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Dynamic and static analysis of Airport capacity
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Abstract

The objective of this paper is to compare two methods of airport capacity analysis: Static Analysis and Dynamic Analysis. For this purpose, the two methods have been evaluated in two different scenarios, the first one related to normal operations and the other to an exceptional event. In the context of the coronavirus COVID-19 pandemic, they can be considered as coinciding with a "Pre-Covid" and a "Covid" scenario. Currently, the calculation of airport capacity is mostly linked to static analysis, a solid historical method, based on empirical formulas dictated by the International Air Transport Association (IATA). The dynamic analysis is a state-of-the-art method that uses software packages to simulate a great variety of non-ordinary situations by incorporating a wide range of information related to the specific case study such as airport layout, entry/exit routes, etc. Nevertheless, since it does not currently have specific guidelines, is still little used. The following study evaluates the two methods, highlighting their strengths and weaknesses.

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1. Introduction

The objective of this paper is to compare two methods of airport capacity analysis: Static Analysis and Dynamic Analysis. The capacity of an airport mainly depends on the capacity of its two most important areas, the landside and the airside. The following study focuses specifically on landside capacity. Landside is a complex collection of individual functional subsystems such as ground access, check-in area, baggage claim and support systems (such as water supply and power supply) that interact with each other. Landside capacity refers to the ability of these functional components to meet the demands of passengers, visitors, cargo, and aircraft (Andrew C. Lemer 1987).

Even though all ground components are important to the satisfactory operation of an airport, only few of them can become bottlenecks and cause crowding or delays. As specified by the Federal Aviation Administration (FAA)
the capacity of a single airport subsystem is independent from the capacity of the other ones and therefore this can be calculated separately (FAA 2007). However, if poorly designed or exposed to excessive high loads they can become constraints on landside capacity. Compared to the airside, airport landside capacity has no generally accepted guidelines (Transportation research board 1987). Software simulation packages or empirical manuals are the main methods to assess landside capacity. Software packages allow simulating a wide range of situations by incorporating many information as an airport's specific layout, entry and exit routes, queues, airport procedures, etc. (EUROCONTROL 2016)(Wibowo and Fadilah 2018). This simulation software packages allows industry organizations to analyze their services in a virtual environment, with the goal of optimizing cost and safety risk (FlexSim 2021) (Airport Research Center 2021).

Cost and time consumption are the disadvantages of the simulation: this is the reason why they are used in the advanced stages of the project when high computational accuracy is required. However, software packages could be essential to study special situations such as COVID-19 emergency management. Among empirical methods, on the other hand, the most widely used are the Federal Aviation Administration (FAA) guidelines and the International Air Transport Association (IATA) manuals (IATA 2019), (Di Mascio, Moretti, and Piacitelli 2020).

2. Methodology

2.1. Analysis and Scenarios

In this paper, Static and Dynamic analysis are illustrated and compared to calculate landside airport capacity. Static Analysis represents a historical procedure based on empirical formulas provided by IATA. Following the IATA guidelines (IATA and ACI 2017), the Level of Service (LoS) to be referred to for design is the Optimum one; setting this parameter means to design foreseeing stable flow conditions, few delays and a good comfort level (Heydemans and Sumabrata 2019). Once the OPTIMUM LoS has been set, two basic parameters are derived from the tables provided by IATA (IATA 2017a), the maximum waiting time and the minimum space required for each passenger. These values, together with other parameters (processing time, number of seats, number of greeters, etc.), represent the input data to be inserted within the IATA empirical formulas for the calculation of airport capacity. The output shows the minimum proportions to be allocated to each subsystem and the number of facilities required to provide an effective and efficient experience to the passengers.

For the dynamic analysis, the "PTV Viswalk" software has been used. This software has been chosen for several reasons:

- it is a well-known and recognized software in pedestrian simulation
- it allows to get a six months thesis license (this paper is a result of a thesis study)
- it is used by the consultant company (One Works) with which collaboration this paper has been carried out

PTV Viswalk performs the microscopic simulation of pedestrians analyzing the existing structure with obstacles or dangers and determining the maximum number of people it can contain (PTV GROUP 2018)(Heydemans and Sumabrata 2019). The PTV Viswalk software outputs a series of parameters including the maximum waiting time for a passenger queueing at a related subsystem and the space available for each one. These values, compared with the limit values (LoS OPTIMUM range) proposed by IATA, allow to optimally model the system. This study specifically deals with the issue of landside capacity assessment, covering all activities carried out by the passengers within the terminal, including security checks. For the capacity calculation, among all airport subsystems, this paper focus on:

- Departure hall
- Self-service check-in area
- Traditional check-in area
- Drop-off area
- Security control area
These components are defined by the Transport Research Board (TBR) study as the focus of most ground capacity evaluations (Andrew C. Lemer 1987). The purpose of this research is to highlight weaknesses and strengths of the two analyses. To this end, they were evaluated on two different scenarios:

- Scenario 1 represents the airport system in a normal operating situation
- Scenario 2 simulates the same system in an exceptional situation

Casting the two scenarios in the current pandemic reality, they have been renamed as "Pre-Covid Scenario" and "Covid Scenario". Nevertheless, the study is not exclusively related to the Covid-19 emergency but has a general character: by changing the boundary conditions, it is possible to simulate any other emergency case. In this paper, a medium-sized airport with average annual traffic of 20 million passengers and a Typical Peak Hour Passenger (TPHP) (Ashford, N. J. & Wright 1992) of 8000 Pax/hour (calculated using the method proposed by the FAA) (Denisiano 2017) has been considered. Based on these assumptions, the system was sized through the two survey methods. The second scenario, the Covid one, simulates the same system affected by an ongoing emergency. With the pandemic, it was necessary to introduce the constraint of physical distancing to ensure the safety and health of the individual and society. In this emergency situation, to eradicate the virus, all unnecessary travels were limited in the first place, this resulted in a 70% reduction of passengers compared to the previous year 2019 (EUROCONTROL 2020). It is expected that shortly will be able to start traveling again but it will still be necessary to perform health checks, respect physical distancing and hygiene rules. Therefore, this research aims to identify the maximum capacity that a medium size airport could meet, in compliance with Covid measures and without providing structural changes to the overall system. With this scope, a comparison between the static analysis and the dynamic analysis is proposed for each scenario.

2.2. Case study

In the first phase of the work, the reference scenario is of normal operation, which coincides with a Pre-covid scenario where restrictive measures are not included. The application study carried out in collaboration with One Works, a design and consulting company, has started with the implementation of an algorithm in Excel for the static analysis. The second step was the calculation of the same capacity with the method of dynamic analysis and with the support of the software "PTV Viswalk". The objective of the first phase was to highlight strengths and weaknesses of the two analyses on a situation of normal operation. As an example, the procedure of the static analysis referring to the area of the traditional check-in desks is shown. Sizing the area of traditional check-in desks involves calculating the number of workstations and space requirements. The following parameters are used as input:

| Variable | Description | Value |
|----------|-------------|-------|
| PK       | Peak of passengers in the 30 minutes (in % di PHP) | 75%   |
| P(Y/J/f) | Proportion of passengers Economy(Y) /Business/J) First class(f) (% di PHP) | Y J f |
| CR       | Percentage of users of Check-in traditional desks | 90% 5% 5% |
| PT(Y/J/f) | Passenger processing time at Check-in desks for: Economy/Business/first Class (sec/pax) | 120 120 120 |
| MQT(Y/J/f) | Maximum waiting time for class passengers: Economy/Business/first Class (minute) | 20 5 3 |
| CDd      | Depth of check in desk (m) | 6.5   |
| CDw      | Width of check-in desk (m) | 2     |
| W        | Width of corridor behind counter (m) | 0     |
| SP       | Space for person (mq) | 1.5   |
In the table, it is noted that the peak of passengers in the 30 minutes is set at 75%. Normally this value range between 65% and 85%, bigger is the size of the airport and more distributed is the traffic during the day. This value was also compared with the information included in the company's databases.

The passengers' profile, such for instance the proportion of passengers among the various classes, the percentage of users using each subsystem (e.g., check-in, baggage drop, etc.), the process time at the different subsystem are set employing the parameters included in "One Works" database.

The remaining values proposed in the table are recommended by IATA and given in the description sheets of the functional subsystems.

The analysis involves four steps: (IATA 2017b)

- Calculation of the approximate number of desks for economy (1), business (2) and first (3) class:

\[
CD_y = \frac{DPHP \cdot PK \cdot (1 - P_f - P_{J}) \cdot CR \cdot \frac{PT_y}{60}}{30 + MQT_y}
\]

(1)

\[
CD_J = \frac{DPHP \cdot PK \cdot P_f \cdot CR \cdot \frac{PT_J}{60}}{30 + MQT_J}
\]

(2)

\[
CD_f = \frac{DPHP \cdot PK \cdot P_f \cdot CR \cdot \frac{PT_f}{60}}{30 + MQT_f}
\]

(3)

The number of desks required for each class results in 78 desks for economy class and 7 desks for business and first class, respectively. A total of 92 desks.

- Correction of the approximate number of desks:

\[
CD = CD_{y, J, f} \cdot Cf
\]

(4)

The approximate values are given a correction factor \((Cf)\) which takes account of the variability of passenger arrivals during the peak period and depends on the maximum waiting time in the passenger queue.

The total number of desks required increases to 95.

- Maximum number of passengers in queue:

\[
Q_{MAX} = Qf \cdot Peak \ 30 - min
\]

(5)

Using this formula, the number of passengers, depending on their class, queuing in front of the check-in desks is estimated. For economy class, the number of passengers expected to queue in the 30-minute peak is 804, for business class 20 and for first-class 13.
From this expression, it is obtained that to carry out the services optimally, with allowable space and waiting times, the hall must have a size of 2491 square meters. The same work was carried out using the formulas provided by IATA, to dimension the remaining subsystems. Through the static analysis, the actual landside capacity was determined, and the various subsystems were sized. Based on this analysis, the dynamic analysis was carried out to optimize the results obtained from the first one.

The first step was to sketch the airport layout focusing on the subsystems included in this study. The figure below shows the PTV Viswalk plan with the various subsystems identified in different colors.

![Figure 1. Plan of airport in PTV Viswalk](image)

After defining the traffic composition, "Static pedestrian routes" and "Partial Pedestrian routes" were set for each class. The Static Pedestrian routes represent the generic route of the passenger, with an origin in the point of generation of the flows and a destination in the final point of their route (where passengers exit from the network). The partial routes define instead the single sub-choices of the route. After setting up the airport model on PTV Viswalk software, a series of simulation runs have been carried out. This approach takes into account the randomness of the flow in terms of number of passengers entering in the network. Below two images of the model implemented in PTV Viswalk, extracted during one of the simulations.

![Figure 2. (a) PTV Viswalk simulation; (b) Focus on Security Area](image)

The first simulation was carried out by placing in the model the number of facilities and the processing time parameters obtained from the static analysis. The dynamic analysis showed as some of the subsystems were overdesigned in terms of the number of facilities. Consequently, a series of other scenarios were simulated by...
varying the number of facilities to reach the optimal LoS for each subsystem. Below a table of the results of the static and dynamic analysis is shown.

| Subsystem               | Nº Facilities (Static analysis) | Reduction | Nº Facilities (Dynamic analysis) |
|-------------------------|---------------------------------|-----------|----------------------------------|
| Check-in business class | 8                               | 0         | 8                                |
| Check-in first class    | 9                               | 2         | 7                                |
| Check in economy class  | 78                              | 5         | 73                               |
| Drop off economy class  | 11                              | 3         | 8                                |
| Drop off economy class  | 2                               | 1         | 1                                |
| Check in Self-service   | 13                              | 1         | 12                               |
| Security lanes          | 22                              | 4         | 18                               |
| Departure Hall          | Optimum                         | -         | Over-design                      |

It is possible to note, by comparing the two analyses, that the most significant discrepancies concern:

- the departures hall
- the security area

The departure hall was sized using static analysis to achieve LoS Optimum. From the simulation carried out with the PTV Viswalk software, the subsystem was found to belong to the "Over-design" LoS. This result is justifiable considering that in the dynamic analysis, unlike the static analysis, the presence of any accompanying persons was not simulated. The inclusion of this parameter in the PTV Viswalk software would entail the definition of specific trajectories for visitors, who would have to accompany some of the passengers in their movements without carrying out boarding operations. The result would be the creation of a much more complex model: the construction and simulation of which would require longer timing analysis that is not in line with those available. For this reason, has been decided to not include this data in the dynamic analysis and only include the percentage of active passengers. Also, the software is used to assess and optimize the various subsystems, without considering any stops or loss of time by individual passengers. During the simulation, passengers use the Hall exclusively as a passageway to access the various subsystems. Thoughts on the area of the security instead regard the number of persons approaching the machine and the process time. The number of approach locations (i.e. where people undress) is not a parameter in the static analysis, where only the total length of the security aisle is included. The number of approach locations in the model indicates the number of passengers that can be processed at the same time. The second discrepancy between the two methods of analysis about the security area concerns the processing time, which in the static analysis indicates the efficiency of the machine (IATA 2017c) while in the dynamic analysis it is detailed in all the various steps, from the "undressing" of the passenger to the passage under the metal detector, to the "dressing" of the passenger.

Comparing the two analyses, it results that dynamic simulation approaches, while being very time consuming (Di Mascio, Moretti, and Piacitelli 2020), allow to get optimized results. This is a very important feature at a time when the need for efficiency at airports has never been greater, with security and labor costs continuing to increase each year (FlexSim 2021). Airport authorities need to ensure that costs associated with staffing, equipment, new technology are optimized, and dynamic simulations are the feasible alternative to faster spreadsheet-based forecasts.

The second phase of the work involved comparing static and dynamic analysis in a Covid scenario. To simulate the pandemic situation, it was necessary to introduce the constraint of physical distancing to ensure the safety of the individual and society. During the emergency period, to eradicate the virus, first, any unnecessary movement was limited. This resulted in a reduction of passengers compared to 2019 of about 70 % (EUROCONTROL 2020). As traffic is greatly reduced, compliance with Covid measures is easily ensured.
Shortly, it is expected that it will be possible to start traveling again but always in compliance with physical distancing and by performing health checks. The static analysis was therefore conducted trying to introduce the current restrictions (Airport Council International 2020) into the formulas proposed by IATA:

- The obligation to guarantee a space of at least 2 sqm per passenger in the departure hall.
- Where seats are present, the number of seats available to passengers has been halved to ensure free space between two occupied seats and thus the correct distance between passengers.

These constraints lead to the need for larger areas to serve passengers. The results of static analysis show that by introducing the Covid restrictions, the areas required to guarantee correct physical distancing exceed the extent of the areas provided during Pre-covid period: in the same area allocated to each subsystem, the number of passengers who can access them is lower. Through the static analysis, it was also possible to identify the threshold beyond which changes to the airport terminal layout would need to be made to increase airport capacity while complying with Covid regulations. The calculation was made by varying the percentage of passenger traffic from normal operating conditions. For each case, the size of the areas and the number of facilities were compared to be less than or equal to the reference values. It was found that, without making any changes to the system, a medium-sized airport can satisfy, passengers that an airport is able to process is 80%.

Therefore, the option of prohibiting access to the terminal for accompanying persons, except for accompanying minors and passengers with reduced mobility, was considered (Airport Milan Bergamo 2021) (Governo Italiano Presidenza del Consiglio dei ministri 2021). By introducing these considerations into the static analysis, the percentage of passengers that an airport is able to process is 80%.

Table 3: Outcomes due to the introduction of Covid restriction

|                          | Case 0: Normal operation | Case 1: 80% of Pre-Covid traffic with the introduction of restriction |
|--------------------------|--------------------------|---------------------------------------------------------------------|
| Departure Hall           |                          |                                                                     |
| n° pax                   | 1560                     | 1040                                                               |
| A (mq)                   | 2215.2                   | 2112                                                               |
| n° facilities            | 13                       | 10                                                                 |
| Check in Self-service    |                          |                                                                     |
| A (mq)                   | 68                       | 66                                                                 |
| n° facilities            | 93                       | 74                                                                 |
| Check-in                 |                          |                                                                     |
| A (mq)                   | 3209                     | 2894                                                               |
| Drop off                 |                          |                                                                     |
| n° facilities            | 11                       | 9                                                                  |
| A (mq)                   | 315                      | 279                                                                |
| Security control area    |                          |                                                                     |
| n° facilities            | 22                       | 17                                                                 |
| A (mq)                   | 1242                     | 1010                                                               |

Departure Hall considerations are the same as for the previous scenario. About the security area, the dynamic analysis shows that a higher number of lanes is necessary to process the total of passengers in compliance with Covid constraints. To ensure correct physical distancing, it was necessary to reduce the number of people approaching the machine per lane from 3 to 2. This parameter is not included in the formulas dictated by IATA, which are therefore not very performing in the case of an extraordinary situation such as the one in question. As far as the remaining subsystems are concerned, since the results of the static analysis are already at the limit of the Optimum range, possible variations are minimal: for instance, the closure of one of the check-in or drop-off desks would bring the subsystems into a Sub-Optimum LoS range.
3. Conclusion

The purpose of this research is comparing the two airport capacity analysis methods, by highlighting the strengths and weaknesses of each. With this purpose, the two analysis were evaluated in two different situations, a normal operation situation and an emergency one. From the results illustrated into the paper, it can be deduced that:

- Static analysis is a simple and clear tool to evaluate the behavior of the system during its peak period. In a situation of normal operations, this type of analysis can be usefully employed to identify and highlight the weak components of the system and to estimate the quality of the service provided. In an emergency, however, it is less efficient because, being based on empirical formulas, it is difficult to include specific parameters.
- The dynamic analysis, thanks to the monitoring of the entire passenger journey, allows the identification of temporary bottlenecks or localized overcrowding that may affect passenger comfort and safety during the journey regardless of the area allocated to the subsystems under examination. Cost and time consumption are the disadvantages of dynamic simulation approaches.

For the reasons listed, the two analyses are usually used in two different phases of the project: at an early stage, static analysis is preferred, while at a more advanced stage where specific points or areas of the layout need to be analyzed in detail, dynamic analysis is favorite. In conclusion, the research results show how the joint use of the two methodologies can allow to develop a correct and accurate analysis of any landside airport. The integration of the two analyses allows to make up for the shortcomings of each: the faster static analysis can be considered the starting point of the dynamic analysis. Following this scheme, it will be possible to optimize the results with minor time consuming.

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