# Airport Smartness Index – evaluation method of airport information services

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## Introduction

The functionality of airports is expanding, the role of operational companies is transforming. They are not only infrastructure operators but service providers as well (e.g. commercial, business centers), as airport operators try to minimize the perceptible decrease of income from the aviation business[1,2]. A diverse range of services increase the spatial extent of the passenger facilities and reduce transparency, in addition passengers have to go through several processes (due to the tightening rules). The aim is to make the airport and the services more attractive for passengers, to smooth processes and to reduce stress. In order to achieve it, technology/service in appropriate quality is needed that covers the whole transportation chain. Airport evaluation methods in many cases omit information technology. Several studies have been found in this topic. However, the range of evaluated aspects, the 'covered' fields and the methods are rather different and incomplete.

In order to fill this niche, a new evaluation method that focuses expressly on information management of airports was developed. Our aim was the objective evaluation and comparison of airports where the ranking is based on the features of infocommunication solutions. The research focused only on the availability and the quality of information technology/services and did not deal with other aspects of airport evaluation (e.g. cleanliness, waiting time, etc.).

The perceived quality of airport services by transfer passengers in the terminal area has been studied in[3]. The services were scored on a scale of 1-6 in a passenger questionnaire. The results depended on the actual subjective opinion of passengers.

The operational characteristics of 10 airports in Taiwan have been evaluated and compared in[4], where the connections were analyzed among 4 factors (airport, passenger, airline, fire brigade). Measurable values were used (e.g. number of check-in counters) as exact indicator. The study did not include the information technology. The service level of an airport was studied in[5]. The efficiency of an airport has been examined with AHP/DEA-AR model[6], which is affected by the passenger related information systems as well. Our method is an easily applicable solution for ranking and comparison of airports.

In[2], the evaluation criteria were categorized into 6 groups (arrival, airport parking, airport facilities, landside services, security and not-aviation services). The evaluation method covered the whole airport, not only the landside but the airside services too.

Literature review showed that beside the general evaluation, it is essential to focus on segment of information and communication services, and to develop an operator-oriented analysis and evaluation method. In our national practice such a solution does not exist; Budapest Airport uses also the ASQ method.

## 1. Model of „smart" airports

The definition of „smart" airport is related to the definition of „smart city". Smart cities apply the technological opportunities in an innovative way in order to create more livable and sustainable urban environment. Urban subsystems are connected by either physical infrastructure (e.g. transportation network) or information infrastructure (e.g. infocommunication network)[7]. Subsystems and elements of „smart cities" work on digital base and communicate with each other. As a consequence of value-added information, the processes are controlled more efficiently and the effects can be predicted[8].

The „smart" airport is a determinative subsystem of the „smart city". It is the place where urban life and aircraft movements are connected, while several other activities are realized. This interface role is also significant regarding the information management. Accordingly, information is exchanged among urban transportation management, systems of air traffic control and airlines. The integrated system of the airport is operated by the information and control center. The ground handling companies are connected to the integrated system through 'internal' information connections. The aim of operation: optimization of individual processes and airport operation as well as enhancement of passenger satisfaction at the same time. The intelligent passenger is aided by the intelligent infrastructure and his/her own personal devices. The development trends of passenger-related information management are: real-time and value-added information provision, as well as enhancement of reliability and satisfaction (e.g. individual services)[9].

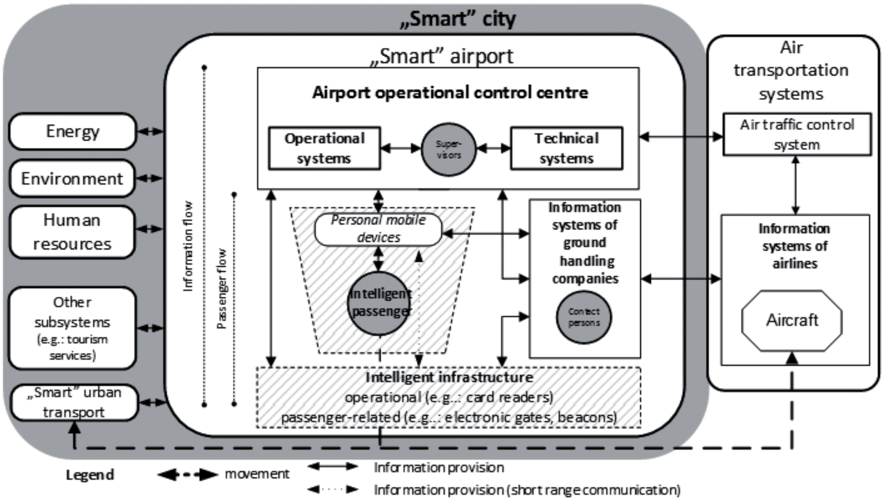


Fig. 1: Model of “smart” airport in the concept of “smart” city

The information system structure of the „smart” airports was modelled on 0. 1. External connections are realized with the following subsystems of „smart city”: information systems of power-supply, environmental properties, human resources (education, healthcare), other functions (e.g. tourism services) and „smart” transportation. Internally, the cooperating companies (ground handling companies, infrastructure maintenance, etc.) and their ICT subsystems are connected. Operational systems are responsible for the allocation of resources (check-in counters, aircraft stands, etc.), whereas the technical systems are responsible for the supervision and the maintenance of the infrastructure, using their own sub-systems. The airport systems communicate with the personal devices of passengers and the intelligent infrastructure. The air traffic control system (as external connection) provides real-time information about aircraft movements. The systems of airlines support the airport operation with data related to passengers and services. The relations of the components of “smart” airports are complex. During the research we focused on the intelligent passengers and the related infrastructure.

## 2. Determination of evaluation scores of passenger-related infocommunication technologies and services

Information management functions were assigned to the elements of air transportation travel chain (basic process) (Fig. 2.). Different font colors indicate the division of functions among the airport operator and other organizations related to aviation. Our method refers to the analysis and evaluation of the passenger related main functions and information management processes, which are highlighted with different colored background in groups „b-e”.

Infocommunication technologies (tools) and services were assigned to the airport functions ($F_i$). The evaluation scores ($e_{Fi}$) were determined in a discrete scale of 1-3 (1: basic technology/service 2: advanced technology/service 3: „smart” technology/service enabling personalization and human-machine interactions). Fractions are not used; they are to be introduced for further refining. The service that belongs to a higher score includes the properties of a service that belongs to a lower score. Technology and services are strongly related to each other. The assignment method is summarized in Table 1. As the basic process and the information management pro-

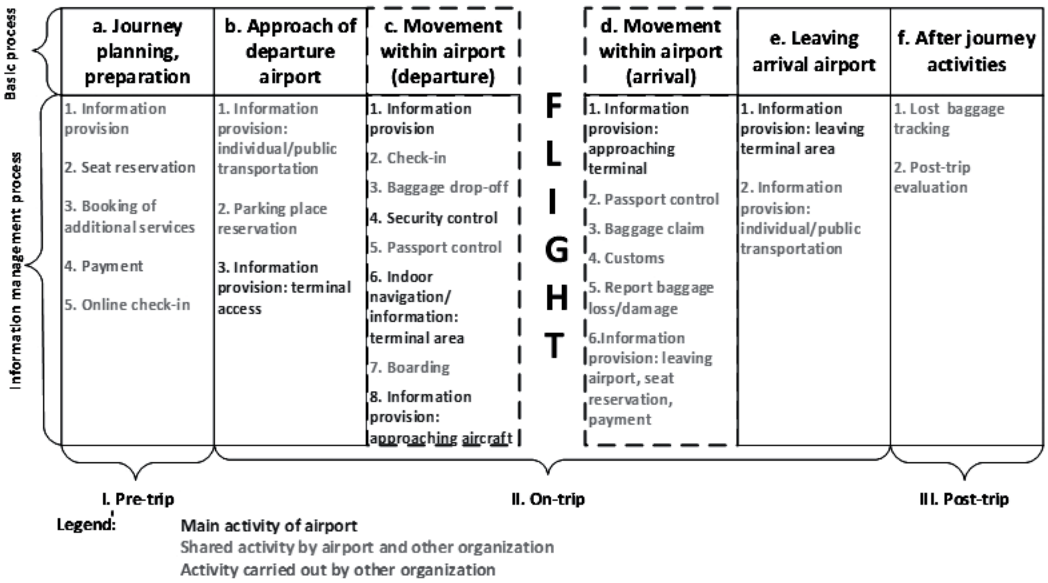


Fig. 2: Structure of air transportation travel chain – passenger information functions[10]

cess are symmetrical about the „flight" axis, only the functions of arrival airport are mentioned, the functions of departure airport can be formed similarly.

The evaluation method can be developed by the introduction of an extended evaluation scale (further subgroups) related to the technologies and services. The improvement of the 'resolution' facilitates the more detailed evaluation and revealing more differences between airports. We have primarily focused on the elaboration of the structure and the logic of evaluation process, highlighting also the opportunities for further development.

**3. Method of evaluation**

In order to determine the development level of airports and facilitate the objective evaluation and benchmarking, we introduced the „smartness" index (S), that is the result of our method (called: ASI – Airport Smartness Index method). The airports are ranked by the „smartness" index according to their infocommunication solutions. The calculation method and the marking technique are represented in Fig. 3.

Input data for the calculation are as follows:

result of status report (collection of available information systems and their characteristics at the airport),

table of parameters that influence the weights, which is to be reviewed annually based on the results of passenger questionnaires.

In order to reduce the subjectivity, we have introduced tables and formulas with interpretation purposes.

Description of the calculation steps:

*a. Determination of function evaluation score ($e_{Fi}$):*

Scores are determined according to Table 1. (and further auxiliary tables). We have taken into account the highest level technology and the associated service that is operationally available for passengers and being over the test period. If the function is not available or not applicable at the airport, then the evaluation score is 0.

*b. Determination of correction values ($n_j$ and $p_k$):*

The scores are modified by correction values either positively or negatively according to usability and operational aspects (Table 2. and 3.). Accordingly, more accurate overview of the service quality and more exact identification of future developments are possible. The following have been taken into consideration:

as negative value (2.1.)

- unreliability (e.g.: common technical failure),
- difficult usage (e.g.: unclear human-machine interface)
- limited availability (in space or in time; e.g. parking place reservation is available only in one terminal),

as positive value (2.2.)

- development potential (e.g. plans are already prepared, being under implementation or in testing phase).

| $F_i$ | $e_{Fi}$ | Technology (tools) | Service |
|---|---|---|---|
| b1 | 1 | webpage | static information |
| | 2 | mobile application | dynamic information |
| | 3 | webpage/mobile application | ticketing/payment |
| b2 | 1 | webpage/mobile application | static and dynamic information |
| | 2 | webpage/mobile application | parking place reservation/payment |
| | 3 | intelligent vehicle + intelligent infrastructure elements | intelligent parking-guidance (navigation, automatic license-plate recognition, parking assistance) |
| b3 | 1 | webpage/guidance signs | static information |
| | 2 | mobile application/intelligent infrastructure elements (e.g.: interactive map) | dynamic, personalized information |
| | 3 | mobile application / virtual assistant/intelligent robot | personalized navigation, guidance |
| c1 | 1 | webpage/guidance signs | static information |
| | 2 | mobile application/intelligent infrastructure elements / displays | dynamic, personalized information |
| | 3 | mobile application / virtual assistant /intelligent robot | personalized navigation, guidance |
| c2 | 1 | check-in desk | traditional check-in |
| | 2 | mobile application /self-service kiosk | online and/or self-service check-in |
| | 3 | external site self-service check-in kiosk | pre-check-in on public transport vehicle or on stations |
| c3 | 1 | baggage check-in desk | baggage check-in, weight control |
| | 2 | self-service baggage drop-off | self-service baggage drop-off/ home printed baggage tag |
| | 3 | automated hand luggage inspection system RFID baggage identification | automated hand luggage inspection, baggage-tracking |
| c4 | 1 | information signs/displays | static information |
| | 2 | boarding pass reader / fast track kiosk / queue management system | boarding pass check / ensuring fast track /dynamic queue information |
| | 3 | intelligent identification and inspection system | biometric/iris technology identification, body scanning, video analysis |
| c5 | 1 | information signs/displays | static information |
| | 2 | e-gates / queue management systems | electronic passport control /biometric identification / dynamic queue information |
| | 3 | „mobile passport" application / QR code readers | passport control through smartphone |
| c6 | 1 | information signs / displays / static maps | static information |
| | 2 | mobile application / wireless internet/ interactive map | dynamic information |
| | 3 | mobile application /installed beacons | indoor navigation / special information provision /payment |
| c7 | 1 | information signs / displays / traditional boarding gates | static information |
| | 2 | mobile application | dynamic information |
| | 3 | boarding pass reader self-service gates | self-service boarding |
| c8 | 1 | information signs | static information |
| | 2 | mobile application | dynamic information |
| | 3 | mobile application | personalized navigation |

Table 1: Evaluation scores of the functions based on the properties of technology and service

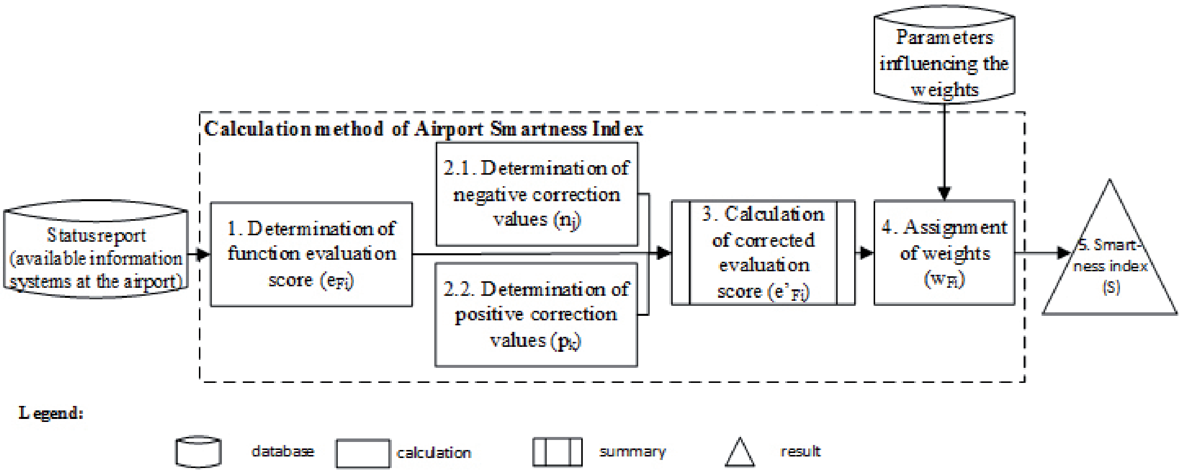


Fig 3: Calculation method of Airport Smartness Index (ASI)

In case of coexistence of several negative aspects at the same airport, the correction values are summarized ($\sum n_j$) towards simple applicability of the method.–Considering the positive correction values, only one is applicable depending on the development phase ($p_k$).

In Table 2, difficult usage means the exhausting and time-consuming handling of equipment for a passenger with ordinary skills. Unreliability means that if the inaccurate information management significantly risks the completion of the journey, resulting in a significant sense of uncertainty (stress).

| **Negative correction values ($n_j$)** | | |
|---|---|---|
| $n_1$ | Limited availability in space | -0.1 |
| $n_2$ | Limited availability in time | -0.1 |
| $n_3$ | Difficult usage | -0.1 |
| $n_4$ | Unreliability (poor data quality) | -0.2 |

Table 2: Negative correction values

| **Positive correction values ($p_k$)** | | |
|---|---|---|
| $p_1$ | Development intentions to the next level | +0.1 |
| $p_2$ | Development in planning phase | +0.2 |
| $p_3$ | Development in implementation phase | +0.3 |
| $p_4$ | Development in test phase | +0.4 |

Table 3: Positive correction values

List of correction values can be extended in the further improvement of the method.

*c. Calculation of corrected evaluation score ($e'_{Fi}$):*

The evaluation score and the correction values are summed up.

$$e'_{Fi} = e_{Fi} + N_{Fi} + P_{Fi} \quad (1)$$
$$N_{Fi} = \sum n_j \quad (2)$$
$$P_{Fi} = p_k \quad (3)$$

*d. Assignment of weights (wFi)*

The importance of functions is different by passenger groups and phases of journey chain. The importance is represented by weight. The weights are influenced by the following parameters (the parameters are taken into account as % values):

Ratio of affected passengers (x): rarely used functions get lower, frequently used get higher weight. If the usage is compulsory during the travel, the ratio of affected passengers is 100%. The ratio of affected passengers in case of not-compulsory functions can be determined by detailed surveys and passenger questionnaires.

Rate of development needs (y): the significant development needs/expectations of the passengers are taken into account with higher weights. This value can be determined by passenger questionnaires.

Rate of negative opinion of the passengers (z): the less popular features are to be developed in order to avoid negative perceptions. It can be determined by passenger questionnaires.

Weighting factors are calculated according to the following formula:

$$w_{Fi} = \frac{1}{i_{max}} * \frac{x}{100} * \left(\frac{y}{100} + 1\right) * \left(\frac{z}{100} + 1\right) \quad (4)$$

where

$i_{max}$: number of functions in the evaluation (currently $i_{max} = 19$)

For the application of our method the values of passenger ratios are taken from the studies[11] and[12], in which the online surveys covered 5 continents, 17 countries and 5871 passengers.

*e. Calculation of „smartness" index (S):*

The „smartness" index is the sum of the weighted, corrected evaluation scores regarding all functions of the airport.

$$S = \sum_{Fi} e'_{Fi} * w_{Fi} \quad (5)$$

## 4. Application of method

The application of the method is demonstrated for two selected functions (b1, b2) in Table 5. The

| $F_i$ | x [passenger %] | y [passenger %] | z [passenger %] | $w_{Fi}$ |
|---|---|---|---|---|
| b1 | 70 | | | 0.04 |
| b2 | 36 | | | 0.02 |
| b3 | 100 | | 0 | 0.05 |
| c1 | 100 | 0 | | 0.05 |
| c2 | 100 | | | 0.05 |
| c3 | 81 | | | 0.04 |
| c4 | 100 | | 36 | 0.07 |
| c5 | 100 | 60 | | 0.08 |
| c6 | 100 | 72 | | 0.09 |
| c7 | 100 | 60 | | 0.08 |
| c8 | 100 | | 0 | 0.05 |
| d1 | 100 | 0 | | 0.05 |
| d2 | 100 | | | 0.05 |
| d3 | 81 | 63 | 31 | 0.09 |
| d4 | 100 | | | 0.05 |
| d5 | 1 | | | 0.00 |
| d6 | 100 | 0 | 0 | 0.05 |
| e1 | 100 | | | 0.05 |
| e2 | 70 | | | 0.04 |

Table 4: Determination of weights [11], [12]

values of $n_j$ and $p_k$ are sample, not real data, however $w_{Fi}$ is coming from Table 4. The calculated values are highlighted with grey background.

| $F_i$ | $e_{Fi}$ | $n_j$ | $p_k$ | $e'_{Fi}$ | $w_{Fi}$ | $e'_{Fi}*w_{Fi}$ |
|---|---|---|---|---|---|---|
| b1 | 2 | $n_1$= -0.1 $n_3$= -0.3 | $p_2$=+0.2 | 1.8 | 0.04 | 0.072 |
| b2 | 3 | $n_2$= -0,1 | $p_3$=+0.3 | 3.2 | 0.02 | 0.064 |
| … | … | … | … | … | … | … |
| **S** | | | | | | **0.136** |

Table 5: Demonstration of the calculation of „smartness" index

## 5. Comparison of the developed method with ASQ

The most common airport evaluation method is the ASQ[13]. This evaluation process has been compared to our developed ASI method (Table 6). Grey background shows the similar properties and white shows the differences.

It has been found that ASQ evaluation procedure provides a more comprehensive analysis, while quantifying the perceived quality of passengers. In contrast, ASI analyzes the information management considering the operator side, quantifying the provided quality. To many services evaluated in the ASQ, a function of the ASI can be assigned (e.g. ASQ: finding your way, ASI: c6 function). One of the further research directions is to analyze the consistency between the results of ASI and ASQ; namely, what is the quality "gap" between the provided quality by the operator and the perceived quality by the passengers. It is also to be examined in case of a low result regarding a service in ASQ, what are "the partial results" in ASI. In case of an unfavorable result, it can be examined whether it is caused by the infrastructure or other factors (e.g. human resources). The joint application of the two evaluation methods provides detailed results referring to the airport services which are the basis of investment decisions.

## 6. Conclusion

Based on our literature review, it is stated that the evaluation method that focuses expressly on information management of airports is currently unavailable. We developed the ASI method whose result is appropriate for benchmarking purposes of airports with a single index. The method takes into consideration the quality of information services, corrects the values according to operation and development aspects as well as weights the values according to ratio of affected passengers, the rate of development needs and the rate of negative opinion of the passengers

We concluded that ASI is useful as a complementary of ASQ; it provides important background knowledge about operation side. We showed that the method can be further improved by using a wider range of the evaluation scale, as result of determination of more technological and service sub-systems, and by more correction factors. Furthermore, if more detailed data from passenger questionnaires are available, the method of the determination of weights can be improved as well. The mentioned improvement opportunities appoint our further research activities.

| Comparison criteria | ASQ | ASI |
|---|---|---|
| Developer | ACI (Airport Council International) | own research result |
| Purpose | airport evaluation for the purpose of benchmarking | airport evaluation for benchmarking |
| Evaluator | passenger | operator(through the weights: passenger) |
| Range of evaluated services | general services, facilities | detailed evaluation of info. technology/services |
| No. of evaluation criteria | 37 criteria in 9 groups* | 19 (according to the functions) |
| Scoring system | scoring of services on 1-5 scale (5: best, 1: worst) | scoring of services on 1-3 scale (3: best, 1: worst); correction of them, then weighting |
| Result | average scores by criteria groups (based on 37 criteria) | only one score: „smartness" index (the values of the functions are available separately) |
| Characteristics of the passenger groups | nationality, country, gender, age group, passenger profile | ratio of affected passengers (x), passenger needs (y,z) |
| Evaluation process | individually, 30-45 minutes prior to departure, 350 passenger questionnaire in every quarter of the year | by operators once a year |
| Frequency of evaluation | 1 year | 1 year |

*ASQ evaluation criteria groups: overall satisfaction, accessibility, check-in, passport control, security, finding your way, airport facilities, environment, arrival services

Table 6: Comparison of ASQ and ASI methods

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