EVALUATION OF PASSENGER FLOW LINES IN INTERNATIONAL AIRPORT TERMINALS

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ABSTRACT

Airport terminals offer a wide variety of functions for both departing and arriving passengers. How best to offer hospitality to passengers, including visitors from abroad, is a major concern of airport managers. Given multiple functions, comprehensive evaluation of airport passenger terminals is crucial for planning, designing, and managing airport performance. The typical evaluation methods of airport terminal performance, however, have not included passenger perspectives, particularly the physical aspects of passenger flow lines in airport terminals. This study focuses on airport passenger flow lines inside international terminal facilities and develops a flow line evaluation index that considers some physical characteristics of terminal facilities. The proposed framework can help airport planners and managers design and operate terminals in manners that are favourable from the perspective of passengers. We apply the proposed index to the data collected in various airport terminals in the world. The surveyed items are weighed based on the judgments of airport experts to conduct comprehensive evaluation. The multidimensional scaling is also applied to visualize various terminal functions and passenger perspectives systematically.

Key words: airport terminals, evaluation, multidimensional scaling, passenger flow line.

INTRODUCTION

Airport passenger terminals offer a wide variety of functions. They facilitate connections between transportation modes and between flights, control the movements of air passengers (e.g., via ticket-holder check-in, customs clearance, immigration control), and provide various supplemental services (e.g., shops, restrooms, dining facilities, greeting areas, business and conference spaces) for departing passengers. Universal design is now being required in public facilities such as airports. Additionally, international airports play an important role as the “gateway” to a country. Visitors from abroad form their first impressions of the country at the arrival terminal. Thus, how to best offer hospitality to passengers, including visitors from abroad, is a pressing issue for airport managers.

Comprehensive evaluation of airport passenger terminals is a key for planning, designing, and managing airport performance. Numerous indices for measuring the performance of broad airport terminal services and amenities have been developed by air transportation agencies. These airport evaluations have primarily been based on macroscopic indices, such as passenger numbers, aircraft movements, and boarding rates. These measures, however, have been criticized because they do not take passenger perspectives into account (c.f., Correia, et al. 2008a).

On the other hand, some studies have conducted surveys to elicit passenger evaluations of terminal facilities (e.g., Correia et al. 2008b). Such studies incorporated passenger perspectives when evaluating airport terminals by subjective indices. Passenger perspectives may be particularly important for airport terminals, where passengers may become tired from walking between poorly-arranged facilities. Moreover, foreign visitors form first impressions of a country as they walk from the aircraft to the airport exit. Thus, the line of flow from deplaning to leaving the airport must be considered. Although these subjective indices are effective for understanding the various needs of passengers, the results are not always universal, because they depend on the perspectives of individual passengers. Therefore, physical characteristics (e.g., walking distance, number of guide boards, wireless internet) should also be considered in the comprehensive evaluation of airport passenger terminals.

This study focuses on airport passenger flow lines inside airport terminal facilities and develops a flow line evaluation index that takes physical characteristics of terminal facilities into account. We apply the proposed index to the data collected in various airport terminals in the world. The surveyed items are weighed based on the judgments of airport experts to conduct comprehensive evaluation. This study then offers a method to show various terminal functions and passenger perspectives systematically, using the proposed index. This method can help airport planners and managers design and operate favourable airport terminal facilities from the perspective of passengers.

LITERATURE REVIEW

This section reviews previous surveys and studies concerning airport terminal evaluation.

Surveys for Airport Evaluation

The ACI World Airport Traffic Report is the one summarized by Airports Council International (ACI). Every year, ACI conducts a survey of macro-indices of airports in the world. It also releases world rankings of the airports, based on the findings (Airports Council International 2008). The indices in this report, however, are mainly composed of macroscopic indicators (e.g., number of passengers, amount of baggage, and number of aircraft movements) and the factors from passengers' perspective are insufficiently incorporated.

ACI also organizes Airport Service Quality (ASQ) research. This research is called "The World Leader in Airport Service Benchmarking," by charging fees to survey participants (Airports Council International 2010). ACI collects questionnaires from each participating airport by conducting interview survey to passengers and reveals part of the results as “airport rankings.” Airports are ranked by overall evaluation, area, and annual numbers of airport users. This survey, however, mostly relies on the subjective evaluation of each passenger. The physical characteristics of airport terminals are not well incorporated.

On a commercial basis, the SKYTRAX Company conducts questionnaire surveys of approximately 200 terminals in various ways (e.g., by telephone, internet, on-site interviews) and releases airport rankings called “World Airport Awards (SKYTRAX 2010)”. The items in the questionnaire are out into the open, but how to make a comprehensive index for airport rankings is not open to the public.

Research on Airport Evaluation

As briefly described in the first session, airport evaluations have mainly been conducted in terms of macroscopic factors, such as passenger numbers, aircraft movements, and boarding rates. Todoroki and Nakamura (1996), for example, evaluated airport services by the time required to get from one’s home to one’s destination. Sarkis and Talluri (2004) evaluated the operational efficiencies of major US airports using the technique of data envelopment analysis. The input and output factors in their analysis, however, are mostly macroscopic ones (e.g., airport operational costs, number of airport employees, gates, runways, operational revenue, passenger demand).

Various researchers have developed original questionnaire surveys and evaluated airports by weighting evaluation criteria based on survey results (e.g., Correra et al. 2008b, de Barros et al. 2007, Caves and Pickard 2001). Wirasinghe and Dada (1995) developed the quantitative measure of wayfinding in airport terminals, mainly focusing on the complexity of passengers flow lines. This study, however, does not deal with factors on facility services (e.g., food, shopping, and restroom). Correia and Wirasinghe (2007) has recently proposed a methodology of developing the service level standards for airport passenger terminals and applied it to the evaluation of São Paulo International Airport in Brazil. The proposed methodology, however, mostly relies on users perceptions toward facilities of airport terminals.

Overview of the Literature Review

As noted above, researchers have examined various aspects and used various approaches when evaluating airports. While some evaluations have focused on airplane takeoffs and landings and airport access, others have used questionnaires to evaluate terminal convenience from passenger viewpoints. Some evaluations have also included the structure of pedestrian flow lines (e.g., Wirasinghe and Dada 1995). However, evaluations concerning passenger flow lines and evaluation criteria have only shown partial aspects of pedestrian-related services (e.g., structure of flow lines and tiredness) using limited physical indices. Furthermore, overall evaluation of passenger flow lines through terminals is lacking: that is, evaluations based on various objective indices of “services concerning pedestrians,” such as direction-choice points, number of level changes, and number of public guide signs, and “services concerning the facility,” such as the number and variety of restaurants and number of chairs. Additionally, indices related to walking flow lines have been limited by difficulties acquiring data in restricted airport areas. Thus, such areas have not been previously targeted in an overall evaluation.

The purpose of this study was to evaluate passenger flow lines at airport terminals by applying physical indices for restricted areas, which have not been fully investigated in previous studies.

ON-SITE SURVEY OF PASSENGER FLOW LINES AT AIRPORT TERMINALS

Overview

A survey of passenger flow lines was conducted to collect physical indices in restricted areas of airport terminals. Data were collected at 13 departure and 12 arrival terminals. This study did not consider transfer between terminals because our aim did not include evaluation of transit passenger perspectives. Thus, the unit for the survey is not the "airport," but the "terminal."

Figure 1 shows the investigation zone in each airport terminal, and Table 1 (Departure) and Table 2 (Arrival) list the surveyed airport terminals. Here, a "departure" terminal is considered the area from the check-in counter to the gate, and the "arrival" terminal is from the gate to the arrival lobby.

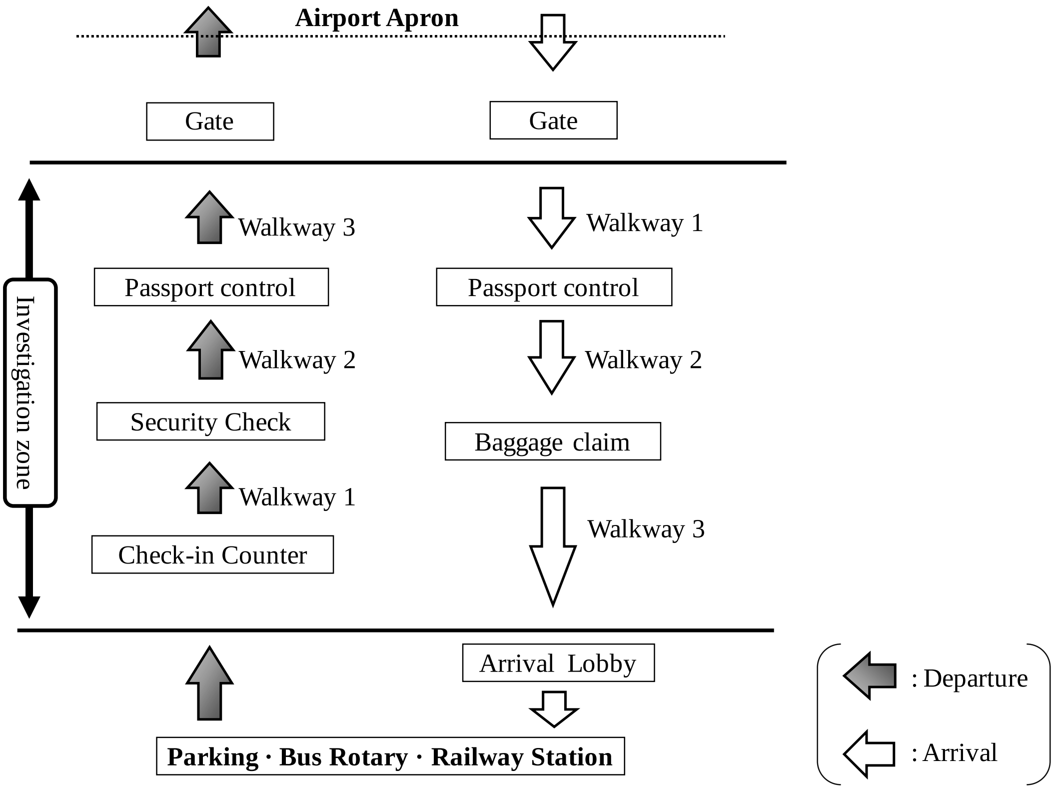

Figure 1 – Passenger flow in airport terminals

Table 1 – Airport terminals surveyed in this study (Departure)

	Flow Line for Departing Passengers	Country
1	Narita International Airport (Terminal 1)	Japan
2	Kansai International Airport	Japan
3	Tokyo International Airport (Terminal 1)	Japan
4	Tokyo International Airport (Terminal 2)	Japan
5	Komatsu Airport	Japan
6	Incheon International Airport	South Korea
7	Glasgow International Airport	United Kingdom
8	London Luton Airport	United Kingdom
9	Copenhagen Airport (Terminal 2)	Denmark
10	Stockholm-Skavsta Airport	Sweden
11	Ataturk International Airport (Terminal 1)	Turkey
12	Queen Alia International Airport (Terminal 2)	Jordan
13	London Heathrow Airport (Terminal 3)	United Kingdom

Table 2 – Airport terminals surveyed in this study (Arrival)

	Flow Line for Arriving Passengers	Country
1	Narita International Airport (Terminal 1)	Japan
2	Kansai International Airport	Japan
3	New Chitose Airport	Japan
4	Komatsu Airport	Japan
5	Incheon International Airport	South Korea
6	Glasgow International Airport	United Kingdom
7	Stockholm-Arlanda Airport (Terminal 5)	Sweden
8	London Gatwick Airport (South Terminal)	United Kingdom
9	Copenhagen Airport (Terminal 2)	Denmark
10	London Stansted Airport	United Kingdom
11	Ataturk International Airport (Terminal 1)	Turkey
12	Queen Alia International Airport (Terminal 2)	Jordan

Evaluation Items

Table 3 lists the evaluation items, divided into “big,” “mid-size,” and “small,” based on the scope of the evaluation criteria. Big items consist of two categories: “walking services” and “facility services.” Walking services includes three items: “mobility,” “information service,” and “amenity.” “Mobility” indicates the speed of movement in the terminal and consists of three small items. “Information service,” consisting of five items, here represents information on walking routes and aircraft departure and arrival times. “Amenity” indicates the ease of the walking environment and includes four items.

The mid-size item “facility services” includes the “variety of facilities,” “information service,” and “amenities.” “Variety of facility” indicates the availability of facilities used by airport passengers and includes nine items. In this category, “information service” means information provided about life and entertainment. Advertisement is categorized as a small item (information concerning walking is excluded here). “Amenity” indicates the comfort of the boarding area waiting environment and includes two items.

Table 3 – Evaluation items for airport terminal service

<table>
<tr><th>Big item</th><th>Mid-size item</th><th colspan="2">Small item</th></tr>
<tr><td rowspan="12">Walking Services</td><td rowspan="3">Mobility</td><td colspan="2">Distance</td></tr>
<tr><td colspan="2">Number of level changes</td></tr>
<tr><td colspan="2">Number of decision points</td></tr>
<tr><td rowspan="5">Information Service</td><td colspan="2">Public sign system</td></tr>
<tr><td colspan="2">Guide board</td></tr>
<tr><td colspan="2">Clock</td></tr>
<tr><td colspan="2">Flight information board</td></tr>
<tr><td colspan="2">Boarding announcement</td></tr>
<tr><td rowspan="4">Amenity</td><td colspan="2">Moving walkways</td></tr>
<tr><td colspan="2">Escalator・elevator</td></tr>
<tr><td colspan="2">Handrail・pavement for visually impaired people</td></tr>
<tr><td colspan="2">Ease of walking / tiredness [a]</td></tr>
<tr><td rowspan="12">Facility Services</td><td rowspan="9">Variety of facilities</td><td rowspan="2">Shopping & dining facilities</td><td>Food</td></tr>
<tr><td>Shopping</td></tr>
<tr><td rowspan="7">Necessary / service facilities</td><td>Restroom</td></tr>
<tr><td>Garbage bins</td></tr>
<tr><td>Vending machine</td></tr>
<tr><td>Smoking area</td></tr>
<tr><td>Bank and ATM</td></tr>
<tr><td>Wireless Internet</td></tr>
<tr><td>Public phone</td></tr>
<tr><td>Information service</td><td colspan="2">Advertisement</td></tr>
<tr><td rowspan="2">Amenity</td><td colspan="2">Chairs</td></tr>
<tr><td colspan="2">Airline lounge</td></tr>
</table>

(Note.)
[a] The definition of the item “tiredness” as an amenity is described in detail in Table 4.

The Evaluation Index

Table 4 shows the evaluation indices, established from the small items shown in Table 3. The numerical value obtained for each terminal was transformed into a deviation value for comparison with other evaluation indices. The deviation value is referred to as the "service point" of each evaluation index.

Table 4 – The evaluation index

	Small item	Evaluation index
1	Distance	Distance of flow line [a] (from departure point to arrival point)
2	Number of level changes	Number of level changes on flow line
3	Number of decision points	Number of decision points on flow line
4	Public sign system	Number of public sign boards and variety of languages on flow line
5	Guide board	Number of guide boards on flow line
6	Clock	Number of clocks on flow line
7	Flight information board	Number of flight information boards on flow line
8	Boarding announcement	Variety of languages of boarding announcement
9	Moving walkways	Ratio of time spent [b]
10	Escalator・Elevator	Barrier-free ratio [c]
11	Handrail・Pavement for visually impaired people	Number of handrails and pavement for visually impaired people on flow line
12	Ease of walking / tiredness	Energy consumed while walking on flow line [d]
13	Dining	Number and variety of places to eat in the terminal (only restricted area)
14	Shops	Number and variety of shops in the terminal (only restricted area)
15	Restrooms	Number of toilets in the terminal (only restricted area)
16	Garbage bin sites	Number of garbage bin sites on flow line
17	Vending machine sites	Number of vending machine sites on flow line
18	Smoking areas	Number of smoking areas in the terminal (only restricted area)
19	Bank and ATM sites	Number of bank and ATM sites in the terminal (only restricted area)
20	Wireless Internet	Availability area ratio in the terminal (only restricted area)
21	Public phone sites	Number of public phone sites on flow line
22	Advertisements	Number of advertisements and variety of languages on flow line
23	Chairs	Number of chairs on flow line
24	Airline lounges	Number of airline lounges in the terminal (only restricted area)

(Note.)
[a] The flow line for departing passengers ranges from the check-in counter to the departure gate. For arriving passengers, it ranges from the arrival gate to the arrival lobby. In the measurement of the distance, the gate which is the farthest away from the other side of the flow line is selected among all the gates.
[b] The walking time is divided by the total travel time.
[c] The number of escalators or/ elevators which are installed per a level change
[d] This measure is calculated by converting walking time into energy consumption.

INTERVIEWS WITH EXPERTS TO WEIGH EVALUATION ITEMS

Overview

Interviews were conducted with airport planning experts to determine weights for the evaluation items along the passenger flow lines. Four academic experts in airport planning participated in the interviews. These participants had a deep understanding of technical terms and special knowledge of airport planning. Hereafter, they are referred to as the "experts."

We asked the experts about the evaluation items shown in Table 3 in regard to the same departure and arrival terminal sections described above (Figure 1). Separate interviews were conducted for "departure" and "arrival" terminals.

Method

Participants were asked to put weights for each evaluation item based on the following rules:

(a) Total maximum score of the two "big" items is 100.
(b) Total maximum score of the three "mid-size" items in the category of walking services is 100.
(c) Total maximum score of the three "mid-size" items in the category of facility services is 100.
(d) The score of "small" items is derived from the score of "mid-size" items.

Finally, data from the four reviewers were averaged for analysis (Table 5).

Table 5 – Average of weighting values

Big item	Mid-size item	Small item	Average	
			Departure	Arrival
Walking Services	Mobility	Distance	6.1	18.9
		Number of level changes	3.8	9.5
		Number of decision points	4.1	5.6
	Information services	Public sign system	4.1	14.7
		Guide board	3.8	2.8
		Clock	0.80	1.3
		Flight information board	3.9	0.21
		Boarding announcement	1.4	0.21
	Amenity	Moving walkways	2.9	7.9
		Escalator・Elevator	5.2	13.2
		Handrail・Pavement for visually impaired people	1.4	4.9
		Ease of walking / tiredness	2.5	6.0
Facility Services	Variety of facilities	Shopping & dining facilities	11.2	11.3
		Necessary / service facilities	7.8	46.1
	Information services	Advertisements	6.0	12.8
	Amenity	Chairs	12.0	2.2
		Airline lounge	10.5	0.41

Comprehensive Evaluation Based on Total Score

Figure 2 shows how the total score was calculated for a passenger flow line. Weighting values obtained from the expert interviews were multiplied by the service points for all the evaluation items of each mid-size item. The sum total of the calculated data was the total score and defined as shown in Figure 2.

Total Score

Walking Services:

= w_1 × **Mobility**
(Distance, Number of level changes, Number of decision points)

\+ w_2 × **Information Service (walking)**
(Public sign system, Guide board, clock, Flight information board, Boarding announcement)

\+ w_3 × **Amenity (walking)**
(Moving walkways, Escalator · elevator, Handrail · pavement for visually impaired people, Tiredness)

Facility Services:

\+ w_4 × **Variety of Facilities**
(Food, Shopping, Restroom, Garbage bins, Vending machine, Smoking area, Bank and ATM, Wireless Internet, public phone)

\+ w_5 × **Information Service (facility)**
(Advertisement)

\+ w_6 × **Amenity (facility)**
(Chairs, Airline lounge)

w_i: weight for the item i (i =1,…,6)

Figure 2 – Definition of the total score

The calculated total score of each airport was transformed into a deviation value. The deviation value is a standard score calculated from the normalized value so that the mean value of 0 corresponds to that of 50 and the standard deviation 1 is replaced with 10. This value is defined as follows:

$$\text{Deviation value} = (\text{Normalized value}) \times 10 + 50 = \frac{(\text{Total Score}) - (\text{Mean})}{(\text{Standard Deviation})} \times 10 + 50.$$

Results

Figure 3 (departure) and Figure 4 (arrival) show airport rankings by the deviation value.

Departure

In Figure 3, Narita International Airport (Terminal 1) had the highest ranking, followed by Incheon International Airport, Haneda Airport (Terminal 2), and London Heathrow Airport (Terminal 3). For these results, large-scale airports have the highest rankings.

Arrival

For arrival terminals, Figure 4 shows Incheon International Airport as ranking highest, followed by Narita International Airport (Terminal 1), New Chitose Airport, and Glasgow International Airport. In this result also, higher rankings were occupied by larger airports, but mid-sized airports, such as New Chitose and Glasgow International, also ranked highly, in third and fourth position, respectively. This result shows that evaluation of the flow line at arrival does not necessarily depend on macro-indices, such as the number of annual passengers and the scale of airport facilities.

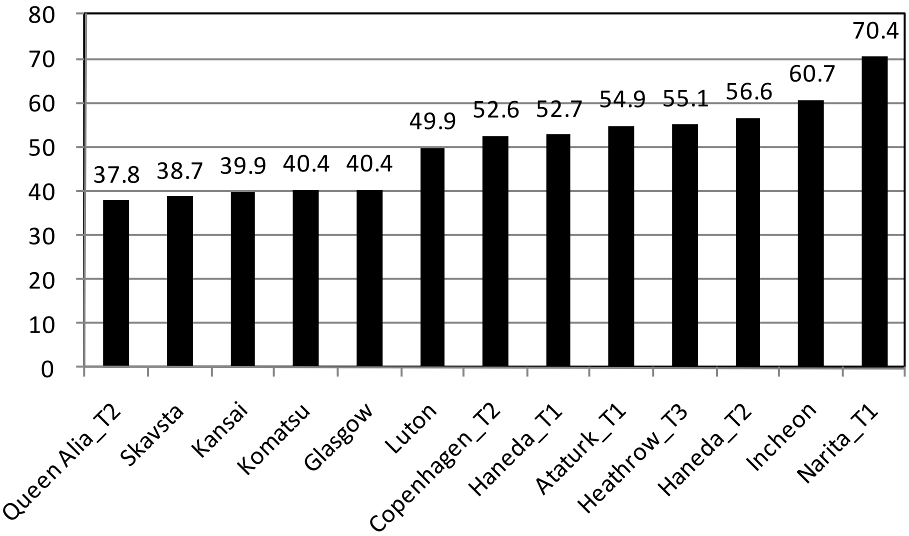

Figure 3 – Deviation values of departure terminals

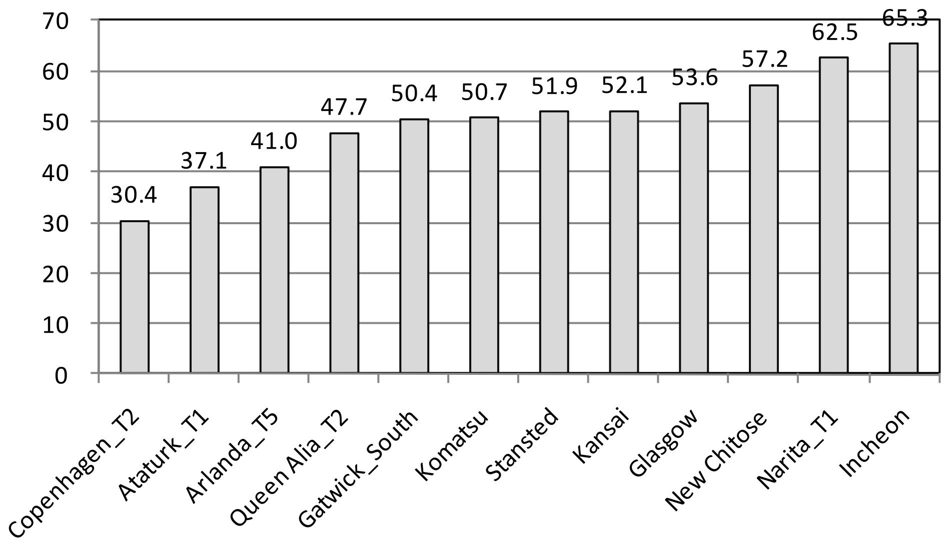

Figure 4 – Deviation values of arrival terminals

AIRPORT EVALUATION BASED ON MULTIDIMENSIONAL SCALING

Outline of the Analysis

This section applies an analytical method based on the theory of multidimensional scaling (e.g., Shepard et al. 1972a and 1972b) to airport terminal evaluation. This method allows for evaluation of each airport terminal as a multidimensional space and can help airport managers systematize relationships among airport terminals and items recognized as important by experts.

In this study, information about airport terminal was categorized into three elements: evaluation items, service points, and expert-recognized items. Evaluation items are the criteria for evaluating passenger flow in the airport terminal. This element consists of two big items, six mid-sized items, and 17 small items. The weighting values for evaluation items and service points of airport terminals (deviation values) presented in the previous section are applied.

The analytical program which has been developed by the previous research (Yamamoto et al. 2008) is used for the multidimensional scaling. This program finds a joint space representation of evaluation items, experts' evaluations, and airports terminals' performances (service points) in the following three steps. First, non-metric multidimensional scaling (Kruskal's M-D-SCAL, Kruskal 1964a and 1964b) is applied to position evaluation items in a special configuration in such a way as to represent best the degree of similarity between every pair of items. Correlation coefficients calculated from reviewers' weighting datum are used for measures of pair-wise similarity among items. Then, the optimum configuration of items is solved such that the Euclidean distances between the positions of pairs of items represent the original similarity scores; the greater the distance between any two items, the less the similarity score for those items. Second, experts are positioned in the multidimensional space according to vector model (Tucker 1960), where experts are represented by vectors. In this model, projections of points of evaluation items onto an expert's vector are assumed to represent weighting evaluation for the expert; projections farther out in the direction of the vector indicates higher evaluations. The algorithm for the vector model is basically the same as that described in Shepard et al. (1972a), in which linear correlations between the weights assigned by experts (preference scales) and the projections of the points of items on the fitted vectors are maximized. Third, unfolding model (or "ideal point model", Coombs 1950, Bennett and Hays 1960) is applied in order to locate airport terminals in the multidimensional space. In this model, distances from terminal's point to items are assumed to define inversely the terminal's service points on the items; the farther an item is from terminal's point, the lower the service points of the terminal on the item is.

This analysis focuses on the relationship between service points for small items and the weighting values for (1) departure and (2) arrival. Analysis results are shown below.

The relationship among small index items, expert-recognized items, and airports (Departure)

Outline of the results

Figure 5 shows the multidimensional scaling result. The stress measure, which is a goodness of fit measure, was 1.30×10^{-1} implying that the model was well fitted (c.f., Kruskal 1964a). Among airports surveyed, Copenhagen_T2 is shown by an arrow, because this airport's service point is located outside Figure 5.

Reviewers

Reviewers A, B, and D placed the most importance on "shopping & dinning." In second place, they tended to emphasize "level changes." Reviewer C placed the most importance on "decision points" and "ease of walking / tiredness." The items "decision points" and "tiredness" could refer to "ease of mobility." Thus, reviewer C emphasized factors that interfered with mobility.

Airport Terminals

In Figure 5, huge airports such as Narita and Incheon are located in the upper right, having enhanced "shopping & dining facilities" and "lounges." On the other hand, small airports, such as Skavsta and Komatsu, are located at the lower left, having enhanced "necessary/service facilities" and less "tiredness."

Airport Terminals Far from Others in Multidimensional Space

<u>(a) Copenhagen_T2</u>
Copenhagen_T2, located outside Figure 5, was found to have low service points regarding information environment elements, such as "flight information boards" and "boarding announcements," compared with other airports.

<u>(b) Queen Alia_T2</u>
Queen Alia_T2 had low service points regarding items such as "shopping & dining facilities," "lounge," and "public signs," compared with other airports. Thus, Queen Alia_T2 was plotted away from these items in the multidimensional space.

Reconsideration of evaluation items

Here we focus on evaluation items and expert-recognized items that are located close together, and reconsider the evaluation items based on the items stressed by the experts for departure flow lines.

First, "shopping & dining facilities" and "necessary/service facilities" belonged to the same mid-size item of "variety of facilities" in this survey. However, the item "shopping & dining facilities" is plotted away from "necessary/service facilities". This indicates that reviewers recognized these items as belonging to separate mid-size items. In particular, three reviewers (all except C) strongly emphasized "shopping & dining facilities." Given this, resetting "shopping & dining facilities" as an independent item appears to be more appropriate, based on the expert reviewer perspectives.

Second, reviewer C emphasized "decision points" and "ease of walking / tiredness." As mentioned above, these items could be regarded as "ease of mobility." This new mid-size item must be considered in flow evaluation.

Furthermore, the items "public sign," "handrail・pavement for visually impaired people," "escalator・elevator," "chair," and "distance" belonged to separate mid-size items. These items, however, were plotted close together and could be regarded as "mobility aid for the differently-able." Additionally, the items "moving walkway," "boarding announcement," "flight information board," and "guide board" also did not belong to the same mid-size category. However, the multidimensional scaling results indicate that these items are located close together and could be regarded as "comprehensive walking aid."

Thus, three new evaluation items ("ease of mobility," "mobility aid for the differently-able," and "comprehensive walking aid") could be used. Use of these revised evaluation items would contribute to accurate evaluation, based on the expert reviewer perspectives.

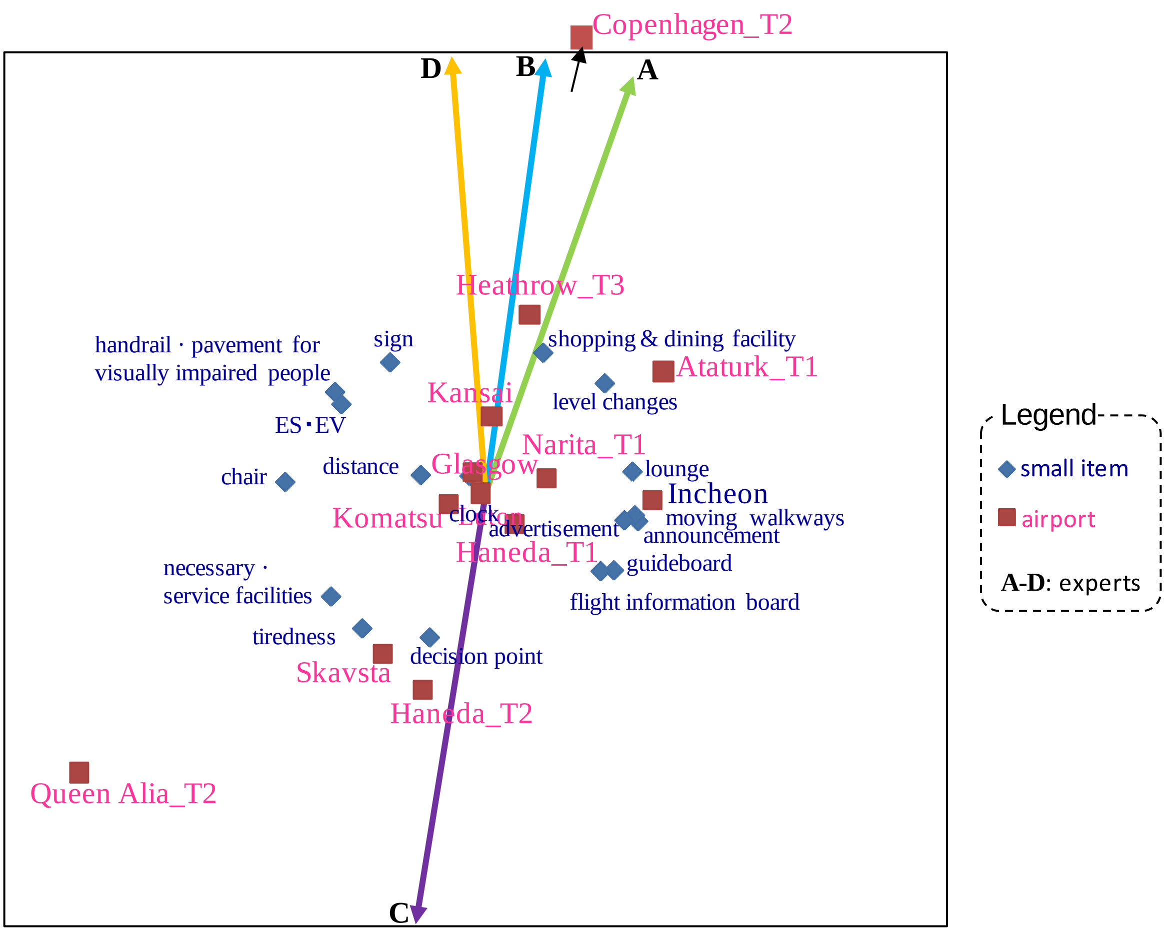

Figure 5 – Result of multidimensional scaling (Departure / small items)

Relationship among small indices, expert-recognized items, and airports (Arrival)

Outline of the results

Results are shown in Figure 6. The stress measure was 1.67×10^{-1} implying that the model was well fitted (c.f., Kruskal 1964a).

Experts

All the experts placed the most importance on the items “moving walkway,” “clock,” “guide board,” and “distance.” These evaluation items all contribute to a “swift change to next trip” soon after travellers arrive at the airport. On the other hand, no expert placed the most importance on “shopping & dining facilities,” “flight information board,” or “boarding announcements.” Thus, this could also support the above suggestion that experts emphasized the importance of a “swift change to next trip.”

Airports

Most airports are locates towards the centre of Figure 6, indicating that most of the airports examined had a favourable balance of service scores. Additionally, some Asian airports, such as Narita, Kansai, and Incheon, are located towards the left-hand side, while European airports, such as Copenhagen_T2, Arlanda_T5, Gatwick_South, Glasgow, and Stansted, are to the right-hand side of the figure. This result suggests that the Asian airports have enhanced services regarding “level changes,” “chairs,” and “handrail · pavement for visually impaired people.” European airports, on the other hand, have enhanced services regarding “decision points,” “public signs,” and “necessary / service facilities.”

Reconsideration of evaluation items

Next, we focus on the evaluation items and expert-emphasized items located close together in the multidimensional space to reconsider the evaluation items based on expert evaluations of arrival flow lines.

First, all reviewers emphasized the importance of a “moving walkway,” “guide board,” and “distance.” As mentioned above, these items can be regarded as contributing to a “swift change to next trip.” This new mid-size item should be considered in evaluating arrival flow. Second, the items “chairs” and “handrail · pavement for visually impaired people” belonged to separate mid-size items in the current evaluation. These items, however, were plotted close together and could be regarded as one item, “mobility aid for the differently-able.” Additionally, items such as “decision point,” “ease of walking / tiredness,” and “public signs” also belonged to separate mid-size items. These items, however, were also plotted close together and could be regarded as “comprehensive walking aid,” as in the departure flow line. Thus, integration of these items should be considered.

Furthermore, none of the experts placed much importance on “shopping & dining facilities,” “flight information board,” and “boarding announcement” as these items are not used on arrival at one’s destination. These items could be removed as evaluation items.

Thus, new evaluation items ("swift change to next trip," "mobility aid for the differently-able," and "comprehensive walking aid") could be used as evaluation items for accurate evaluation from the expert reviewers' perspectives.

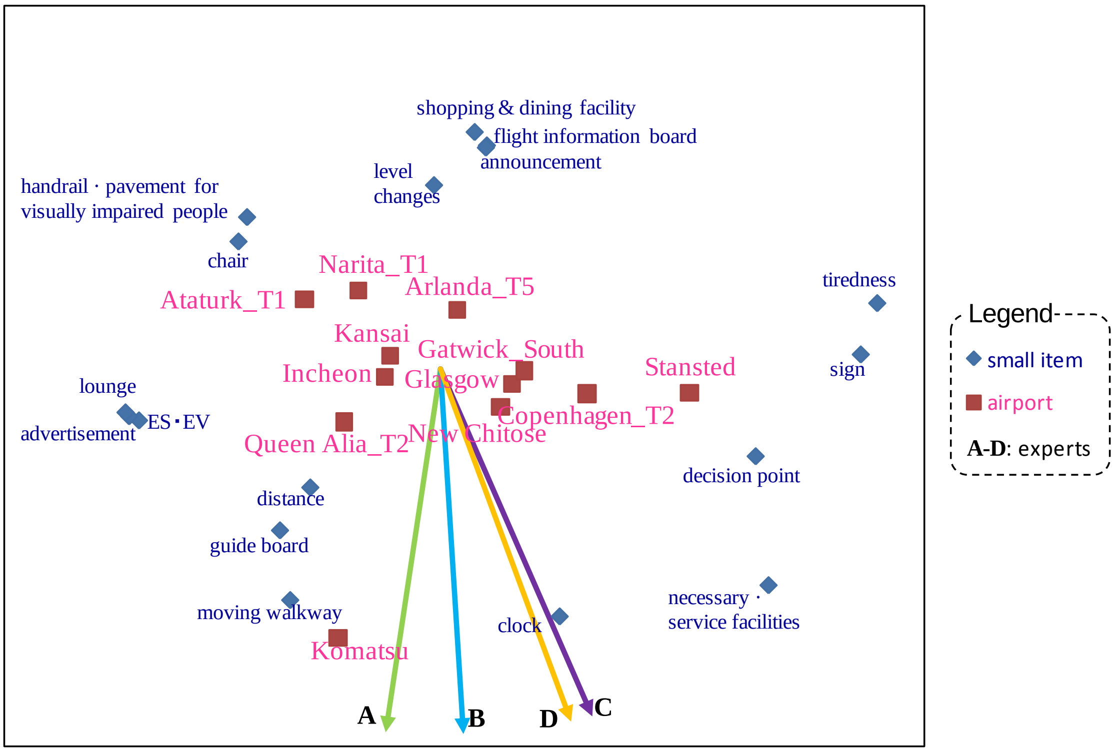

Figure 6 – Result of multidimensional scaling (Arrival / small items)

Discussion of comprehensive evaluation based on multidimensional scaling

The multidimensional scaling results provide several findings regarding expert opinions, airports, and evaluation items.

First, the analysis revealed the perspectives of experts as well as similarities and differences in these perspectives. The similar directions of the "expert vectors" indicated that the experts had similar views. In case where vectors indicated different directions, the directions and positions of the evaluation item indicated conflicting points between reviewers.

Second, the results show that a number of airports could be categorized based on "ease of mobility" and "shopping & dining facilities." This suggests that airports can be categorized by viewpoints other than "passenger scale" and "zone character."

Finally, our analysis shows that, according to experts, the importance of some evaluation items depends on whether it is for a departure or an arrival terminal. Thus, separate evaluation item systems may be required depending on the situation. For evaluation of departure flow, experts tended to stress the importance of "shopping & dining facilities," as well as "ease of mobility" and "mobility aid for the differently-able." Analysts should thus consider such items when developing new systems for the evaluation of departure terminals. For arrival flow, new items involving "swift change to next trip" were indicated. Analysts should thus consider the "swift change" item when evaluating arrival. However, "shopping & dining facilities" and "flight information" were not emphasized for arrival, unlike for departure. Thus, elimination of these items can be considered.

CONCLUSIONS

This study focused on passenger flow lines in airport terminals and has proposed a comprehensive evaluation method of passenger flow lines, based on some physical indices of airport terminals. By this method, we could systematically show various terminal functions and passenger perspectives. We examined the service level of passenger flow lines with total service scores of each airport and visualized relationship among evaluation items, experts, and airports systematically. The empirical analysis demonstrated the significance of introducing new evaluation items such as "ease of mobility," "mobility aid for the differently-able," and "swift change to next trip."

For accurate analyses, it is important to conduct further expert interviews to estimate weights for the new evaluation items. Additionally, data from many other airports should be collected to enhance the general applicability of these comprehensive evaluation methods. These efforts would help airport managers to design and operate favourable airport terminal facilities from various perspectives of passengers.

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