Future airport concept

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Abstract—The continuous growth in air traffic is gradually exhausting available airport capacity. If the air traffic growth remains on the expected level, many of large world's airports would not be able to handle increased traffic demand if no radical solution is found. The environmental, political and economical constraints more then ever inhibit the construction of new runways or new airports. This paper aims to analyze the current approaches to capacity increase and tries to identify possible ways of solving the future airport capacity problem from global point of view.

I. INTRODUCTION

The major predictions about air traffic anticipate the annual growth in air travel close to five per cent. [1] That means that the air traffic would double in next fifteen years. One of the ambitious goals is to enable the Air Transport System to accommodate 3 times the volume of passengers, freight and air traffic by 2020 compared with 2000. [2]

Air traffic growth is traditionally outstripping airport capacity growth, especially in recent years. Airport capacity shortage is linked to economic, environmental, political and physical constraints which have hampered the efforts to increase airport capacity. The level of utilization on many major airports is approaching their ultimate capacity. Unless increased significantly, existing airport capacity would not be able to accommodate the expected growth of air traffic in the future.

II. INITIAL OBJECTIVE

The discrepancy between air traffic growth and airport capacity growth is an area of our research. The initial objective has been to investigate the possibilities to increase the airport capacity. Firstly we have decided to identify current concepts and try to think out new possible ideas to radically increase airport capacity.

III. STATE OF THE ART

Until the recent past the lack of airport capacity was often solved by simple extending the existing capacity. This was done by adding new runway or by reconstructing smaller airport to large international airport. According to today's constraints it was relatively simple solution. Today this way of capacity extension is becoming less and less possible and is often practically impossible. The environmental, political, physical and other constraints placed on the airports have significantly higher importance than in the past and they are seriously inhibiting the required capacity increase.

We have identified several methods or procedures which are already in use or which are under development in the world according to airport capacity increase. Many of them are related to the wake vortex induced separations issues. As an example we can mention few of them:
• Simultaneous Offset Instrument Approach
• Displaced runway threshold
• Landing aircraft and departure aircraft sequencing depending on weight.
• Wake vortex reduced separations

Wake vortex related problems are actually decreasing the capacity of final airspace and departure airspace since the wake vortices start to be significant when the aircraft is rolling and they disappear after the touch-down of the aircraft. Increasing the capacity of the final and departure airspace does not increase the runway capacity, neither apron /gate capacity or passenger terminal capacity. Therefore it just partially contributes to airport capacity. Additionally there might not be enough capacity gain from these solutions.

Another way how to increase the airport capacity is to increase runway throughput. This has been often done by construction of rapid exit taxiways which has significantly reduced runway occupancy time. We have not identified any further radical improvement in this area.

As a conclusion of our state of the art research phase we can say that we did not find any concrete new airport concept radically increasing the airport capacity.

IV. INNOVATIVE IDEAS

In parallel with identification of current capacity increasing concepts we have conducted the brainstorming to generate possible concepts to increase airport capacity. The concepts and ideas identified or encountered during this process were following:

• Turning runway
• Multilayer runway
• Breaking the constraints between terminals and runways - Airside-Landside Separation (ASLS)

A. Turning runway

Within this concept we investigated the possibility of gaining the capacity through the runway throughput. The main part was to propose special turning runway which would allow aircraft to start turn off the initial runway course at the higher speeds than today with the purpose of reducing the runway occupancy time.

B. Multilayer runway

In this concept we investigated the possibility to build second layer of runway over other runway or taxiway so that the traffic on second-layer runway will be independent to some extent from the lower runway system. This would bring the higher airport runway capacity at the same place without acquisition of additional land.

C. Breaking the constraints between terminals and runways/Airside-Landside Separation

The one of the key elements in this idea is the physical separation of the landside from the airside (ASLS) of the airport while at the same time connecting the two with the high-speed transport means. This might bring the terminal areas back to the city so that it will appear like the airport is in the city. The runways could be built far from the city, where the capacity extension constraints are significantly lower than those in the city area. It would be efficient to use existing remote airports around the city and to integrate them into the single airport system. This integration of the airports shall bring the global benefits in comparison to today's traditional isolated airport distribution and management.
This concept has shown the possibilities of offering significantly higher capacity increase than other concepts while respecting other constraints. The radical capacity increase would be made by using existing and building new runways and by integrated time management of the overall travel process. Additionally this solution would respect other important constraints such as costs, environment, safety and security. After proper selection we have decided to focus on this concept within this PhD research.

The motivation for this idea is based on several positive aspects which the concept might bring:

- **Time savings.** Part of the standard activities or processes the passenger has regularly to go through might be made in the train on the way to or from the airport. There would be time saved because of two processes running in parallel. Potential processes conducted in the train while traveling to the or from the airport can be passenger and baggage screening, passport control, passenger screening, baggage sorting, baggage claim, customs. The positive effect could be the passenger's perception that there is not that much waiting at departure and arrival and that he is constantly traveling.

- **Coordination.** The passenger and baggage transport would be coordinated already from the center of city of departure to the center of the city of destination. This might decrease the overall time of the passenger in the system in comparison with non-coordinated transport.

- **Security.** Some of the passenger facilities and areas could be put far from the runway areas which would result to general decrease of amount of objects and facilities at the airport as well as decreased complexity. This might have significant positive impact on increased security and reduction of security costs as well. Additionally the lower number of people at the airside might have positive impact on security.

- **Infrastructure.** If the landside areas are integrated in the city and shared among multiple airsides, there would be less infrastructure needed in general. Additionally there is already certain level of infrastructure in the city which might serve air passengers resulting in less new infrastructure built. In this case secondary and remote airports around the city could be used and their runways extended without requiring large landside infrastructure to be built at each airport and requiring only necessary airside infrastructure. If no existing airports can be used then new airports can be built but having only essential airside objects.

- **Door-to-door support.** The passenger and the luggage will be processed already in the city which might be closer to the passenger's starting point and therefore it would be a contribution to Door-to-Door concept.

- **Flight delay decrease.** The concept might decrease the number of flight delays due to the passenger late arrival. The passenger would become a part of the coordinated system much earlier than today principally in the city before traveling to actual airside. This could help better planning of the departure of the aircraft whereas earlier identification of certain problems might help to avoid the delay. In the CDM concept this may play important role.

- **Intermodality.** The very basics of the concept is the passenger travel to the airport using high speed ground transport means like for example high speed train and the mode change at the airside. The high speed transport means might be connected to the national network, so that passengers would be able to travel to the airport from longer distances changing the transport mode at the airside.

- **Road traffic decrease.** In the case of airside and landside connected with the high speed train there might be less road traffic towards the airside. This would release the highways coming to the airport, decrease the amount of required parking at the airport and decrease the car induced pollution at the airport. This might, as well, have positive impact on reducing traffic jams on normally saturated highways leading to airport.
• Security. The optimization of security within the whole process might lead to increased security level and overall decrease of related costs.

• Public transportation. Placing the landside to the city will enable people to travel from their starting point to the destination using only the public transportation. This could be advantageous for the people who do not have a car or do not want to use their car to travel to the airport. Additionally the people which do not want to use public transport could still use a taxi or a shuttle to get to the landside within the city which might cost significantly less than the taxi service from the city to the airport.

• Diverging traffic. In bad weather conditions in case of diverging flight there might be other airports integrated in the same system which may be able to accommodate diverging traffic and finally bring passengers to the same landside.

V. BREAKING THE CONSTRAINTS BETWEEN TERMINALS AND RUNWAYS / AIRSIDE-LANDSIDE SEPARATION (ASLS)

As mentioned before we have decided to make further research on the ASLS concept. As a next step we realized that firstly we need to understand the objects, processes and relations which are important for the airport capacity and secondly we need to have suitable definition of airport capacity which would help us to identify the problems and investigate the feasibility of ASLS concept.

So as to understand the objects, processes at the airport and relations among them, we have gathered the information from literature [3] [4] and other different sources into special tables, lists and diagrams.

A. Passenger and baggage flow
The identification of the objects and processes at the airport has led us to creation of the passenger and baggage flow diagram. This diagram shows the passenger and baggage travel process sequence from the beginning of the trip, through the departure airport, airspace, destination airport to the point of destination.

B. Actors and interests
After gaining the basic overview about the physical objects and processes at the airport we have looked on the different parties involved in air passenger travel, their interests and factors constraining these interests. This was as well to help us to identify which interests are similar and which are contradictory among which parties. The initial investigation brought up following table of interests and their possible constraints.

C. Factors related to passenger flow
One of the important things we have realized during our research was that the passenger as a customer with his/her needs and interests is the key element of the travel process. This has led us to the investigation which factors are affecting the air passenger travel. We have created an initial list of factors and variables which play important role for the existence and intensity of air passenger flow. In other words these factors can contribute to or prevent the passengers from travel.

D. Definition of airport capacity
The consequent step in our work was to find suitable definition of Airport Capacity. The common definitions can be divided into two groups. One is representing throughput point of view where the airport capacity can be defined as the rate at which aircraft can be brought into or out of the airfield, without considering any delay they might experience expressed in aircraft movements per hour. This definition assumes that aircraft will always be present waiting to take off or land, and capacity is measured in terms of the number of such operations that can be accomplished in a given period of time. Second definition is practical capacity and it is the number of operations (takeoffs and landings) that can be accommodated with no more than a given amount of delay, usually expressed in terms of maximum acceptable delay[4].
Generally there has been a lot of work done on capacity research and many models of the capacity have been developed. However these models and common definitions are mostly describing local capacity of a particular object like terminal airspace capacity models or airport airside capacity models and they are often ignoring the global approach. For our purposes we need to have a holistic view on the capacity of the airports. Therefore our aim in this research is to combine the knowledge from known models and to create a definition and corresponding model of the global capacity of airport network.

VI. METHODOLOGY

A. Abstraction

All the created tables, lists and diagrams as well as particular definitions found will serve us to develop our airport capacity definition. We believe that its development will lead us to create a kind of function, formula or system of formulas which will represent the airport capacity.

It shall be mathematical abstraction from what is happening at the airport from capacity point of view. This function will contain certain variables and parameters and could be very complex. In any case it would be a kind of logical structure which would then help us to assess the current capacity situation as a capacity baseline. This baseline would serve for the investigation and evaluation of the feasibility of concept of separating the air-side from the land-side and their integration in a system. More concretely we would like to implement certain changes to the current airport layout and by using our airport capacity definition and function to see what the impacts on the airport capacity are.

![Global Capacity Structure and Relations Scheme](image)

Fig. 7. Global capacity structure and relations scheme

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\text{Global Capacity} = f(C_E, C_{Ch2}, C_{A2}, C_{S2}, C_{G2}, C_{R2}, C_{AS})
\]

\[
\text{Local Capacity} = f(Pax/Time)
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B. Modeling

For the purpose of studying impact of our proposed changes to the system we plan to develop multi-agent model of airport network which would additionally to essential airport objects and processes contain as well the required parameters and variables from our capacity function. The reason why we identified that the airport system might be modeled as a multi-agent system is that it contains certain essential objects which act autonomously according to their own rules of behavior. The passengers are behaving independently despite the fact that we can often describe their flow with the queuing theory for example. The airports can be considered as autonomous subjects reacting to the air traffic demand. As well the airlines are autonomous and react to the outside activity by their rules of behavior. Therefore the whole system seems to act like a system of autonomous agents with certain characteristics of the behavior of each agent.

After initial search for suitable tool we have chosen the NetLogo. NetLogo is a cross-platform multi-agent programmable modeling environment for simulating natural and social phenomena. It is particularly well suited for modeling complex systems developing over time. Modelers can give instructions to hundreds or thousands of independent agents all operating concurrently. This makes it possible to explore the connection between the micro-level behavior of individuals and the macro-level patterns that emerge from the interaction of many individuals.

VII. CURRENT WORK

At this moment we are on the way of identifying the important elements for our capacity function. This might be a very complex problem. The first step will be identification of the static and dynamic elements within the part of the airport network system, let us say within landside terminal. Each element has its parameters which can describe its functioning. As well each element has certain relations with other elements in the system. All these elements, parameters and relations we would like to describe by mathematical model if possible. This mathematical approach will require an abstraction from the physical elements which we have schematically described in our diagram of passenger and baggage flow. Of course this approach will go much more into the detail. We expect that results of this modeling would bring the better understanding of the possibilities and possible next step in our airport capacity issues.

![Sample of Elements, Parameters and Relations Within the Transport System](image)

Fig. 8. Sample of elements, parameters and relations within the transport system

We are aware about the fact that the kind of function or model describing the functioning of the system can be very complex and therefore impossible to describe using simple mathematical tools. We consider possibility of describing the system by studying the behavior of the system as a complex system. This could lead us to determination of the parameters...
influencing the behavior of the system and the relation between the input parameter and resulting behavior of the system. Perhaps it will be possible for us to determine certain key criteria which would then describe the system.

Another possible way of looking on the flow of the passengers through the airport system is an analogy with fluid systems. When a fluid is flowing through a pipe or manifold, there is a force pushing the fluid through the manifold system and as well there is a drag of the fluid which compensates the force. Perhaps this analogy could be used to identify the behavior of passenger flow through the airport system.

VIII. FUTURE WORK

As mentioned before the first step is to have a suitable mathematical representation of the airport system with all required factors and constraints. Then we shall translate this model into the computer understandable form using the modeling software to be able to make simulations. Basic scenario for the simulations shall be the scenario representing the current system. This would provide us with capacity baseline assessment. Into the later scenarios we would integrate the principal parts of the ASLS concept so as to see the impact of the changes on the airport system and the resulting capacity. The results would be confronted with our capacity baseline so as to clarify the feasibility of our concept.

REFERENCES