ANALYSIS OF DESIGN AND CAPACITY BY ARRANGING THE FUNCTIONS IN SMALL SCALED AIRPORT TERMINAL BUILDING

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Statement of the problem. In this study, airports terminal buildings, the capacity of the airport terminal building, and the factors affected the capacity were searched. It was determined that the airport terminal building may vary and their spatial functions affect all airport functions. It was observed that any positive/negative change in the functions of terminal buildings affected the operation of terminal building. Method: A program was developed as a result of observations and studies while investigating the airport terminal buildings. Applicable regulations and the factors which negatively affect the capacity of the terminal, with improvements on the total capacity of the system were investigated.

Results. As a result of analysis with developed software, a different and theoretical perspective was developed to capacity calculation methods developed according to international standards referring to capacity accounts in the literature. With developed software, can calculate and be detailed necessary lower limits should be allowed variables to target the volume and capacity, new and different functioned terminal buildings were designed.

Conclusions. These terminal buildings just designed were evaluated by developed software and owing to that the most suitable designing method found as spatial and functional for the airport terminal buildings.

Keywords: Airport Terminal Building; Design and Capacity; Computational Design.

Introduction

Airport terminals are structures that combine architecturally and engineering-wise complex systems. Therefore, the design of this type of structures requires meticulous study and analysis. The ATArch-A® software which is developed by the writers’ functions as a guide in im-
provement activities for present buildings as well as in the modeling of newly designed terminal buildings. When the structural features of the airport terminal building to be designed are fed into the ATArch-A software, data that can be used for the relevant design can be generated very fast. One of the most important of these data that are of interest to many researchers is those pertaining to the concept "Level of Service" (Correia and Wirasinghe, 2004). The ATArch-software calculates this concept rapidly and can offer suggestions for the improvement of a design. For example, the program can determine in terms of area of space the arrangements to be made to improve the ticket control area without changing the number of counters. In addition, it can immediately illustrate the outcome of a change in the number of counters without changing the size of the area in question. These operations can be run for the entrance control halls, departure hall entrance, or the circulation and waiting areas (Brunetta and Romanin-Jacur, 1999). The ATArch-software employs the IATA standards. When the space output is the level of service, it is possible to interpret the capacity conditions and even the appropriateness of the IATA standards. The program can present these in graphic form. It can also form the passenger arrival distribution by taking observational data as reference, and if necessary, its users can enter the passenger arrival data as they wish (according to a scenario). ATArch-A can digitize the luggage pick up area in the passenger arrival hall with respect to the IATA standards. It can take the passenger distribution graph and place it as photo file on the computer desktop. Taking as basis passenger characteristics and the distance that passengers cover between spaces, it can determine the average distance cover time of passengers. It can illustrate the effect of passenger characteristics on space. It can analyze the conditions of terminal used by passengers with different characteristics. ATArch-A can present passenger circulation conditions such as density and flow as output in a graphic screen and save it onto the desktop, as is the case with the other concepts. ATArch-A can show the accumulation of passengers getting of a bus and enter a hall in cases where tour operators carry large groups of passengers in more than ten tour busses and present relevant scenarios. With these features, ATArch-A is a software program with an algorithm that can form the parameters influencing airport terminal buildings with respect to IATA standards, that can guide architects and transportation engineers, and that can significantly contribute to the literature. With ATArch-A, it is possible to produce an airport terminal building architectural design in accordance with the right standards and scale. In the present study, different airport terminal building designs were formed and analyzed with ATArch-A®. These designs consist of airport terminal buildings that were “redesigned” by taking into consideration present concepts.
The results of the analyses revealed some space related needs that airport terminal buildings must meet. The basic aim was to determine some basic data that yield the functional and IATA standards for airport terminal buildings (de Neufville, R. and Odoni, 2003). Another aim was to use the analysis superiority of ATArch-A while determining immediately how a present design can be improved. First, an airport terminal building designed with a linear method was formed. After different scenarios were formed for the linear design, each was analyzed with ATArch-A. Despite September 11 2001, many international airports are operating close to capacity, a problem that is likely to become more acute given the projected long-term growth in air traffic of between 3 and 4 % per annum (ACIE, 2003). Much of the problem in the current design philosophy stems from the traditional view of airport buildings as "terminals". As such, an airport building is seen as the end (or beginning) of a passenger's journey and acts as a gateway to the surrounding city or community. According to the FAA Advisory Circular on Airport Master Plans in 1971; the objective of the Terminal Area Plan should be to achieve an acceptable balance between passenger convenience, operating efficiency, facility investment, and aesthetics... the terminal area should afford the passenger orderly and convenient progress from his (or her) automobile or public transportation through the terminal to the aircraft. Thus, the principal objective of an airport building (according to the Advisory Circular) is to provide a high level of convenience only for originating (and similarly, terminating) passengers. The FAA requires a single forecast, passengers enplaned annually, when producing a master plan. According to the Advisory Circular (FAA, 1985): "The idea is to forecast the different elements of aviation demand, compare that demand over time with the capacity of airports' various facilities, and to identify the time when new or expanded airport facilities may be necessary". The actual design of the airport buildings is often the responsibility of a single or a team of architects, who use different set of criteria to describe the objectives of the terminal area.

**Airport Design Concept**

A terminal building design can be categorized as one of four basic concepts or a variation or combination of them (Fig. 1).

Combinations and variations of terminal concepts often result from the changing conditions experience at an airport. An airport may have many types of passenger activity, varying from originating passengers using the full range of terminal services to passengers using limited services on passengers’ flights. The predominant type of activity usually affects the initial terminal concept selected. In time, the amount of traffic may increase, necessitating modification of the facilities.
Growth of aircraft size, a new combination of aircraft types serving the airport, or a change in the type of service may affect the suitability of the initial concepts. Combined concepts acquire some of the advantages and disadvantages of each basic concept used. A combination of concept types can be advantageous that costly modifications will be necessary to maintain the original concept. Particularly at high activity locations, a thorough analysis of the type of Airport terminal concept to be utilized at an airport should be conducted before a final decision is made. Initial evaluation efforts should narrow the choices down to two or more alternative schemes before development of preliminary layouts and drawings. The final choice should be made only after depth analyses are completed. Quantifiable aspects of each concept (walking distances, areas required, etc.) should be compared; efficiency studies of passenger and aircraft flows, ground vehicular movements, and operational/functional sequences conducted; and cost estimates do. In evaluating alternate terminal concepts and building designs, major consideration should be directed toward keeping passenger walking distances to a minimum. This is particularly important at locations where there is considerable transfer between aircrafts. Under these circumstances, walking distances become more time critical.

**Terminal Building Designed with Columns**

The linear design concept is a concept that expands in both directions and spreads from a central system. It consists of an air side (apron, runway, taxi roads, etc.) and land side, as well as systems that allow transport from and to the terminal. Usually, departing passengers and luggage actions are dealt with in the central area. Fig. 2 presents the function scheme of the linearly designed airport terminal building.
Fig. 2. Function scheme of terminal building designed with columns

The airport terminal building that is designed with this function scheme and the solution of which is produced with columns is given in Fig. 3.

Fig. 3. Plan of terminal building designed with columns

This design is problematic for airport terminal buildings because columns create problems in spaces where circulation is dense. The entrance control hall is designed as 60 m². It features 6
X-ray systems and 26 ticket control counters. As indicated in the plan, the columns will not only affect general passenger movement, but also the passengers that will line up in the ticket control area. At the entrance of the departure hall, there are 4 X-ray systems. In order to indicate the hall entrances, this area has been tried to be divided with screens. As in the ticket control area, the problems that the columns create for the lining up passengers can be observed in the plan. In the designed terminal building, passengers who leave the entrance area encounter the departure hall security control area. The ticket control points are situated parallel to the entrance axis. Although ample space has been left between the entrance-ticket control and departure hall, the column solution limits mobility. Moreover, the axis movements of passengers who head towards the rest area and passengers who come from the rest area can result in clashes in case of passenger density. The terminal building was analyzed with ATArch-A. Numbers at peak hours, passenger characteristics and other input components are presented in Table 1.

Table 1

<table>
<thead>
<tr>
<th>Ave. Waiting</th>
<th>PBPH</th>
<th>PPH</th>
<th>B</th>
<th>PC</th>
<th>EH-XRAY</th>
<th>BK</th>
<th>CHE-XRAY</th>
<th>Gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>21/35/19</td>
<td>97</td>
<td>105</td>
<td>L</td>
<td>75M/75Y/85N</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>24/40/21</td>
<td>198</td>
<td>210</td>
<td>N</td>
<td>80M/80Y/80N</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>25/45/23</td>
<td>255</td>
<td>270</td>
<td>N</td>
<td>85M/80Y/85N</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>27/50/25</td>
<td>303</td>
<td>321</td>
<td>N</td>
<td>90M/95Y/90N</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>30/55/27</td>
<td>415</td>
<td>439</td>
<td>H</td>
<td>75M/75Y/70N</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>7</td>
</tr>
</tbody>
</table>

The meanings/definitions of the abbreviations in the table are given below.

Table 2

<table>
<thead>
<tr>
<th>Ave. Waiting</th>
<th>the average waiting time of the passengers in the areas (E, average waiting time in the entrance control hall; TC, average waiting time at ticket control counters; CH, average waiting time in departure hall)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPH</td>
<td>number of passengers at peak hour</td>
</tr>
<tr>
<td>PBPH</td>
<td>number of passengers before peak hour</td>
</tr>
<tr>
<td>PC</td>
<td>Passenger characteristics</td>
</tr>
</tbody>
</table>
EH-XRAY  Number of active X-Ray systems in entrance control hall
TC      Number of open counters in ticket control area
CHE-XRAY Number of active X-Ray systems at the departure hall entrance
Gap     The time for passengers to add to each other in the areas
M       Percentage of male passengers
Y       Percentage of young passengers
N       Percentage of passengers of normal weight
B       Passenger luggage carrying condition
L       Passengers with little luggage (Passengers with only hand luggage)
N       Passengers with normal luggage (1 and/or 2 pieces)
H       Passengers with normal luggage (1 and/or 2 pieces)

The distances between spaces (entrance control hall-ticket control, ticket control-departure hall) were determined, and when the data were separately fed to the ATArch-A environment, Fig. 4 emerged.

When the data were fed to ATArch-A, the program indicated the time to cover the distances between the spaces as process time. However, when the passenger arrival times were analyzed with data of previous observations that were stored in the database of ATArch-A, the graphical distribution given in Figure 4 was obtained. In addition, the user can enter passenger arrival distributions. As seen in Fig. 5, hourly passenger data can be entered.
Instead of manual feeding of hourly passenger distributions, the percentage of passengers using online check-in can be entered as well. While performing analyses with ATArch-A, many algorithms overlap with each other. One of the most important design problems in terminal buildings is function complexity. Therefore, it is important to know how different functions will operate with respect to their practical value. While designing airport terminal buildings, especially the characteristics of passengers need to be considered. The ATArch-A software includes a passenger characteristics menu which displays the effects of passengers’ physical conditions on the space. In addition, the passengers’ family rate option was developed for manual feeding of passenger arrival distribution. This option was developed as a result of observations conducted at airports. It was seen that passengers line up at the entrance control hall, ticket control counters, or departure hall entrances. Especially at the ticket control counters, passengers’ line up one after another. However, observation revealed that some passenger groups did not line up behind another but next to another, which is related to the family or group phenomenon. This queuing form is presented in Fig. 6.
When passengers line up in groups or as a family, they prefer to wait next to rather than behind each other. This changes the line length and waiting time because while one family member has their ticket checked at the counter and is waiting for it to finish, the other members wait right by their side at the counter as well. This is also often the case when tour operators come with large groups of passengers. Only one person or the tour leader deals with the procedures of passengers from the same country while the others stand around and wait in scattered fashion instead of a straight line, which can affect the line length in front of the counter. To address this situation, the “Family Rate” variable of the ATArch-A was developed to ask for the group percentage of the group in the number of passengers. For example, if this is entered as 20%, 1 in 5 passengers will be counted as family. The family rate analysis is the calculation of process time of the group procedures, which is different than the process time calculation of separate passengers. As it will change the length of the line formed behind the counter, it is an important input variable. On the second page of ATArch-A, where the user can enter the passenger distribution, the percentage of passengers using online check-in, and the family rate, it is also possible to determine the percentage of passengers that will head to spaces. In the “Areas” module, the ratio of passengers that will also use the 3 different spaces (entrance control hall, ticket control area, and departure hall entrance) they are moving toward can be indicated. After the data are entered, ATArch-A can produce the graph for the passenger distribution as the user wishes, as in Fig. 7.

![Fig. 7. Revised ATArch-A analysis of passenger arrival distribution for terminal building with columns](image)

The determined values were fed to the ATArch-A analysis resulting in Fig. 8. In the ATArch-A screen view presented in Fig. 8, it is observed that the size of the area in m² allocated to the different spaces is sufficient, and that the entrance control hall and the ticket control areas are sufficient when the algorithm between the number of passengers and the space, and the IATA data are considered. The departure hall entrance is of B Level of Service,
which is adequate by IATA standards. If the user wishes to change the space inputs, ATArch-A defines the necessary area as shown in Fig. 9 to increase its level to A.

![Fig. 8. ATArch-A analysis for terminal building with columns](image)

![Fig. 9. Service level analysis for terminal building designed with columns](image)

Furthermore, ATArch-A analyzes passengers’ queuing conditions. It uses Fruin (1971) analysis for passengers that line up one behind another (Fig. 10). When ATArch-A forms this algorithm, it calculates the sizes of the passenger according to the accepted values of Fruin (1971). Based on this, ATArch-A can calculate the length of passenger lines with the assumption that passengers line up one behind another in a single line without distorting it. By this way it is possible to calculate the maximum possible length of the line and to design the spaces accor-
dingly. As Figure 11 shows that when the number of entrance X-ray systems is reduced to 2, the level of service instantly drops to “C” level.

![Fig. 10. Fruin human movement and ATArch-A accepted values](image)

![Fig. 11. ATArch-A line length analysis](image)

In addition to the decrease in level of service, the maximum waiting times also change. The same algorithm operates in the same manner for the other spaces. Moreover, by changing the operating counters or X-ray systems in the ATArch-A capacity interface, the level of service can be immediately analyzed (Fig. 12).

In the capacity interface, ATArch-A analyzes passenger flow conditions and performs graphical analyses (Fig. 13) by using speed, average density, and space width. This analysis of ATArch-A is usually employed in the design of circulation spaces.
ATArch-A analyzes the terminal building system solved with columns with the interface it develops. The analyzed circulation space is shown in Fig. 14.

In this space, the circulation areas are assumed to be the area between the columns because especially passengers walking in groups (crowds) tend to identify an axis for themselves and to proceed along that axis (Teknomo, 2008). As observed, in circulation systems designed with columns, flow and level of service are lower due to square meter area limitations because columns are situated within the circulation area, take up space, and reduce the circulation area in square meter.
Terminal Building Designed without Columns

In another terminal building design, where the linear design logic and function scheme were kept identical, especially the circulation spaces and the spaces with high passenger density were totally designed without columns (Fig. 15). This design is the main concept of especially recently designed airports (such as Beijing Airport, China).

Fig. 15. Plan of terminal building designed without columns

In the circulation system solved without columns, the seating areas were assumed to be located in the farthest point. The other spaces remain in the same place, and only the circulation area expanded. The relationship between the circulation spaces with and without columns is as in Fig. 16.

The solution with columns here is not like a real solution; instead of columns, barriers or seats could stand as well. What follows from this is similar to the result in Figure 4.90 revealed with ATArch-A analysis. In the comparison presented in Figure 16, the width of the first circulation space was assumed to be 7.5 meters. ATArch-A assumed the number of passengers to use this space as the 150 passengers that ATArch-A assumed to go to ticket control at peak hour, and the 142 passengers before peak hour. This assumption is based on the theory in the work of Hsu and Chao (2005) that states that the passengers using the circulation space consist for the most part of those that spread from the ticket control area.
On the other hand, speed is taken as the average speed that ATArch-A determines according to passenger characteristics. In the circulation space without columns presented in Fig. 16, the width of the space is taken as 30 meters, though with the same number of passengers. The graphic analysis and interface screen of ATArch-A for these conditions are shown in Fig. 17.

The first blue line on the ATArch-A capacity screen shows the passenger flow and arrival distribution graph to occur in the circulation space with columns. In the red graph, the same pas-
senger distribution and passenger density was taken, and flow was observed to increase only due to the expansion in circulation space. In the graph that ATArch-A produced, the passenger arrival intervals are divided into 7 parts (Fig. 18).

![Division of Passenger Arrival Interval](image)

**Fig. 18.** Passenger arrival intervals for ATArch-A analysis

Thus, ATArch-A can calculate hourly passenger flow. When the problems that a linearly designed airport system will cause in the circulation are considered, a solution without columns was determined. Additionally, the location of seating groups in a linear terminal system is quite important. Whether a space will be divided into seating groups or not, or whether the seating groups will be solved in an expandable space or not is an issue that should not be ignored in the design of terminals. In Fig. 19, the seating groups are placed in the circulation space but close to the departure hall entrance. The possible results of this placement can be analyzed with ATArch-A.

![Strategy for seating group placement in terminal building -A](image)

**Fig. 19.** Strategy for seating group placement in terminal building -A
The values for the peak hour passenger numbers were entered for ATArch-A. Distances, especially distance to departure hall entrance, and line lengths probable to occur were analyzed. The determined flight is as in Table 3.

<table>
<thead>
<tr>
<th>Ave.Waiting E/TC/CH</th>
<th>PBPH</th>
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<th>BK</th>
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</table>

Here, the average waiting times in spaces, number of passenger at and before peak hour, open ticket control counters and X-ray systems, and passenger addition times are listed. Data related to entrance control hall were not considered as they are directly relevant to the space to be analyzed, departure hall entrance, and ticket control space. The ATArch-A analysis is given in Fig. 20.

As the ATArch-An analysis show, when peak hour passenger numbers are entered, the minimum ticket control line length becomes 16 meters and the departure hall line length 38 meters. While no problem is observed in the ticket control area, the departure hall level of service is found to be “F”. If one more X-ray system is opened under these conditions, this level rises to “B” and the minimum line length drops to 25 meters (Fig. 21).
When all the data and the designed plan strategy are considered, Fig. 22 emerges.

As can be seen in the sketch, the queue prolongs into the waiting area, substantially obstructing the circulation area. It is possible to prevent this obstruction by means of making walkways, which is to be implemented in front of the departure hall. However, locating seating groups in front of the departure hall is regarded as an architectural design mistake in terms of functionality. Having determined that the seating groups cannot be located in front of the departure hall, the fact that, in several small-scale and medium-scale airports, the waiting area is located in front of the check-in counter needs to be further analyzed. As can be seen in Fig. 23, seating groups are located within the circulation space, yet near the check-in counters. Designed as “Strategy B”, this is a commonly used method. The front of the departure hall in Strategy “A” is left empty in this design.
Considering that the flight data belonging to the previous strategy was used, ATArch-A is expected to reach the previously done analyses. However, the previous analysis is based on when all 5 check-in counters are open. The possible queue length and service level when less than 5 counters are open is to be effective in deciding whether or not to choose this design (Fig. 24).
As can be seen in the ATArch-A analysis, the service level decreases as the number of ticket counters decreases, leading to longer queues. Possible lengths of queues that may occur in such a case are marked on the sketch, and this region is labeled “check-in activity area”. It has been observed that the absence of seating groups within the activity range of check-in counters is significant for the service quality and queue length. Thus, seating groups (regardless of how many there are) should not be organized in front of the check-in counters. If there is such a restriction, that is, if seating groups should be eliminated from in front of the check-in counters because of insufficient space, the place of seating groups should be arranged based on sound observation of the peak time of passengers using a particular airport. This analysis clearly demonstrates that placement of check-in area in the circulation area may bring about problems as to the queue axis. The main rationale is that it should not have any effect on the circulation area. However, when the check-in counter-desks are placed in this way, the queues may stretch up to the entrance of departure hall, causing congestion and several inconveniences. Determination of the location of certain spaces in a terminal design is critical because there is a direct relation between these spaces. Therefore, especially the main spaces (check-in lounge, check-in point and departure hall entrance) should be dealt with considering the interaction between them. The place of check-in counters, as well as other spaces, should be carefully designed, especially in large-scale airports. After all, check-in area is where passengers have to wait and are delayed most commonly. The location of this area determines its efficiency. The situation of certain service points where the average time individual or group passengers spend to receive service is important because it has a direct effect in increasing or decreasing this average time. In addition, the distance between the entrance control point through which a passenger passes with her/his luggage and the closest check-in desk up to which s/he has to walk with his luggage has to be kept at minimum. The check-in counter is an actively operating space. It is important that the passengers’ movement area not restricted because of irregular opening and closing of counters and changing of line-up paths according to volume of passengers. Fig. 25 exemplifies the way check-in counter can be situated in the terminal building. The layout plan displayed by the image is the most commonly used design in today’s airport systems. It is widely accepted that this plan allows for more orderly queuing of passengers and, because such queuing has a vertical impact on the circulation, it does not cause the problems in the other layouts. In addition, this will help the sustainability of systems for separating and conveying baggage, and their secure transportation. Replication of ATArch-A analysis with the same number of passengers and data results in Fig. 26.
When the ticket control space is solved as in Fig. 26, it will have designed its “own space”. When enough of space is saved for check-in activity area, the circulation of passengers will not be prevented. Provided that the number of check-in in ticket control area is kept constant, this can be analyzed as in Fig. 27.
When the arrangement of check-in counters is done as in Fig. 27, it should cover the whole space and placed linearly (Fruin, 1971). IATA attributes the necessity of this linear placement to many factors, the most important one of which is the need to camouflage the luggage flow. That is why, such mistakes occur in some small terminals. On the other hand, undefined spaces form right along the luggage flow camouflage line, which the passengers cannot use. Regardless of whether they are linear type, pier type, or other concept, the situation of check-in counter desks is significant for passenger-flow. Accordingly, designers and some international institutions (FAA, 1983; ICAO, 1987; FAA, 1997; ICAO, 2004) have developed standard design forms. However, ATArch-A analyses show that where and how to design it is directly related with the number and characteristics of the passengers that are to use an airport. Among the check-in counters, the most different design method is the "island type" check-in counter. It is generally seen in large scale linear terminal buildings. Indeed, it is seen in centralized linear type terminals. If each check-in counter island is situated parallel to the direction of passengers’ flow through terminal entrance control hall, it means 10—20 separate check-in counters on each side. The desks on each side of the check-in island stand back to back, each having a luggage conveyor below. The suggested distance between two islands is 24—26 meters (IATA, 1995a). Also, there must be information boards and screens for ticketing processes in front of each check-in desk. Each check-in island is marked with a number or letter (IATA, 1995b). And sometimes, the area between two islands is numbered. The island type check-in counter space is shown in Fig. 28.
In this design, circulation area has to form behind the check-in counters in the island type ticket control space. The passengers are directed from this circulation space to departure hall. Fig. 29 displays the ATArch-A analysis. Here, the walking distance of the circulation area is taken as 5 meters, and the walking pace is taken as 0.71 m/sec. Circulation area was doubled, and passengers’ pace was taken as 0.91 m/sec. The average pace was taken as 0.71 m/sec in a 5-meter circulation space and as 0.91 m/sec in a 10 meter circulation space due to the average passenger pace found in observations of two corridors that are of similar type.

The flow analysis shows that the biggest disadvantage of island designs is that it leads to a problematic space behind the check-in place during group check-in. The passengers head from spacious places towards narrower places, which hinder the passenger flow. The entrance control hall was also analyzed in the same design concept. Figure 30 presents entrance control halls designed with two different concepts.

Design-1 is a design which becomes progressively wider from the terminal entrance towards x-ray area in the entrance control hall, whereas design-2 is one which becomes progressively narrower from the terminal entrance towards x-ray area. The square meters are set in these
designs. All one has to do for a ATArch-A analysis is to upload the same number of passengers in both designs and enter the data set for spaces to ATArch-A. These data are displayed in Table 4.

**Fig. 29.** ATArch-A flow analysis of Island type check-in counters

**Fig. 30.** Entrance control halls designed with two different concepts

<table>
<thead>
<tr>
<th>Ave.Wait</th>
<th>PSOY</th>
<th>PSY</th>
<th>B</th>
<th>YK</th>
<th>G-XRAY</th>
<th>Gap</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>303</td>
<td>321</td>
<td>N</td>
<td>90E/95G/90N</td>
<td>3/2</td>
<td>7</td>
</tr>
</tbody>
</table>
Fig. 31 presents the ATArch-A analysis.

ATArch-A analysis reveals that service level in design-1 is “A”, whereas it is “F” in design-2. This was mainly caused by the fact that one of the x-ray appliances in design-2 could not be used due to a design related reason. Because of this, although there are three x-ray appliances, only two of them are in use. X-ray appliances solved with columns (e.g., columns placed adjacent to column pillows, or those obstructed by something placed in front) are a few examples to such wrong applications. What is more, in design-1, the whole space area is 90 m². Here 30 m² is spared to the x-ray, with a remaining area of 60 m², which is left for possible formation of queues. However, in design-2, the whole area is 60 m². Here, 20 m² is spared for the x-ray, leaving 40 m² for possible queues. Because of this, it is crucial that the entrance control halls be solved by a rather flat geometry or by a concept that gets wider inwards for the smooth operating of entrance control hall. In addition, as soon as one x-ray appliance was activated, the service level in the space changes, which was shown by ATArch-A. Leaving from this, implementation of architecture that can expand or allows for potential expansion is crucial for smooth running of the terminal building. After examining architectural structures built with linear design concept, the "pier type" terminal was designed. Many presently used terminal designs were examined to establish a common ground for the pier type terminal design. The analysis screen shows that entrance control hall is insufficient and it is about to get congested. It further shows that departure hall entrance area is also congested, that the flow has completely stopped, and that the level of service is unacceptable. Moreover, the analysis
made considering the passenger characteristics from the entrance area to the ticket control point and from the ticket control point to the departure hall entrance indicates that the passengers cover the distances especially between the spaces in a short time as seen in Fig. 32.

Fig. 32. Time spent to cover the distances in the other terminal building

No matter how short it takes for the passengers to cover the distances between the spaces, the main spaces (entrance control hall, ticket control point and cleared hall entrance area) and the crowd that will gather at the entrances of the main spaces eliminate the advantage of shortening distances among the spaces and passengers’ covering the distances in a short time. Therefore, although it seems important to shorten the distances among the spaces, the arrangement of the spaces that particularly passengers have to visit before boarding the plane needs to be the central issue. Two different departure hall concepts are designed in the newly-designed terminal building complex. The designs can be seen in Fig. 33.

Fig. 33. Differences in the departure hall entrance area in the other terminal building
In the design of the other terminal building, symmetrical solutions were used on both sides along the entrance axis. In the design, the corridors were narrowed with stairs and projections, and the impact of this change on the flow was analyzed with ATArch-A. Fig. 34 shows the corridors that were first narrowed and then expanded.

![Fig. 34. Narrowed and expanded corridors in the other terminal building](image)

The flow in these corridor systems was analyzed via ATArch-A and presented in Fig. 35.

![Fig. 35. ATArch-A flow analysis for the circulation corridor in the other terminal building](image)
The results of the analysis indicate that the flow increases toward zone “z”. Considering the fact that this situation will lead to problems particularly when the number of passengers is vast, passing directly through “z” space rather than through “x” and “y” spaces would ease the flow. In addition to these analysis, ATArch-A can also analyze the values for the service level in the departure hall and the space where arriving passengers pick up their luggage. The ATArch-A screen view seen in Figure 36 forms an algorithm with respect to the standards determined by FAA and IATA and can predict such features as the service level of the space.

Fig. 36. ATArch-A analysis for the other spaces

ATArch-A, which makes the analysis of the departure hall based on FAA standards and the calculations by forming algorithm, can reveal the necessary square meter per space after the required service level is chosen. Furthermore, ATArch-A can measure the service level of the area where arriving passengers pick up their luggage taking the number of open conveyors and passengers and square meter into account. Accordingly, in case service level is inadequate, it may be changed by increasing the number of the conveyors. ATArch-A, which can analyze the main spaces, can also analyze the auxiliary spaces with respect to the standards.

One of the auxiliary spaces is the passport control. As in the other spaces, ATArch-A can analyze the level of service in passport control area and calculate the waiting time of the passengers in present conditions. Based on the results of the analysis, the number of passport control points may be increased.

Results

Airports are the structures that are usually built under government guarantee. Based on the predictions made by ACI in 1998, it was stipulated that a 350 billion-dollar investment is necessary in the air transport industry (TRBNRC, 2010). Such an economic burden causes coun-
tries all around the world to make such investments cautiously and to keep them under control. Moreover, gradually escalating international air traffic has increased the competition among the countries (Pearce, 2015). Apart from the international competition, the most important characteristics of airports are the passengers. The facilities for passengers and passengers’ being able to leave the airport without any problems, safely and quickly are the essential features that must be present in terminal buildings. At airports which experience complexities in functions, numeric values gain considerable importance. Moreover, numerical analysis (monitoring, counting, data collection, etc.) of the people that use the building is of importance. When some data are acquired numerically, it will be more realistic to present quantitative solutions about the building during both the design and revision stages. If numerical data are obtained, necessities regarding the size, location and practices suitable for the purpose of the building can completely be satisfied. Size suitable for the purpose of the building brings with itself adequate and essential space design construct. Location serving the purpose helps optimally determines where and how spaces will be located and prevents complexities in functions. Practices suitable for the purpose, on the other hand, make it easier to reach everybody, and thus, the (in) accessibility of some spaces is determined. Such features enable to reveal the alternatives that are important to solve the common problems encountered in terminal buildings. In the present study, terminal buildings were redesigned in line with the present terminal concepts. Observational data indicate that knowing only about the peak hour passenger number does not have a meaning per se. It is necessary to find out both peak hour and pre-peak hour passenger number at the same time. A distance between these two data sets is not realistic. Therefore, pre-peak hour passenger number is as important as peak hour passenger number. ATArch-A is the first software in airport capacity analysis that functions with respect to architectural functions and the analysis of the capacity. The results obtained from the analysis may be used in the analysis of the capacity of terminal buildings. ATArch-A is a highly significant software in terms of management since it aims the effective use of airport terminal buildings. One of the fundamental shortcomings of terminal buildings is the lack of adequate connection among the terminal spaces. Thus, ATArch-A was developed to provide an insight into the modeling of the spaces through the analyses it conducts. Compared to other analysis software, ATArch-A can produce instant responses. Moreover, ATArch-A can be updated based on changing factors and conditions. Given the ineffectiveness and defectiveness of the present airport designs, the model and the software that were developed for airport terminal buildings are of great significance for capacity planning and for the improvement of the designs.
Conclusion
This study develops an algorithm for capacity analysis through the analysis of data such as related literature, and data belong to movements of about 20,000 passengers including waiting periods, walking axis, and transition time between spaces. This algorithm is transferred into a software program named as ATArch-A. Although the software is a capacity analysis program, it provides a significant analysis and synthesis potentiality for the designers. It is designed of different terminal building plans with the software program, and it is tried to be determined of effective and profitable spaces within the buildings. The newly designed terminal buildings are analyzed and interpreted in terms of spaces and architecture quality from the service level and capacity through the ATArch-A program. The model has also the potential to guide designers for developing different airport terminal architecture. It is particularly significant of being a guide for analyzing airport terminal buildings apart from the common or familiar architectural typologies. Moreover, if the model can be enhanced and improved, it will be applied for other transportation buildings.

Recommendations for future works
The study aims to not only analyzing terminal building capacity but also developing a reference source within the literature in terms of terminal building design and spatial analysis. The model and the developed software have the potential to produce and enhance quick response systems for congestion and chaotic situations if it is integrated with automation systems. For instance, a system which monitoring the check-in desks, and detecting the congestion quickly within the queue in terms of expanding queue length in order to inform the general automation system as soon as possible for mobilizing the other check-in desk automatically. It is important to integrate the automation system with the software program for enhancing the reliability and originality of the model. Further studies need to focus on this integration works. In that sense, it is believed that such enhancements are needed to develop more effective and sustainable design facilitators for terminal building design among the related literature.

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