

Passenger Behavior and Design of Airport Terminals

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The main deficiency in current terminal design methodology relates to the lack of empirically based information regarding passenger behavior and passenger requirements in airport terminals. This is exacerbated by the fact that airport planners do not have an adequate model of passenger behavior. This paper describes a research program that has attempted to alleviate these problems. The basis of the research has been the development of a design procedure and rationale capable of explicitly catering to the requirements of all terminal users. This approach will enable the airport planner to define levels of service to suit both the extent of passenger flow and the operational characteristics of the terminal. The central theme of the design methodology was the development of a set of linked analytical queuing models that can act as a framework for interpreting the processing activities of terminal users. This approach was complemented by an extensive survey of passenger behavior at an airport terminal. The survey was designed to both validate the modeling approach and test some general hypotheses about how various passenger groups spend their time in airport terminals. The latter aspect is dealt with in a discussion of some of the design implications of observed passenger behavior.

The level of demand for medium- and long-distance air transport has been known for some time to be dependent on a number of factors, including the cost, comfort, safety, and convenience of the service being provided. Air travel is recognized as the most expensive of all intercity modes of travel. A consequence of this is that traffic is attracted by offering a premium service in terms of speed, comfort, and convenience. However, it is evident that, within the air transport system, the airport terminal has become a major impedance to the rapid and comfortable processing of passengers from origin to destination. During the past 20 years, the airport terminal has had to reduce its level of passenger service in 3 distinct areas: access to and from the airport, the period spent within the terminal and its immediate environs, and the time spent within the aircraft both in ground delays and in the "stack."

The discussion here relates to the second, and possibly most significant, problem area, the time spent by

the passenger within the airport terminal. The implications of observed airport terminal passenger behavior are considered for the overall terminal design procedures that have been adopted for airport planning. The research described is based on observations at a medium-sized regional airport; the applications are thus limited to the function of this type of airport with yearly passenger movements between 200 000 and 2 million. The relevance of the work to the larger metropolitan airports such as John F. Kennedy, Heathrow, and O'Hare has not been explicitly considered. The problems discussed here are unlikely to be of relevance to small airports where the elements of congestion are unlikely to occur over long periods.

The problem with current airport terminals is that the passenger is subject to delays and procedures that, together with increasing congestion of the airway system, have produced a marked deterioration in the overall level of service in air travel. For example, many passenger terminals are subject to crowding in peak hours and passengers have to endure long waiting times. This problem has been exacerbated by the fact that many terminals have been designed to cut down aircraft movement times to minimize aircraft operation costs. The result is a further increase in passenger waiting times and special difficulties for those passengers transferring between flights. Another facet of the problem is the apparent inability of airport designers to cope adequately with secular and short-term variations of passenger demand (1, 2). Airport authorities are familiar with the problem of the rapid obsolescence of terminal buildings (3, 4). The British Airports Authority, for example, recognizes that terminals may be subject to major alterations at intervals as frequent as 5 years and major restructuring and rebuilding at intervals of 15 years. Compared with the economic life of other transport infrastructure and the physical life of the component structures, the renovation and renewal periods of airport terminals would appear inordinately short. The same problem is apparent for short-term design forecasts, as current terminal designs seem to be inflexible with respect to hourly, daily, and seasonal variations in passenger flow (3). Some of these problems have been tackled by airport designers who have considered strategies such

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as mobile lounges as temporary terminal building expansions or remote gate boarding areas for services where terminal facilities can be deemphasized (3, 5).

Many of these problems are considered to be related to the use of inflexible and inappropriate terminal design procedures and criteria. A review of current terminal design methodology (1) has indicated that the inappropriateness results from the lack of an explicit consideration of passenger behavior and requirements (2, 6). Without such information it is difficult for the airport planner to define levels of terminal service to suit both the extent of passenger flow and the operation characteristics of the terminal.

A research approach to the problems of terminal design is proposed that is based on an empirical study of the macroscopic behavior of passengers at terminals. The research, which has been multidisciplinary in nature, has had several aspects; 3 in particular are relevant to the arguments put forward in this paper.

1. A survey was carried out at a British regional airport to determine the parameters of passenger behavior and requirements while in the airport terminal (7).

2. A stochastic model was developed that described in broad terms the pattern of passenger behavior as a series of linked queuing models. The model was calibrated against survey data (8).

3. An overall rationale and procedure were developed for terminal design based on an explicit model of passenger behavior that can ensure that an adequate level of service is maintained for the premium travel mode (1, 9).

SURVEY DESIGN AND ORGANIZATION

Survey Scope

Passenger behavior in airport terminals can be classified in terms of processing, throughput, circulation, and auxiliary times. This classification, together with the data requirements of the airport modeling procedure that has been developed, formed the basis for a definition of the required survey information.

Processing Times

At various points in the terminal, servers are required to process passengers on an individual basis (customs, immigration, and check-in). Representative distributions were required for the various processing characteristics of these facilities, such as arrival rate, processing time, and variation in queue length.

Throughput Times

In other parts of the terminal, the method of processing passengers is not characterized by the server-passenger relationship. These are mainly holding areas or areas where passengers serve themselves (departure lounge and baggage reclaim). Again, distributions for the time spent by passengers in these facilities, or throughput times, are required.

Circulation and Auxiliary Times

A considerable amount of time is spent by passengers in most airports passing from one facility to the next or using nonessential facilities such as banks, shops, and restaurants. These times were not specifically measured in the current series of surveys.

As will be discussed in the next section, the total

time in the terminal is also of importance for the model validation. Two measures of this time were defined for the purposes of the survey.

1. Total terminal time for enplaning passengers is defined as the time lapse between entering the terminal and the scheduled departure time of the flight. For deplaning international passengers, it is the time lapse between the actual time of arrival of the aircraft at the pier and passenger exit from customs.

2. Terminal occupancy time is a composite measure of the time spent in the main body of the terminal. For enplaning passengers, it is the time lapse between arrival at check-in and exit from the departure lounge. For deplaning international passengers, it is the time lapse between arrival at immigration control and exit from customs.

Description of Methods Used

The problems of airport survey organization choice of data collection methods and sampling procedures have been discussed elsewhere (7). For the surveys described in this paper, 3 main data collection techniques were evolved.

Card System

The main characteristic of the card system was that it involved passengers only to the extent of their being agents for the timing of their own movements within the terminal. The practical basis for this survey procedure was that each passenger involved carried a specially designed time-check card through the terminal. Passengers were asked to hand the card to members of the survey team at one or more chosen locations, or check points, so that a time could be recorded. This technique was used for the recording and estimation of throughput times such as the time spent in the departure lounge or baggage reclaim and for the estimation of circulation times and terminal occupancy. The cards were dispensed to passengers at the start of the process in which they were examined with the aid of a brief initial interview.

Direct Observation

A separate technique was evolved for the collection of processing time data at individual facilities such as immigration control. This involved the use of team members as observers at these facilities to record arrival rates, service times, and variation in queue length. The behavior of passengers was sampled either as a total record of discrete events (in the case of processing times) or at intervals (queue length was sampled at minute intervals).

Time-Lapse Cinecamera

For the survey of the check-in facility, it was decided to collect the passenger processing information by a time-lapse cinecamera. Apart from its unobtrusiveness, the main advantage of this approach was that no potential information was wasted; the required level of data could be subsequently extracted from the film within the degree of accuracy of the time lapse.

Survey Organization

The surveys of airport terminal processing were carried out at the International Airport at Manchester, England, during 1974. Most of the data obtained related to week-

day conditions; large samples of passengers were involved for both international and scheduled and charter domestic flights. For the card system surveys some individual data on reasons for travel and previous experience of the airport terminal process were collected. The overall survey was subdivided into 7 separate parts; a summary of these surveys, including information on the technique used and the data required, is given in Table 1.

SURVEY RESULTS

It is not possible to give a comprehensive description of the survey results (7) in the context of the present paper. Here, certain aspects of the information obtained are selected to demonstrate, first, the relevance of the research approach and, second, the importance to terminal planning and design of obtaining some basic information on the behavior of terminal users.

Terminal Occupancy Time

The survey provided some interesting information in relation to the established differences between the arriving (deplaning) and departing (enplaning) passenger processing systems. The terminal occupancy time for international enplaning passengers averaged 55 min (Figure 1). The equivalent measure for international deplaning passengers was 8 min (Figure 2). Thus the deplaning passengers spent on average a seventh of the time that enplaning passengers spent in the main body of the terminal.

On the surface, this large difference between the 2 groups of passengers seems to be of little consequence; after a passenger is in the terminal, he or she will require approximately the same amount of space for equivalent facilities no matter how long he or she spends in the terminal. However, if the length of stay is such that other flights arrive or depart during this interval, then there could be competition among passengers from different flights for the available space. Thus, the combination of flight schedule and terminal occupancy is the important design factor. The deplaning passengers arrived at immigration control over an approximate 4-min period; thus only rarely were there more than 2 or 3 flights occupying the arrival facilities and processes such as baggage reclaim and immigration. For enplaning passengers, however, there will often be 7 or 8 flights during the average occupancy times, and considerable interaction among passengers from different flights and competition for terminal facilities are likely to result.

The difference between enplaning and deplaning passengers of 15 min for average terminal occupancy was less marked for domestic passengers than for international passengers. Although the average for international enplaning passengers was 55 min, there was a wide variation according to type of flight. The average terminal occupancy of charter passengers was 62 min, for example, compared to 48 min for scheduled passengers. There was a similar degree of difference between charter and scheduled deplaning passengers (5.5 and 8 min respectively).

Total Terminal Time

Some interesting observations can be made in relation to differences of various groups of enplaning passengers with respect to how long before their scheduled time of departure (STD) they arrive at the terminal check-in. Intercontinental scheduled passengers arrived at check-in 83 min, on average, before STD; European scheduled

passengers arrived 66 min before STD (Figure 3). As one might expect, international charter and scheduled passengers had average total terminal times of 84 and 71 min respectively (Figure 4). If one examines the tail end of the distribution of times for arrival at the terminal before STD, one can see that all international scheduled passengers had arrived by some 20 min before their latest reporting time (LRT) and that the latest European scheduled passengers were only 5 min before LRT. This difference could be explained by the greater number of business passengers on European scheduled flights; one presumes that time is more valuable to those on business than to those traveling purely for pleasure.

Distribution of Time in Terminal

Apart from being designed to examine the total amount of time spent in the main body of the terminal, the survey was designed to investigate the manner in which passengers divided that time among various processes, auxiliary facilities, and the time spent waiting at or moving between the various facilities. Some of the results that were obtained are given in Tables 2 and 3.

If one considers international enplaning passengers, the first feature of interest is the small amount of time in which the passenger is actually being processed. For scheduled passengers, for example, only 3.5 min or 8 percent of terminal occupancy is required for actual processing. If the time spent queuing at these various processes is included, this still increases the proportion of service time to only 13 percent. Comparing this with international deplaning passengers shows that their stay in the terminal is not only shorter but busier; only 20 percent of terminal occupancy is required for activities other than processing. The longer service times obtained for charter passengers probably reflect the generally larger load factors for these flights. For each of the individual facilities described in Tables 2 and 3, a set of empirical distributions were obtained to characterize the processing system. As has already been mentioned, this characterization involved the derivation of distributions for queue length, arrival rate, and service times. The obtained distributions for most facilities confirmed the stochastic nature of processing at airport terminals. Figures 5 and 6 show typical distributions obtained; they describe the arrival rate and service time for international scheduled passengers at the Manchester check-in facility.

Terminal User Survey

Apart from obtaining time distributions, the survey also considered the proportion of different groups of terminal users (Table 4). It is interesting to note that 40 percent of terminal users were nonpassengers (people were interviewed as they entered the main terminal building). Of the 60 percent who were passengers, only a few were deplaning passengers (2 percent) using the main body of the terminal.

MODEL OF PASSENGER BEHAVIOR

The information obtained in the airport surveys was used primarily for the development of a stochastic modeling procedure for the passenger processing system. The basis of the modeling methodology is a series of linked analytical queuing models embedded in a matrix of walking time estimates. This approach allows the estimation of both distributional and average terminal processing times. Thus the model is a planning tool that can identify the major focal points of delay within the terminal process. It can also be used to evaluate the

efficiency of alternative functional rearrangements or technological innovations.

Processing Models

Figure 7 shows the deplaning processing system typical of most medium-sized regional airports. The nodes represent the processing centers, and the links represent the proportion of total passenger flow. There are 3 main problems in modeling such a network:

1. Maintenance of mathematical tractability when linking queuing models,
2. Parallel processing of flows in the system, and
3. Interaction of passenger and baggage flows.

The solution of all these problems required simplifying assumptions that were tested in the field (the section on model validation). Table 5 gives a summary of the primary modeling assumptions by using Kendall's queuing notation (10). Each facility queuing model embodies a

Table 1. Summary of Manchester Airport survey.

Survey	Period	Technique	Information	Passengers
Departures process	5 h, Friday morning	Card system, random sample	Landside terminal time, departure lounge time	207
Immigration arrivals	3 h, Friday afternoon	Observation, total sample	Arrival rate, queue length, service time	109
Immigration departures	5 h, Wednesday morning	Observation, total sample	Arrival rate, queue length, service time	154
Check-in departures	5 h, Tuesday morning	Time lapse, total sample	Arrival rate, queue length, service time	89
Domestic arrivals, baggage	4 h, Thursday afternoon	Card system, random sample	Baggage or no baggage, baggage reclaim time	76
International arrivals, customs	4 h, Thursday afternoon	Card system, random sample	Customs time, red or green channel	112
Terminal user	5 h, Thursday morning	Interviews, time sample	Reasons for using terminal	222
International arrivals	3 h, Friday afternoon			
International arrivals	4 h, Friday afternoon	Card system, random sample	Landside terminal time, baggage reclaim time	94

Figure 1. Terminal occupancy times for domestic and international enplaning passengers.

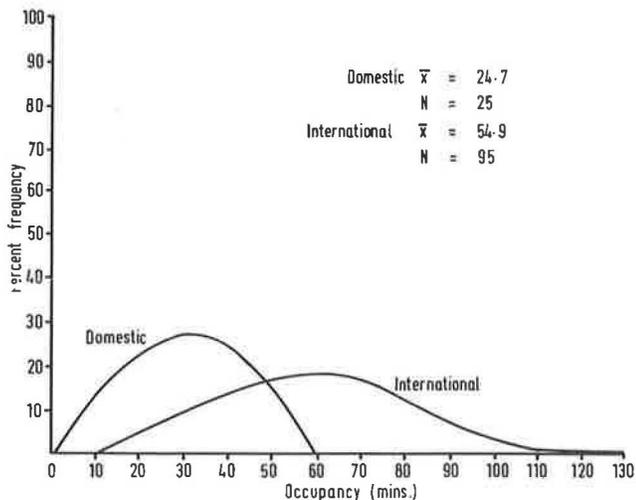


Figure 2. Terminal occupancy times for domestic and international deplaning passengers.

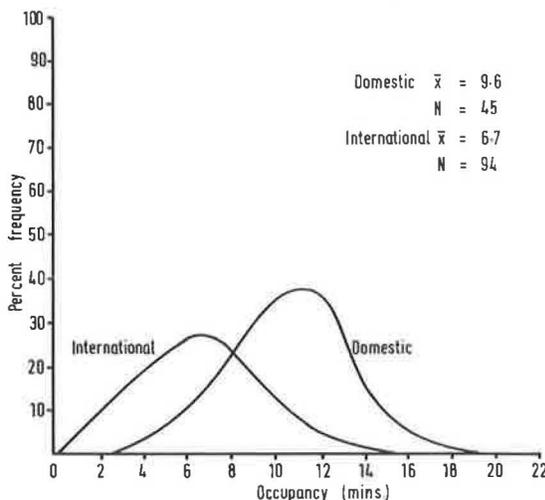


Figure 3. Arrival time at check-in before STD for intercontinental and European scheduled passengers.

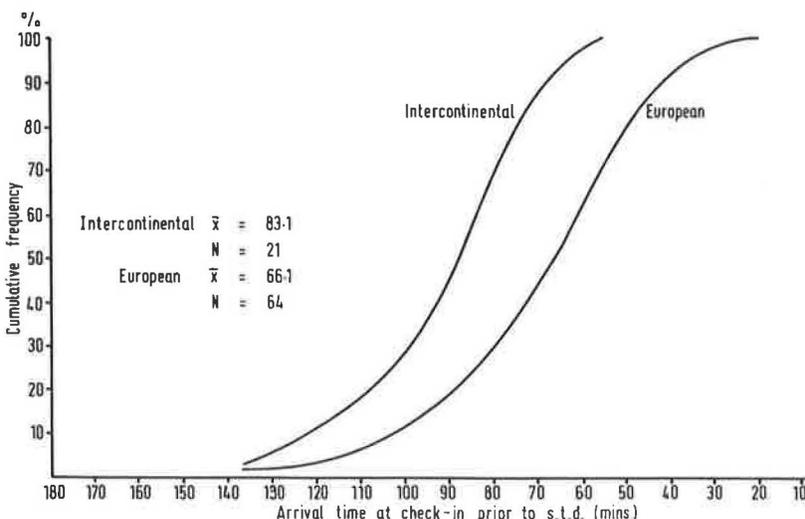


Figure 4. Arrival time at check-in before STD for international charter and scheduled passengers.

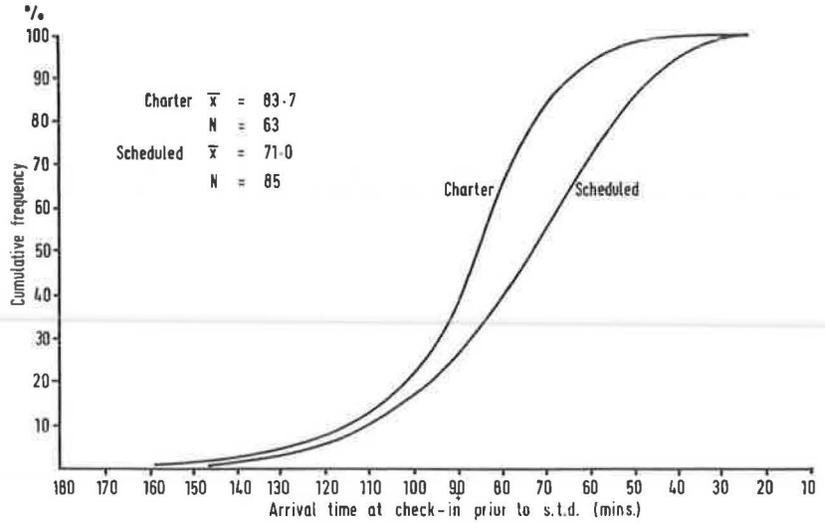


Table 2. Average time spent by enplaning passengers in terminal facilities.

Type of Flight	Check-In					Passport Control						Departure Lounge		Circulation and Holding Areas		Total Minutes	
	Waiting		Being Served		Total		Waiting		Being Served		Total		Minutes	%	Minutes		%
	Minutes	%	Minutes	%	Minutes	%	Minutes	%	Minutes	%	Minutes	%					
International scheduled	2.1	4	3.3	7	5.4	11	0.6	1	0.2	1	0.8	2	23.9	49	18.3	39	48.4
International charter	7.6	12	1.3	2	8.9	14	0.6	1	0.2	1	0.8	2	19.2	31	32.8	53	61.7
Domestic scheduled	2.1	9	3.3	4	5.4	22									19.3	75	24.7

Table 3. Average time spent by deplaning passengers in terminal facilities.

Type of Flight	Immigration Control						Baggage Reclaim		Customs		Circulation and Holding Areas		Total Minutes
	Waiting		Being Served		Total		Minutes	%	Minutes	%	Minutes	%	
	Minutes	%	Minutes	%	Minutes	%							
International scheduled	1.2	18	0.3	5	1.5	23	2.7	42	1.0	15	1.3	20	6.5
International charter	1.0	10	0.1	1	1.1	11	5.0	52	1.3	14	2.2	23	9.6
Domestic scheduled							5.5	57			4.1	43	9.6

Figure 5. Poisson distribution fitted to the observed arrival distribution of scheduled passengers at check-in.

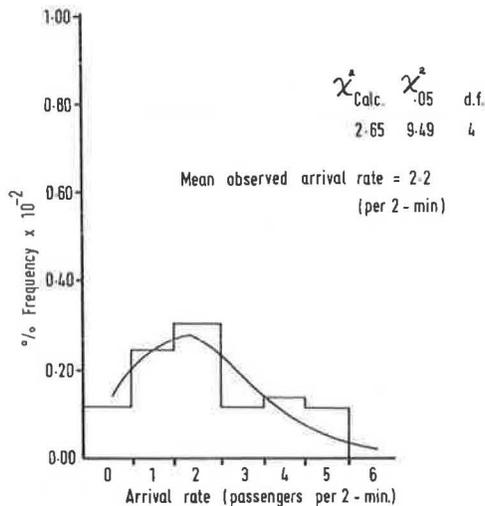
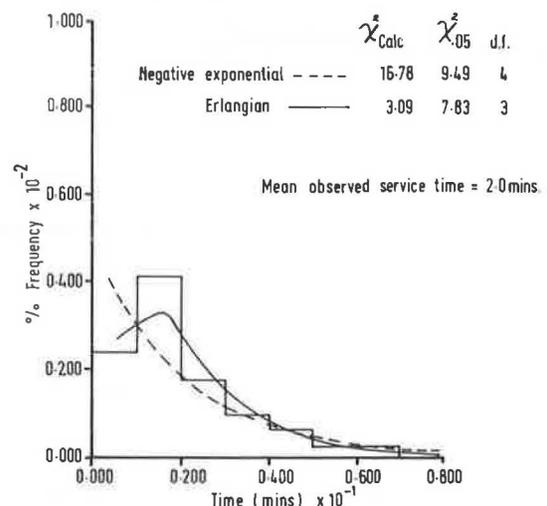


Figure 6. Erlang ($\alpha = 2$) and negative exponential distributions fitted to the observed service time distribution of international passengers at check-in.



Poisson input or arrivals process M, a negative exponential service distribution M, an appropriate number of servers C, and a universal first-come, first-served queuing discipline FCFS. The aim of such a distributional characterization is to encapsulate the essential stochastic nature of passenger behavior by measuring not only the average activity but also the variation about that average.

There are, however, other good analytical reasons for these modeling assumptions. From the work of Burke (11) and Reich (12), we know that, under certain capacity assumptions, the steady state output of a queuing system with a Poisson input rate and exponential service times will be Poisson at the same rate. Thus, if we assume that the effect of the spatial separation of processing centers on queuing times in a serial process is negligible, then the initial Poisson process is propagated (13). Thus it follows that averages for the serial process are simply the sum of the "averages" of its centers. Clearly this principle has direct application to the network of 4 serial processes in Figure 7. A similar argument can be used for the summation of individual center waiting time distributions. From the work of Nelson (14), the order of the centers in a serial process can be transposed without affecting the resulting service and waiting time distributions. Thus the network shown in Figure 7 can be transformed to the network shown in Figure 8. The average queuing time for the network can be shown to be equal to the weighted contributions from the centers making up each route. That is,

$$\begin{aligned} \overline{WQ}_{1234567} = & pr \times \sum_{1,4,7,2,5} \overline{WQ}_j + ps \times \sum_{1,4,7,2,6} \overline{WQ}_j \\ & + qr \times \sum_{1,4,7,3,5} \overline{WQ}_j + qs \times \sum_{1,4,7,3,6} \overline{WQ}_j \end{aligned} \quad (1)$$

where

$$\begin{aligned} \overline{WQ}_{1234567} &= \text{average queuing time in the network,} \\ p, q, r, \text{ and } s &= \text{passenger split-flow proportions as} \\ &\text{shown in Figures 7 and 8, and} \\ \overline{WQ}_j &= \text{average queuing time at center } j \text{ in} \\ &\text{the network.} \end{aligned}$$

Similarly, with an FCFS queuing discipline, the network queuing time distribution (that is, the probability of waiting in the queue longer than τ) is given by

$$\begin{aligned} \text{Prob}(\text{delay} > \tau)_{1234567} = & pr \times \text{prob}(\text{delay} > \tau)_{14725} \\ & + ps \times \text{prob}(\text{delay} > \tau)_{14726} \\ & + qr \times \text{prob}(\text{delay} > \tau)_{14735} \\ & + qs \times \text{prob}(\text{delay} > \tau)_{14736} \end{aligned} \quad (2)$$

A final problem is related to the modeling of baggage reclaim. This facility combines 2 inputs, passenger and baggage flows, to provide 1 output. This problem was overcome by thinking of the time passengers wait for their baggage as their service; this can be done by using in Kendall's notation an M/M/∞: FCFS infinite channel queuing model. Here the number of servers is always equal to the number of passengers because passengers serve themselves.

The problems associated with the enplaning flow are similar to those of the deplaning flow and were solved by using similar devices. Table 6 gives a summary of the models used.

Model Validation

It must be recognized that the use of analytical queuing

theory represents an approximation by obtaining operational solutions with models that deductively are often inaccurate but are rapid and simple to use. Thus, when testing the assumptions underlying such models, the planner need not be too critical in his or her expectations.

The completed validation studies (7, 8) have shown that the assumptions of Poisson arrival and negative exponential service times are reasonable. Figures 5 and 6 show the sort of agreement achieved between the observed and theoretical distributions. Although the theoretical distributions do not fit the measured data exactly, they do not differ from them sufficiently to warrant the use of a more complex modeling procedure. A possible extension to the queuing models that retains a fair degree of computational simplicity is the use of erlang distributions to represent passenger service times. Such distributions fit the skewed empirical distribution more exactly (Figure 6), but their use destroys the linking theme of the queuing system model. Thus they are only recommended as an adjunct to the modeling process, if planning emphasis must be switched from an overall view to the design of individual facilities.

DESIGN IMPLICATIONS OF PASSENGER BEHAVIOR

It is evident that the information elicited in the survey of passenger behavior has important implications for the planning and design of terminals. Some of these implications have been dealt with in detail elsewhere (7, 8, 9); in this section, 2 particular points have been selected to demonstrate, it is hoped, the relevance of the research approach to airport planning. The first point relates to ticketing requirements at terminals; the second relates to the need for a more flexible terminal design based on a sound knowledge of passenger behavior.

Design Solutions to Ticketing Congestion at Terminals

The problems related to ticketing and checking in passengers at the terminal have received a considerable amount of attention from airport planners in the last decade in both Europe and the United States. The reason for this attention is the recognition of check-in as perhaps the major point of congestion in the terminal. The survey at Manchester has shown that a large number of passengers arrive at the terminal well in advance of their LRT, which means that, in the departures process, there is considerable competition between passengers on different flights for use of the various facilities. Those passengers who arrive at the terminal particularly early are typically holiday passengers on charter flights; most of them are using the terminal for the first time and are probably apprehensive of the processing system at the terminal. There has also probably been some uncertainty in their access mode. Whatever the reason is, the result is the same—long queues, excessive waiting times, and congestion.

Currently, a number of solutions are being tried at airports in the United States and Europe:

1. Adaptations of conventional check-in systems at central terminals,
2. Gate check-in,
3. Satellite terminals,
4. Automation in check-in and ticketing, and
5. Car park check-in.

Perhaps the point that was really highlighted at Manchester was that different passenger groups (split in

Table 4. Terminal users survey.

User Category	September 11, 1974, 7:40 a.m. to 12:45 p.m.		September 12, 1974, 2:30 p.m. to 5:00 p.m.		Both Days Combined	
	Number	%	Number	%	Number	%
Enplaning passengers	62	54	60	61	122	59
Deplaning passengers	3	3	1	1	4	2
Senders	11	10	14	12	25	11
Greeters	7	6	20	18	27	12
Temporary staff	6	6	3	3	9	4
Permanent staff	7	6	1	1	8	4
Terminal facility users	10	10	5	4	15	7
Spectators	3	3	0	—	3	1
Total	109		104		213	

Figure 7. Double split network of queuing processes.

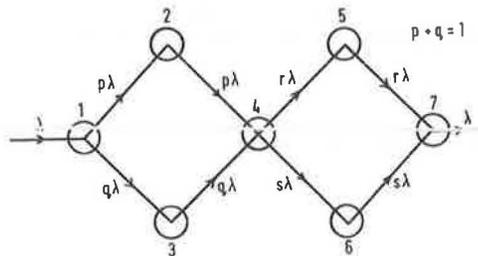


Figure 8. Rearranged network.

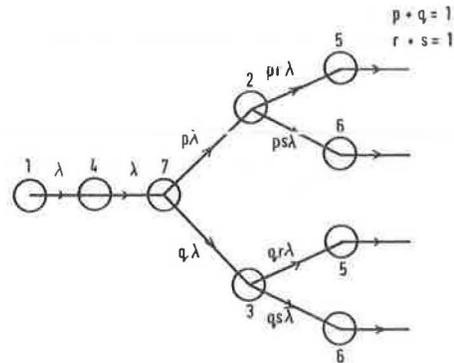


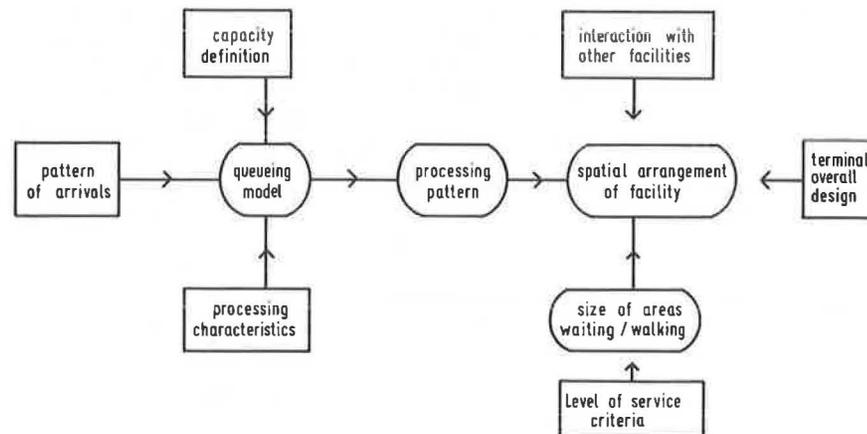
Table 5. Network of models describing arriving passenger processing system.

Node	Description	Model to be Used
1	Disembarkation	Dummy node
2	Immigration, U.K.	M/M/1
3	Immigration, non-U.K.	M/M/C
4	Baggage reclaim	M/M/∞
5	Customs, red	M/M/C
6	Customs, green	M/M/C or M/M/∞
7	Leaving terminal	Dummy node

Table 6. Network of models describing departing passenger processing system.

Node	Description	Model to be Used
1	Entering terminal	Dummy node
2	Check-in	M/M/C
3	Passport control	M/M/C
4	Departure lounge	M/M/∞
5	Embarkation	M/M/1

Figure 9. Individual facility design process.



terms of either journey purpose or type of flight) exhibit different behaviors and consequently have different requirements. For example, the business passenger who has considerable flying experience will probably time his or her check-in for the last possible minute. The inexperienced charter passenger, on the other hand, might regard the time in the terminal as part of the holiday and plan to shop or eat before flying. This difference in behavioral requirements is reflected in travel agent practice; when the charter passenger books his or her holiday, for example, the agent will recommend that he or she arrive at the airport well in advance of the airline-determined LRT. The important implication is that a mixed strategy would seem appropriate for the type of airport investigated in this research; perhaps gate check-in could be available for the business passenger and conventional check-in could be available for charter passengers.

Flexibility in Terminal Design

It would appear to be a mistake to employ constraining technological solutions to problems of passenger flow when experience has shown that flexibility and adaptability make for economic and comfortable terminals (3). A feature of modern terminal designs is that the aircraft has assumed primacy in the terminal layout and particular importance is attached to the terminal-apron interface. To achieve this, the landside access system is funneled either above or below ground and sophisticated people movers are used between the main terminal and the gate positions. In the long term, such arrangements are likely to suffer from the effects of inflexible building design, which is typical of older terminals. In some cases the problems associated with such terminal designs are already apparent. Satellite lounges, for example, are devoid of the usual facilities associated with passenger waiting areas. Thus they are inconvenient and particularly unappreciated when there are aircraft delays. In other cases, those passengers whose patterns of terminal use differ from the norm imposed by the design can suffer considerable inconvenience; this is especially true where passenger movement systems have been designed for 1-way operation.

CONCLUSIONS: DEVELOPMENT OF TERMINAL DESIGN METHODOLOGY

A recent consumer survey (15) of the quality of service at British airports has stated:

This summer, 20 million passengers will struggle through British airports for reasons of business or holiday pleasure. All of them face up to two hours waiting for the plane to take off and for baggage to arrive after landing. Some will face much longer delays.

In general, the problems have resulted from the large increase in the demand for air travel. Specifically they have resulted from the inadequate provision for peak passenger flows (1). These peak flows have resulted primarily from the massive developments in holiday charter flights, although an important contributory factor has been the introduction of larger aircraft. Various design solutions have been proposed, but an examination of recent airport terminal procedures (1, 2, 4) reveals that there is an apparent emphasis on the problems of handling aircraft at the expense of passenger requirements. Within the terminal itself there is a tendency to rely on technological innovations, such as people movers, baggage carousels, and computer ticketing, to solve passenger flow problems that do not appear to be completely understood. The main deficiency

in current terminal design methodology appears to be a lack of knowledge regarding passenger behavior and requirements in terminals, combined with a lack of an adequate planning model of that behavior.

An important part of the research program involved a number of more general aims that were pursued concurrently with the practical studies of passenger behavior in airport terminals. A primary aim was the identification of a design procedure and rationale capable of explicitly catering to the requirements of terminal users and facility operators. The basis and rationale of this design approach, namely the airport survey and the calibration of an overall system flow model, have already been discussed. The next stage was the development of an overall procedure that could serve as a design framework capable of incorporating design criteria and methods that will retain for the air mode its reputation for premium level of service.

Figure 9 shows the conceptualized design procedure. It is based upon the rational interaction of elements within the complex organizational and planning structure of airports. The aim of this particular conceptualization is the production of a functional design for a facility; this is achieved primarily by the explicit examination of the behavioral implications of each stage in the design process.

The flow chart in Figure 9 is composed of 2 types of elements. Inputs are shown as rectangular boxes, and the processes for producing the facility design are shown as oval boxes. The prime inputs are the pattern of arrivals, capacity definition, and processing characteristics, which together constitute the queuing or waiting characterization. The input described as level-of-service criteria is associated with the attitudes and the requirements of passengers (15, 16) and involves both subjective and objective measures of passenger response to the terminal processing system. The other 2 inputs are primarily interactive; that is, they show the interrelationship with the function of other facilities and the implications and constraints imposed by a consideration of the overall terminal design philosophy (3, 6). The prime division of terminal design concepts relates to the use of modular or central philosophies, but other considerations would be the relationship between domestic and international passenger flows or the security provisions in the terminal (1, 3).

The balanced design of airport terminals is thus necessarily interactive and also interdisciplinary. The often competing requirements of passenger comfort, operator convenience, and, of course, cost must be considered in relation to the particular problems of the airport user, the airlines, and the operator. The design philosophy described in this paper has, itself, derived from an interdisciplinary research program involving the skills and philosophies of industrial design, ergonomics, operations research, and transport planning; this is described in detail elsewhere (1, 9). It is sufficient to note here that overall design procedures have been evolved that emphasize flexibility and level of service to passengers in the provision of facilities, space, and structures at both the airport planning and terminal design phase.

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