Criteria for Evaluating Quality of Service in Air Terminals

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A set of indexes for evaluating the quality of service in air terminals is presented. It is assumed that quality is comfort and convenience as perceived by users, and a set of indexes that makes evaluation simple and fast is proposed. These indexes represent several terminal characteristics (e.g., walking distance, accessibility, availability of seats, and orientation) identified by passengers during an attitudinal survey at Montreal International Airport at Dorval, Quebec, as well as the conventional level-of-service measures such as density and delays. Six intervals are defined for each index, and each interval represents a specific level of service offered to users. These indexes may be used easily to evaluate the quality of service in other multimodal terminals.

Although airport managers have been using efficiency measures for many years to monitor financial and economic performance of passenger terminals, there are no standardized procedures or universally accepted criteria for evaluating terminal quality of service in relation to user expectations. Even the standard manuals and texts on airport engineering that have emphasized the need to pay attention to social, environmental, and political concerns have not referred to the user needs other than broadly. For example, Ashford et al. (*1*) state only two planning objectives that relate directly to passenger terminals: to provide luxurious facilities in waiting areas and to provide a wide range of commercial activities in the terminal. Apart from such vague descriptions, there is limited information on what constitutes an acceptable level of service or good performance in the eyes of the users. There is also uncertainty about the significance and measurement or quantification of performance measures.

This paper presents a conceptual framework for evaluating the quality of service in air terminals, focuses on performance in relation to the serviceability of terminal subsystems as perceived by users, and proposes a set of indicators that makes evaluation simple, flexible, and quick. These indexes represent several terminal characteristics (e.g., walking distance, accessibility, availability of seats, and orientation) identified by passengers during an attitudinal survey at Montreal International Airport at Dorval, Quebec, as well as the conventional level-of-service measures such as density and delays. Six intervals are defined for each index, and each interval describes the level of service offered to users. Terminal performance in relation to any characteristic then can be rated according to these levels of service.

PERFORMANCE INDICATORS

Almost two decades ago, the participants at a TRB workshop (*2*) examined terminal performance indicators comprehensively. They identified more than 25 qualitative and quantitative characteristics relevant to 12 terminal subsystems or components. More recently, the International Foundation of Airline Passengers' Associations conducted a survey of 30,000 passengers (*3*). Most of those passengers indicated that time spent at check-in and baggage claim is the single most important characteristic that they look for in an airport. Seneviratne and Martel (*4*) performed a survey of departing passengers at the Montreal Airport in Dorval, Canada, to determine their perceptions of a subset of characteristics identified by Heathington and Jones (*2*). One of the key findings of this study was that each subsystem has a particular characteristic that is considerably more important to the majority of the passengers than other characteristics are. For instance, most respondents indicated that the availability of information and signs is the single most important characteristic in circulation subsystems but emphasized that waiting time is the most significant in processing subsystems.

From this point of view, the capacity analysis framework suggested by the Airport Associations Coordinating Council/International Air Transport Association (AACC)/(IATA) (*5*), which considers density to be the critical performance indicator (PI) regardless of the subsystem, has two major deficiencies: first, density is more of an efficiency measure than a characteristic that truly reflects user perceptions, and second, the six-level scheme used to rate each terminal subsystem performance is dated and rigid. The framework is not geared for assessing the influence of different characteristics of passenger streams (e.g., baggage carrying versus cart pushing or different ratios of moving passengers to stationary passengers) on capacity. The only recognizable change in density-based PIs during the past 15 years has been in the intervals assigned to the different levels of service and in the treatment of subsystems. In other words, AACC/IATA recommends more space per person at each level of service (*5*) than does IATA in its 1976 manual (*6*); also space standards for check-in areas differ from those for waiting areas, baggage claim areas, and so forth. The other noteworthy change is that in Europe waiting time has become a standard measure of level of service in processing subsystems.

REPRESENTATIVE INDICATORS

Performance indicators can be designed to reflect either efficiency or effectiveness. Whereas efficiency indicators are important for management to assess the extent to which the system is being used, the effectiveness indicators are what will capture information on the extent to which basic passenger needs are met.

According to Silcock (*7*), the chosen indicators should satisfy the following four criteria:

- Reflect the specific objectives of the management,
- Be simple to define and quantify,
- Not require in-depth and expensive data collection, and

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- Be sensitive to changes due to improvements or managerial actions.

Each subsystem has a different assortment of physical and operational characteristics important to users. Not all characteristics are simple to quantify or define, however, and acceptable standards for them can only be established through in-depth interviews and surveys. Although characteristics, such as density (i.e., level of congestion), currently used to set standards for physical design and to measure service level can satisfy all the foregoing criteria, users do not always view them as important. Thus, the management should have a set of indicators available from which it can select those most suited for its own purposes.

In the present case, six indexes were developed to describe terminal subsystem characteristics, with the first five identified by passengers (*4*) as critical for the general comfort and convenience of the transfer between airside and landside:

- Availability of seats,
- Walking distance,
- Accessibility,
- Orientation (i.e., availability of information),
- Waiting time, and
- Occupancy (i.e., density).

To be consistent with the existing practice, six intervals were defined for each index. These intervals, or levels of service in this case, were derived subjectively, but they can be adjusted easily to suit management needs or changing user perceptions.

Availability of Seats

In the survey reported by Seneviratne and Martel (*4*), 44 percent of the respondents in waiting areas considered availability of seats to be the most significant performance indicator. Thus, the present policy of many airport authorities to provide seats for 50 percent of the occupants in the gatehold areas immediately before departure of the flight seems reasonable. However, if user preferences can be accounted for by willingness to pay as suggested by Wirasinghe and Shehata (*8*), the optimal number of seats (N_o) can be estimated at any given cost for furnishing the seats. Using this estimate, a seating availability index is defined as follows:

$$\mathrm{PI}_{as} = \frac{N_a}{N_o} \tag{1}$$

where

N_a = number of available seats in area considered at a given time,
N_o = optimal number of seats, and
PI_{as} = performance index for availability of seats.

Thus, level of service (LOS) in relation to availability of seats can be defined as

LOS	PI_{as}
A	≥1.0
B	0.9–0.7
C	0.6–0.4
D	0.3–0.2
E	0.2–0.1
F	<0.1

Walking Distance

Despite their importance, reliable data on passenger walking distances in terminal buildings are not readily available. Thus, it generally is assumed that most passengers walk either from gate to gate if they are transferring passengers or between gates and curbside if they are terminating or originating passengers. These distances generally are measured from the floor plans. In reality, however, because of the positioning of the subsystems (i.e., terminal configuration) and the number of alternative routes connecting most nodes, the walking distance between any two points in a terminal often varies. Thus, the objective should be not only to minimize average walking distance but also to minimize the variance.

In this paper the authors assume that, ideally, all passengers walk the same distance, otherwise the standard deviation of the walking distance distribution in a terminal should be as small as possible. Accordingly, the performance index (PI_w) is defined as a function of the coefficient of variation (CV_w) of walking distance, or the ratio of the standard deviation to the mean. The following index is easy to compute and is sensitive to the standard deviation of walking distance, making it suitable for comparing different terminals or alternative terminal configurations:

$$\mathrm{PI}_w = \frac{1}{1 + CV_w} \tag{2}$$

LOSs are defined in relation to PI_w:

LOS	PI_w
A	≥1.0
B	0.8–0.9
C	0.6–0.7
D	0.4–0.5
E	0.2–0.3
F	≥0.1

Accessibility

An earlier passenger survey by Seneviratne and Martel (*4*) revealed that accessibility to concessions and services is the second most significant characteristic, or indicator, of performance in waiting areas. The concessions in that study included rest rooms, communication facilities (i.e., phones and facsimile), retail outlets, and restaurants. The following accessibility index is defined on the basis of the additional distance that a passenger has to walk while proceeding from one activity to another:

$$\mathrm{PI}_a = \frac{\sum_{\text{all } i} \sum_{\text{all } j} d_{ij} v_j}{V \sum_{\text{all } i} d_{ik}} \tag{3}$$

where

PI_a = performance indicator for accessibility,
d_{ij} = walking distance from activity i to concession j,
v_j = number of passengers attracted to concession j in a given time,
d_{ik} = walking distance from activity i to activity k, and
$V = \Sigma v_j$.

This index accounts for the importance of the different concessions by attaching a weight that is relative to the number of passengers attracted to each concession. Because PI_a can take values greater than 1, LOSs are defined in relation to PI_a's inverse. In other words, as PI_a increases, LOS decreases so that $PI_a = 1$ represents perfect accessibility, or LOS A. The ranges that the accessibility index may take at the different levels of service are as follows:

LOS	*$1/PI_a$*
A	≥0.9
B	0.9–0.7
C	0.6–0.4
D	0.3–0.2
E	0.2–0.1
F	<0.1

To illustrate the estimation and the use of this index, a case study of the domestic wing of the Montreal International Airport at Dorval is presented. The floor plan of the study area is shown in Figure 1. Major activities, such as check-in counters of different airlines, security checks, concessions, and waiting areas, are considered as independent nodes. The distance d_{ik} represents the distance between nodes. In cases in which there are several links between a node pair, the average of all link lengths may be used or, if detailed data are available, all paths could be used in the analysis. This example uses the average length approach. For instance, the distance between the entrance and check-in is taken to be the mean of the distances between all entry points and one central check-in counter.

The number of passengers visiting each concession (v_j) was available from the airport authority. These numbers and the distances estimated from the floor plan, given in Table 1, were used to compute an accessibility index of 1.88 for the departing passengers. This index suggests that the existing terminal configuration and the location of concessions require the average passenger to walk 88 percent more than the passenger who would not visit any concessions. According to the preceding accessibility LOSs, the departure facility at Dorval operates in LOS C (i.e., $1/PI_a = 0.53$).

Orientation

One of the first efforts to quantify passenger terminal building orientation is reported by Braaksma and Cook (*9*). Braaksma and Cook's proposed quantification technique requires the terminal to be represented by a set of nodes and links and each node to be classified into two groups according to whether the other nodes are visible from it. By collating this information into an origin-destination matrix and taking the proportions of visible nodes from each node, an index can be computed for the entire terminal or any given subsystem.

This technique has two drawbacks: first, it does not consider the relation between nodes in connectivity; second, the order in which a passenger proceeds through the nodes is disregarded. In other words, no distinction is made between the primary (or mandatory) nodes (i.e., the nodes that every passenger must pass through) and the secondary (or optional) nodes (i.e., the nodes that one can avoid passing through).

This paper defines an orientation index that overcomes the preceding two deficiencies and describes this index in the following example.

Consider the enplaning process with few concessions shown in Figure 2 and assume the following:

1. The primary activities (nodes) are entry equals 1, check-in equals 2, and security check equals 3.
2. The secondary activities (nodes) are concession equals 4, concession equals 5, and concession equals 6.
3. It is not possible or normally required to return to a primary activity already visited.
4. A passenger cannot or is not normally required to return to the first activity (i.e., entry).
5. Once at the last activity (i.e., security check), a passenger cannot return to the public area.

With these assumptions, the visibility matrix (Figure 3) for the example is defined as

0 = not visible

1 = visible (either directly or indirectly through signs)

— = visibility not required because of the relation between nodes (activities)

Suppose that the matrix can be divided into three parts and two triangles, as follows:

- Part A: upper-left quarter (primary activities versus primary activities),
- Part B: upper-right and lower-left quarters (primary activities versus secondary activities),
- Part C: lower-right quarter (secondary activities versus secondary activities),
- $V_{\text{upper triangle}}$ = sum of entries in each row in upper triangle of matrix, and
- $V_{\text{lower triangle}}$ = sum of entries in each column in lower triangle of matrix.

Global Orientation

The global orientation index (V_g) for the terminal is defined as the ratio of total available sight lines to the required number of sight lines. The parameters needed for estimating this ratio are as follows:

Total number of nodes $(N) = K + J$

where K is the number of primary nodes = 3, and J is the number of secondary nodes = 3.

$$\text{Total observed number of sight lines } (L_o) = \sum V_{\text{lower triangle}} + \sum V_{\text{upper triangle}}$$

$$\text{Required number of sight lines } (L_r) = N(N-1) - [K(K-1) - (K-1)^2] - [2(N-K)] = N^2 - 3N + K - 1 \quad (4)$$

where

$N(N-1)$ = total number of cells in matrix,
$K(K-1) - (K-1)^2$ = number of cells in which visibility is not required because of order of primary activities, and
$2(N-K)$ = number of cells in which visibility is not required because of Assumptions 4 and 5.

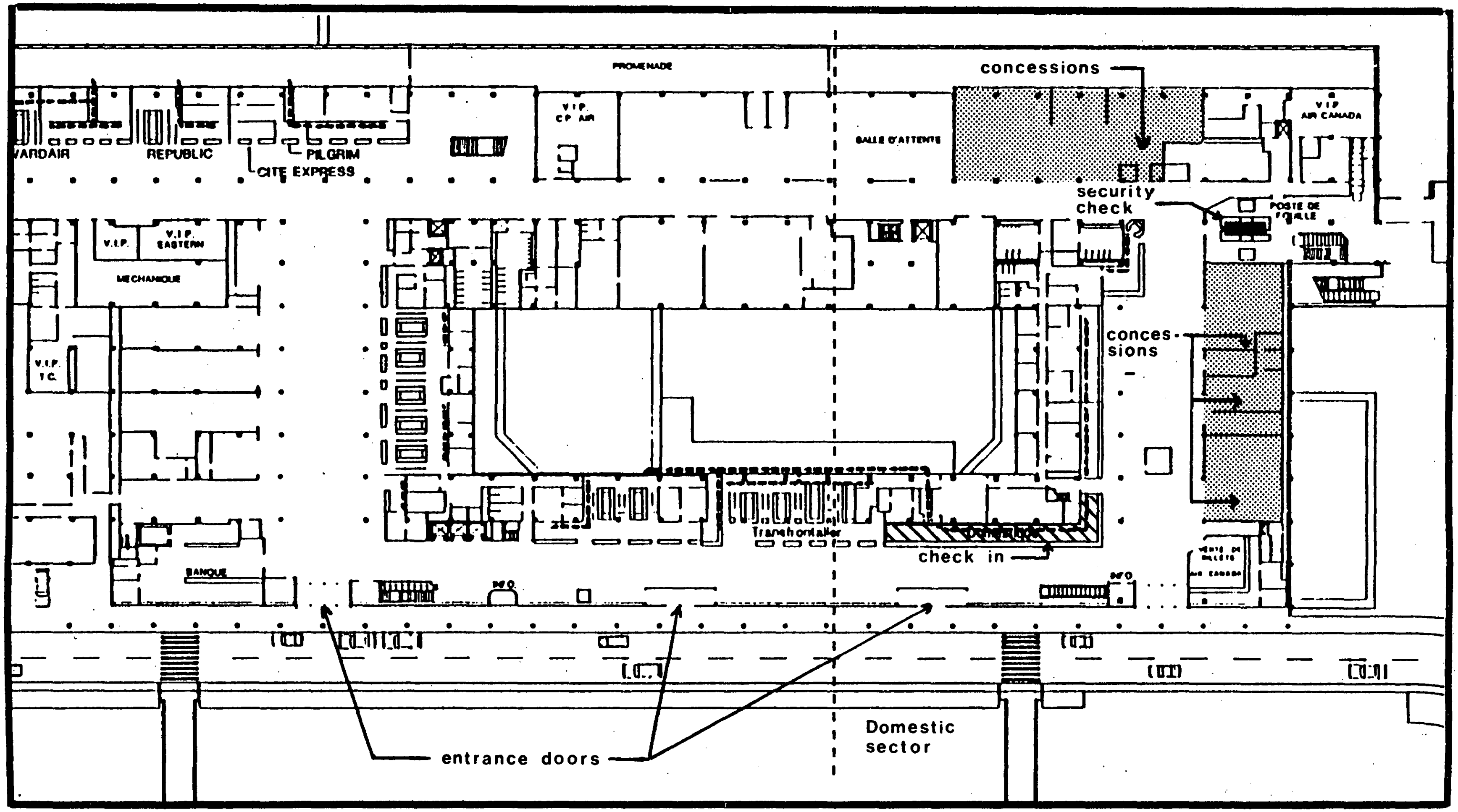

FIGURE 1 **Floor plan of Dorval airport.**

TABLE 1 Detailed Calculations for Accessibility Index: Domestic Sector

Activity 1 - Activity 2	Distance for door 1	Distance for door 2	Distance for door 3	Mean for all doors	Passenger volumes at concessions	Mean * Volumes
Entry-conc.1	130	180	142	151	102	15402
Entry-conc.2	132	80	41	84	25	2100
Entry-conc.3	140	85	47	91	2	182
Entry-conc.4	147	90	52	96	16	1536
Entry-conc.5	154	97	59	103	51	5253
Entry-conc.6	166	105	69	113	29	3277
Entry-conc.7	180	127	90	132	25	3300
Check-in-conc.1	135	135	135	135	102	13770
Check-in-conc.2	34	34	34	34	25	850
Check-in-conc.3	42	42	42	42	2	84
Check-in-conc.4	49	49	49	49	16	784
Check-in-conc.5	56	56	56	56	51	2856
Check-in-conc.6	64	64	64	64	29	1856
Check-in-conc.7	83	83	83	83	25	2075
Security-conc.1	57	57	57	57	102	5814
Security-conc.2	44	44	44	44	25	1600
Security-conc.3	35	35	35	35	2	70
Security-conc.4	30	30	30	30	16	480
Security-conc.5	26	26	26	26	51	1326
Security-conc.6	15	15	15	15	29	435
Security-conc.7	15	15	15	15	25	375

Sum = 63425

Distances from:
Doors 1 to check-in = 107 m
Doors 2 to check-in = 50 m
Doors 3 to check-in = 17 m

Mean distance from doors to check-in = 58 m

Sum of distances d ik = 135 m

Passenger volumes visiting concessions = 250

$$\text{Accessibility index for domestic sector} = \frac{250 * 135}{63425} = 0.53$$

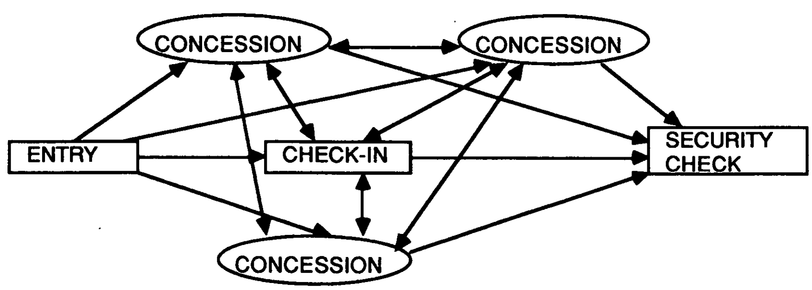

FIGURE 2 Hypothetical enplaning process.

$$V_g = \frac{L_o}{L_r} \times 100 \text{ percent} \tag{5}$$

In the present case,

$L_o = (1 + 1 + 1) + (3 + 4 + 1) = 11$
$L_r = 6^2 - 3(6) + 3 - 1 = 20$
$V_g = 11/20 * 100 \text{ percent} = 55 \text{ percent}$

Orientation for Part A

Part A is concerned with primary activities, and the orientation index V represents the effectiveness of the signs and information during the enplaning and deplaning process. That is,

Total observed number of sight lines in Part A (L_A)
$= \sum V$ of cells for which visibility is required in A (6)

Required number of visibility lines in Part A (L_{rA})
$= K(K - 1) - (K - 1)^2$ (7)

where $K(K - 1)$ is the number of cells in Part A of matrix, and $(K - 1)^2$ is the number of cells for which visibility is not required because of Assumption 3.

The orientation index for Part A (V_A) is defined as

$$V_A = \frac{L_A}{L_{rA}} \times 100 \text{ percent} \tag{8}$$

In the present case,

$L_{rA} = 3(3 - 1) - (3 - 1)^2 = 2$
$L_A = 2$
$V_A = (2 \div 2) \times 100 \text{ percent} = 100 \text{ percent}$

Orientation for Part B

Part B corresponds to the effectiveness of the information system for orienting passengers between primary and secondary activities. That is,

Total observed number of visibility lines in Part B (L_B)
$= \sum V$ of cells for which visibility is required in B (9)

Maximum number of visibility lines in Part B (L_{rB})
$= 2(JK) - 2(N - K)$
$= 2(JK) - 2J$ (10)

where $2(JK)$ is the number of cells in Part B of matrix, and $2J$ is the number of cells for which visibility is not required because of Assumptions 4 and 5.

The orientation index for Part B is defined as

$$V_B = \frac{L_B}{L_{rB}} \times 100 \text{ percent} \tag{11}$$

From the preceding example,

$L_{rB} = 2(3 \times 3) - 2(3) = 12$

To node

From node	1	2	3	4	5	6	$V_{\text{upper triangle}}$
1		1	_	1	0	1	3
2	_		1	1	1	1	4
3	_	_		_	_	_	_
4	_	0	0		1	0	1
5	_	0	1	1		0	0
6	_	1	0	0	0		
$V_{\text{lower triangle}}$	_	1	1	1	0		

FIGURE 3 Visibility matrix.

$L_B = 7$
$V_B = 7 \div 12 \times 100 \text{ percent} = 58 \text{ percent}$

Orientation for Part C

Part C evaluates the visibility of secondary activities from one another. That is,

Required number of visibility lines in Part C (L_{rC})
$= J(J - 1)$ (12)

Total observed number of visibility lines in Part C (L_C)
$= \sum V$ of cells in C (13)

The orientation index for Part C V_C is defined as

$$V_C = \frac{L_C}{L_{rC}} \times 100 \text{ percent} \tag{14}$$

From the example,

$L_{rC} = 3(3 - 1) = 6$
$L_C = 2$
$V_C = (2 \div 6) \times 100 \text{ percent} = 33 \text{ percent}$

LOSs in relation to orientation are defined as

LOS	PI_v (%)
A	90–100
B	70–89
C	40–69
D	20–39
E	10–19
F	0–9

According to the preceding LOS definitions, the global orientation in the example can be classified as LOS C. If primary activities are considered independently, LOS is A, meaning that passengers can orient themselves very easily with the existing signs and information. LOS D, derived for Part B, indicates a deficiency in the signing to guide passengers between secondary activities.

Occupancy

The continued reliance on occupancy as a performance indicator is partly attributable to the assumption that passenger comfort is directly proportional to the level of congestion. This assumption may be true in corridors when all persons are moving or in queuing areas when all persons are stationary. When passengers are carrying luggage or when there are stationary as well as moving passengers in the same area, however, density in passengers per unit area will not necessarily govern the degrees of freedom available for movement. Even if a small share of these people wished to move, they would not be able to do so with the desired level of ease. Thus, until appropriate adjustment factors are developed, LOS in the subsystems will need to be assessed according to the existing criteria.

The following criteria are suggested by AACC/IATA (*5*) for assessing check-in area LOS when PI_a is defined as

$$PI_a = \frac{A}{p} \quad (15)$$

where A is the effective floor area in the subsystem (in square meters), and p is the passenger accumulation in the same area.

LOS	*PI_a (m²/person)*
A	1.8
B	1.6
C	1.4
D	1.2
E	1.0
F	system breakdown

Waiting Time

The British Airport Authority (BAA) has established time-based criteria for evaluating processing subsystems. Instead of the traditional six-level scheme, these criteria take the form of reliability measures. For example, the criterion for check-in facilities is less than 3 min of waiting 95 percent of the time.

Mumayiz and Ashford (*10*) categorized delay in a much broader form than BAA by defining three levels of service according to passenger perception of delay. The levels for check-in subsystems for scheduled long-haul flights, for example, are defined as

LOS	*PI_t (min)*
A (good)	<15
B (tolerable)	15–25
C (bad)	>25

PI_t is the performance indicator for time.

CONCLUSIONS

A set of indexes for evaluating terminal quality of service in relation to user needs has been presented. Such user-related performance indexes are extremely important from marketing and operational points of view. These indexes enable airport authorities to compare their systems with others and to examine the effect of operational and physical changes on system performance. The deficient elements in a system can be identified readily and corrected before they can affect user comfort.

Except for walking distance and accessibility, which are not truly independent, the six indicators are sufficient for management to assess the quality of service. Yet there is a need for a comprehensive or composite index that would enable all the subsystems to be considered as a whole unit. A composite index is especially important if the authorities are looking at strategies for alternative terminal improvement.

The intervals for each performance index have been specified arbitrarily. Such limits and acceptable performance levels can be addressed only through extensive attitudinal surveys.

Despite these drawbacks, the proposed method sets the stage for more research on this subject, and the findings demonstrate that measures other than density could be brought into the evaluation process. When pressure is mounting on authorities to increase the efficiency of terminals, this framework allows the expected consequences to be evaluated before authorities implement a particular strategy.

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