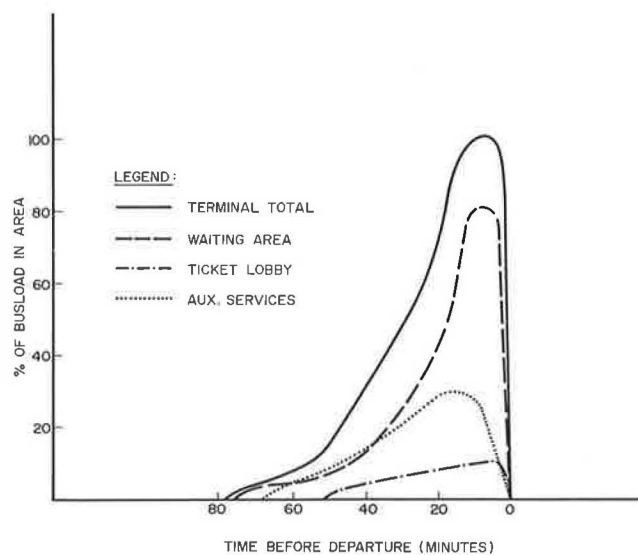
Figure 4. Area-temporal utilization.

Figure 5. Outbound passenger area occupancy curves.

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and to reduce distances walked. In this instance, exchanging bus bay #1 through #6 with bus bays #7 through #12 was found to reduce the average walking distance by almost 15%. This could also be an aid to designers when several layouts can be examined and compared.

Weighted Average Walking Distances

Weighted average walking distances have been calculated for the inbound and outbound passengers, visitors and the total. This was done by multiplying the elements of the origin-destination trip matrix with the corresponding elements of a matrix of walking distances between each O-D. The result is then a matrix of the number of person-m (person-ft) walked between each O-D pair. The sum of all elements, when divided by the number of people, produces this weighted average walking distance. Table 5 gives the results, with a "trip" being the movement between a pair of checkpoints. The relative proportion of terminal user types is also shown.

Length of Stay Distribution

The distribution of length of stay in the terminal was determined. For this particular setup, the outbound passenger had the longest average length of stay (mean = 22.79 minutes, standard deviation = 22.64 minutes), followed by visitors (mean = 19.31 minutes, standard deviation = 26.08 minutes) and inbound passengers (mean = 17.76 minutes, standard deviation = 22.46 minutes). The overall mean value was 20.77 minutes with a standard deviation of 22.18 minutes. The high degree of dispersion, as evident by the high standard deviation to mean ratio indicates a widely spread, skewed distribution of occupancy times as shown in Figure 7. Thus, the mean values alone are not truly indicative of the service being offered by the terminal. This distribution can be used in before and after type studies to determine the effects of terminal layout or operations changes on the length of stay.

Conclusions

1. At the present time, the Voyageur-Colonial terminal in Ottawa has no capacity related problems during a busy weekly rushhour. Examination of the holding area L/C ratios and processor/link V/C ratios showed the most heavily taxed essential element of the terminal was the main waiting area. It has a peak 15 minute average occupancy of 70% of its holding capacity.

According to expected traffic growth predictions, the terminal should experience capacity problems around the year 1985. This assumes all factors such as traffic mix, length of stay in the terminal etc. will remain relatively constant.

2. With scheduling revisions alone, it is estimated that the present levels of service can be preserved for roughly 10 years, thus extending the useful life of the terminal.

3. The time-stamping survey technique has proved to be applicable to a terminal of this size, layout and mode. The data base provided a wide variety of quantitative data concerning the terminal, in operation, with a minimum of disruption during its execution.

It is recommended that such surveys be incorporated in a continuing program to update the data base and to investigate the effects of seasonal variations on service provided to the user.

4. The planner can now produce a great deal of quantitative information specifically concerning the present performance of an entire terminal, in operation. Using this, future problem prediction and solution may be carried out, leading possibly to improved design techniques in the future.

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Table 5. Weighted average walking distance.

Statistic	Terminal User			
	Outbound Passenger	Inbound Passenger	Visitor	Total
No. of card-carriers	616	290	293	1,199
Total distance walked (person-m)	45,894	16,504	15,862	78,260
Weighted ave. distance walked (m)	74.5	56.9	54.1	65.3
Standard dev. of distance walked (m)	15.1	19.6	17.5	17.0
Average No. of "trips" per person	2.4	1.6	1.7	2.1
Average "trip" length (m)	31.0	34.7	31.2	31.1

1 m = 3.28 ft.

Figure 6. Typical desire line map.
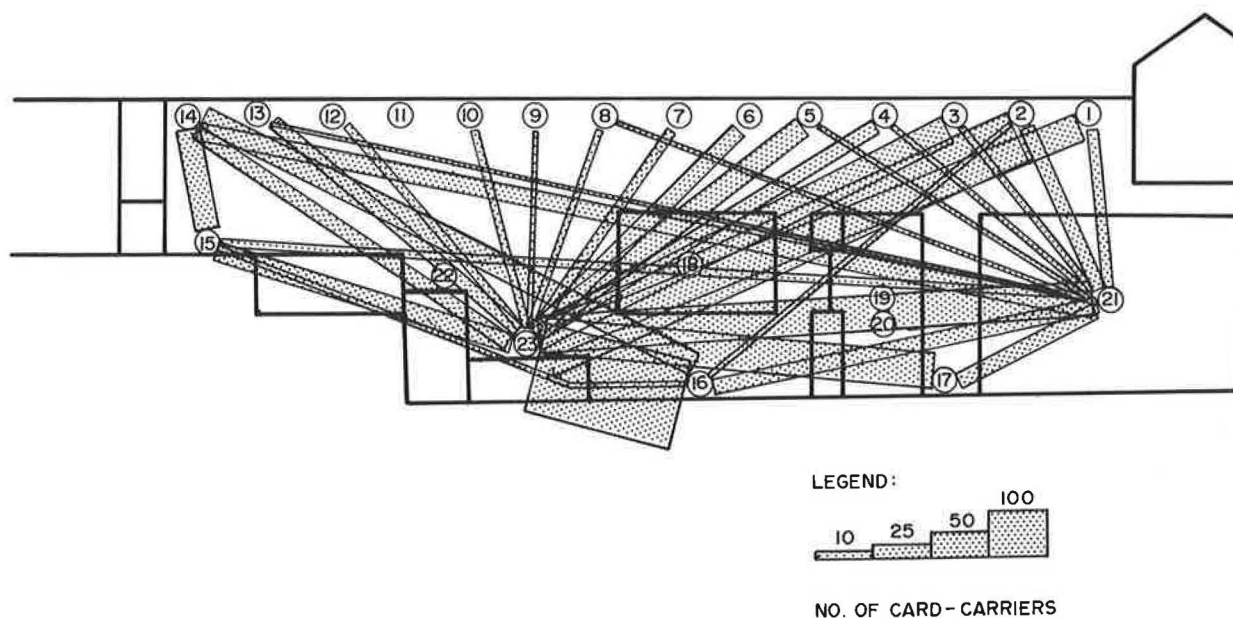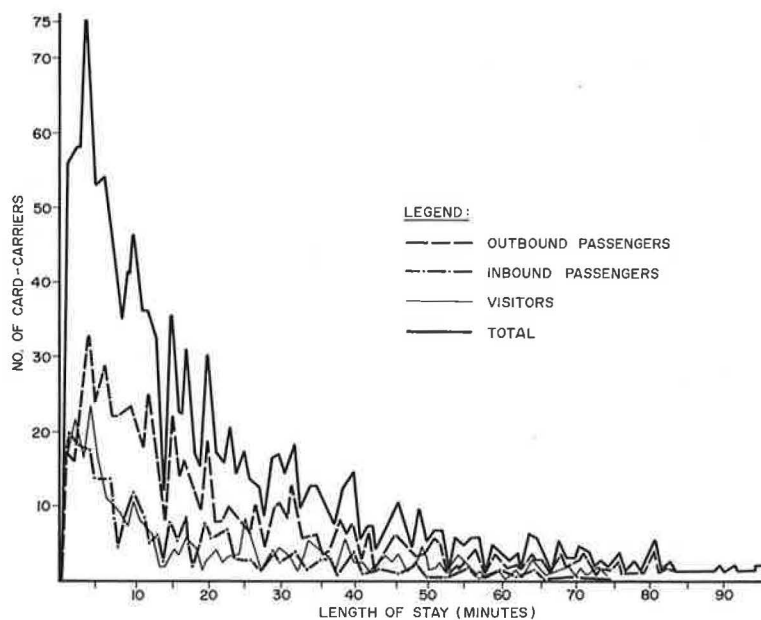

LEGEND:

100

10 25 50

NO. OF CARD-CARRIERS

Figure 7. Terminal occupancy duration frequency distribution.

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