Airport Ground Access and Egress Passenger Flow Model (AGAP)

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***Abstract*— The problems of airport landside capacity assessment are of industry-wide interest. Evaluation of landside capacity enables airport operators and airport designers to identify passenger and baggage flow bottlenecks, identify the primary cause of bottlenecks formation and take measures mitigating the impact of bottlenecks on the airport terminal operation.**

Many studies dealing with the problems of airport landside capacity are focused mainly on the processing part of the airport terminal and consider the airport terminal to be an isolated system. Even the most well known models of airport landside operations (e.g. PaxSim, SLAM, WITNESS, ARENA or EXTEND) are designed for simulating the passenger and baggage flows only between curb-side and apron. Although this approach provides valuable data concerning capacity, delays or processing bottlenecks, in some cases identified capacity constraints are only the symptoms of the actual problem. In order to discover the cause of the problem, it is necessary to consider the airport terminal as an integral part of much more complex regional, national or international transportation system.

This article reflects the above mentioned requirements and introduces an innovative approach to passenger and baggage flow simulation based on the fact that airport terminal is considered as an integral part of air passenger door-to-door transportation process.

Keywords-airport ground access; fast-time simulations; airport capacity enhancement; door-to-door transportation process.

I. INTRODUCTION

The air transport in Europe as well as worldwide has been undergoing a rapid and continuous growth in the recent years and it is anticipated that by 2030 there will be between 1.7 and 2.2 times the number of flights in Europe seen in 2007 [1]. One of the most serious problems of air traffic system that will have to be solved in the following years is the capacity issue, and that applies to both airports and airspace. The airports are generally considered as a principal constraint to traffic growth and increasing demand will definitely lead to congestion of airports and Terminal Manoeuvring Areas (TMAs) and to generation of delays. It is expected that despite planned airport infrastructure investments, in 2030, 19 European airports will be operating at full capacity eight hours a day, every day of the year and involving 50% of all flights each day. If the most challenging scenario is considered, there will be as much as 39 airports in Europe operating at their full capacity and involving as much as 70% of all flights [2].

However, this trend does not necessarily mean that duplication infrastructure will be required to accommodate the demand in 2030. Implementation of measures that lead to more efficient traffic flows and better utilisation of existing infrastructure (ACE, CDM, TAM etc.) seems to be the right approach for solving the current and future capacity issues. In fact, thanks to these measures the efficiency with which the physical infrastructure at airports is used is increasing significantly. Thus despite the absence of obvious investments such as new runways or terminal buildings the Europe's most congested airports keep their ability to accommodate the growing demand. Needless to point out that these airports have been considered as saturated for years [3].

However, the airside capacity is not the only problem the European airports currently face to. After September the 11th and after security alerts in UK during summer 2006, the airport security became a priority and it has affected passenger flows within the airport terminals. The security procedures that were introduced at European airports after summer 2006 caused the 35% dwell time increase [4]. However, the long queues at check-in counters and at security checkpoints are not the only issues the airport operators have to deal with. A large percentage of private vehicles access trips at many airports lead to congestion of airport access roads and car parks. Moreover, high share of individual car access trips has negative impact on the environment. At many airports, the ground access trips of private cars associated with the airport operation generate a greater share of air pollution than the aircraft movements [5].

In order to increase the capacity and thus keep the capability to accommodate the growing demand, 138 European airports reported that they are planning significant investments. If these plans can be delivered, these 138 airports in total projected that their capacity would be 41% higher in 2030 compared to 2007. These plans include investments in building new runways and in improving airside (taxiways, aprons etc.) and landside (passenger terminals etc.) infrastructure [2].

Despite the planned investments into airport infrastructure, the airports will become the principal bottleneck of the air transport network that will generate enormous delays and unaccommodated flight demand. It is anticipated that in 2030, the highly-congested air traffic network will generate 2.3 million of unaccommodated flights, which will be approximately 11% of the overall flight demand [2].

However, the headless investments into airport infrastructure do not seem to be the right solution of the capacity problems due to time and geographical flight demand imbalance. It is necessary to realize that the air transport is the subject of significant seasonal, daily and hourly demand fluctuations. It means that many airports are congested during traffic peaks but fairly deserted during times that are not so attractive for passengers. In other words, there are times of day when the traffic is very high and reaches critical hourly values for either the airside or landside (or both); these are called peak hours. Nevertheless, looking at the annual operation many airports can be far from hitting the line. The peak hours simply reveal the bottlenecks of airports. Moreover, thanks to the existence of geographical flight demand imbalance only top 133 out of more than 2000 European airports carry as much as 90% of the ECAC IFR traffic [6].

It means that there is a big mismatch between when and where the capacity is available, and when and where the demand is present. This leads to inefficient utilisation of the existing airport infrastructure. Taking this into account, the following methods have been identified as measures that could be potentially used for mitigating the effects of the congested European air transport network [2]:

- Schedule smoothing: Move flights to times of the day when more capacity is available.
- Alternative airports: Move excess traffic either to secondary or to regional airports.
- Larger aircraft: Use larger aircraft to reduce daily frequencies on congested airports.
- Investments into high-speed train networks: Replace busy, short-range airport pairs flights by high-speed train connections.
- Exploitation of benefits of SESAR: The SESAR programme will be making a major contribution to the efficiency of air traffic management in the 2020 – 2030 timeframe.

All the above listed methods consider air transport network as an isolated and independent transportation system and the problems of airport terminals and airport ground access are being underestimated. However, it is necessary to realize that due to physical and nuisance constraints the airports have been built far from city centres and their operations and consequently their competitiveness thus have always been dependent on ground transport modes connecting airports with urban areas. It means that air transport is by nature intermodal since all passengers or goods have to go from their origin point to the airport and from the airport to their destination point using ground transport modes [7]. For this reason, when dealing with airport capacity, it is necessary to consider all parts of the airport, i.e. airside (runways, taxiways and apron), landside (airport terminals) and airport ground access.

II. Innovative Approach to Airport Landside Capacity Assessment

As mentioned in the section I., the main problem of current measures that could be potentially used for mitigating the effects of the congested European air transport network is underestimation of the problems of airport terminals and airport ground access. Bearing in mind that both, terminals as well as airport ground access have direct influence on airport landside capacity we will mainly focus on addressing this issue in the following parts of this article.

Airport landside capacity assessment is very complex interdisciplinary problem that does not have a universal solution. Each airport has a specific infrastructure and is operated in a specific environment in terms of economic, geographic and demographic conditions. For this reason, it is not possible to define generic approach that could be used for assessing the landside capacity at any airport. This fact is reflected especially in the field of computer-based models of airport operations. Although these models are generally used for evaluation of the airport capacity, none of these models has attained the status of 'international standard' [8]. Summarizing the current status of the problems, the process of assessing the airport landside capacity is based on the set of general practices and recommendations concerning the aspects of airport operations that should be considered, and concerning the methods and tools that should be used.

The problems of airport landside capacity assessment are of industry-wide interest. Evaluation of landside capacity enables airport operators and airport designers to identify passenger and baggage flows bottlenecks, find the primary cause of the bottlenecks formation and take measures mitigating the impact of bottlenecks on the airport terminal operations. For this reason, the airport landside capacity evaluation should be an integral part of airport design and airport operations as it provides a solid base for continuous process of the airport capacity enhancement.

We have identified one principal issue in the research dealing with the problems of airport landside capacity assessment; it is the limited scope of landside capacity assessment studies. Many studies dealing with the problems of airport landside capacity are focused mainly on the processing part of the airport terminal and consider the airport terminal to be an isolated system. Although this approach provides valuable data concerning capacity, delays or processing bottlenecks, in some cases, identified capacity constraints are only the symptoms of the actual problem. In order to identify the cause of the problem, it is necessary to consider the airport terminal as an integral part of much more complex regional, national or international transportation system.

In order to solve the identified research issue, our research has been focused on investigation of the relationships between airport ground access/egress and terminal operations with a view to develop computer-based model that simulates traffic flows between passenger origin/destination and the airport.

As a result of our research and development activities a first beta version of Airport Ground Access and Egress Passenger Flow Model (AGAP) is presented in this article.

The AGAP model is a stochastic microscopic computer-based model that simulates entire airport access/egress related traffic within airport's catchment area. Its scope begins at the place of passenger's origin/destination and ends in the airport terminal. The AGAP model extends the capabilities of model simulating passenger and baggage flows in new terminal of Bratislava airport, which has been developed using PaxSim simulation tool.

Passenger movement Simulation System (PaxSim) is a set of software tools that enable simulation of passenger and baggage movements within an airport terminal and on the apron. PaxSim was developed by The Preston Group (later Preston Aviation Solutions, now Jeppesen), which is a leader in the development of advanced airspace and airport simulation, decision support and scheduling systems for the global aviation industry (The Preston Group also developed well known airside simulation tool TAAM).

PaxSim is a graphics-based computer program used for the fast-time simulation of airport landside operation. It processes information from flight schedules to determine number of arriving and departing passengers and daily distribution of traffic at the airport. PaxSim is microscopic simulation tool that allows simulating each passenger and baggage as individual objects, rather than modelling 'global' passenger flows. As PaxSim employs sophisticated algorithms of real passenger behaviour, the simulation outcomes reach a high level of conformity with real terminal operation [9].

AGAP model and PaxSim simulation model constitute a microscopic model for simulation of door-to-door passenger flows. This comprehensive simulation model enables to see the airport in the context of regional, national and international transportation network. Thanks to this approach, it is possible to analyse the interactions between traffic flows within airport's catchment area and passenger and baggage flows inside airport terminal building. This enables to identify potential capacity constraints outside the terminal building and perform comprehensive feasibility assessments of future airport ground access/egress concepts.

III. Airport Ground Access and Egress Passenger Flow Model

AGAP model has been developed using MS Excel and Visual Basic programming environment. The model enables to simulate passenger flows from the place of passenger's origin (home or office) to the airport and back. Thanks to this airport ground access/egress passenger flow model, it is possible to simulate passenger flows within the airport's catchment area to and from the airport and to investigate the interactions between airport ground access/egress and airport terminal operations.

Figure 1 depicts a flow chart of the algorithm used in the Airport Ground Access and Egress Passenger Flow model.

The Airport Ground Access and Egress Passenger Flow model is a stochastic microscopic computer-based model that simulates entire airport access/egress related traffic within airport's catchment area. Its scope begins at the place of passenger's origin/destination and ends in the airport terminal. The model consists of the following two modules:

- *Air passenger trips generation module:* This module is responsible for simulating the demand distribution within the airport's catchment area. Based on the input data this module allocates passengers to particular flights, generates passenger groups and passenger distribution to the cities within airport's catchment area.
- *Passenger transport mode choice module:* This module is responsible for simulating passenger airport ground access/egress mode choice. Based on outputs from air passenger trips generation module this module selects the most favourable airport access/egress transport mode taking into account price, travel time and convenience. This module employs algorithm of passenger behaviour.

A. Air passenger trips generation module

A flight schedule is the source of primary input data for generation the air passenger trips. Before the flight schedule can be imported into the AGAP model, it has to be supplemented by additional information and all the data needs to be pre-processed to ensure they are in correct format. A completed flight schedule contains the following information on each flight:

- Flight number
- Scheduled time of departure
- Actual time of departure
- Destination airports
- Operator
- Aircraft type
- Aircraft seat capacity
- Load factor
- Number of passengers
- Indication if flight is international or domestic
- Indication if flight is scheduled or charter
- Indication if flight's destination is a holiday resort
- Share of business passengers in flight
- Share of leisure passengers in flight
- Number of business passengers
- Number of leisure passengers

- Possible times of arrival (assuming that passenger uses services of same operator for both outbound and inbound flights)

Based on the information from the flight schedule (i.e. based on flight type, destination, aircraft capacity, load factor, and proportion of leisure and business passengers) the model allocates passengers to each particular flight. The characteristics related to passenger flows within airport's catchment area are then randomly generated and assigned to each passenger based on relevant probability distributions.

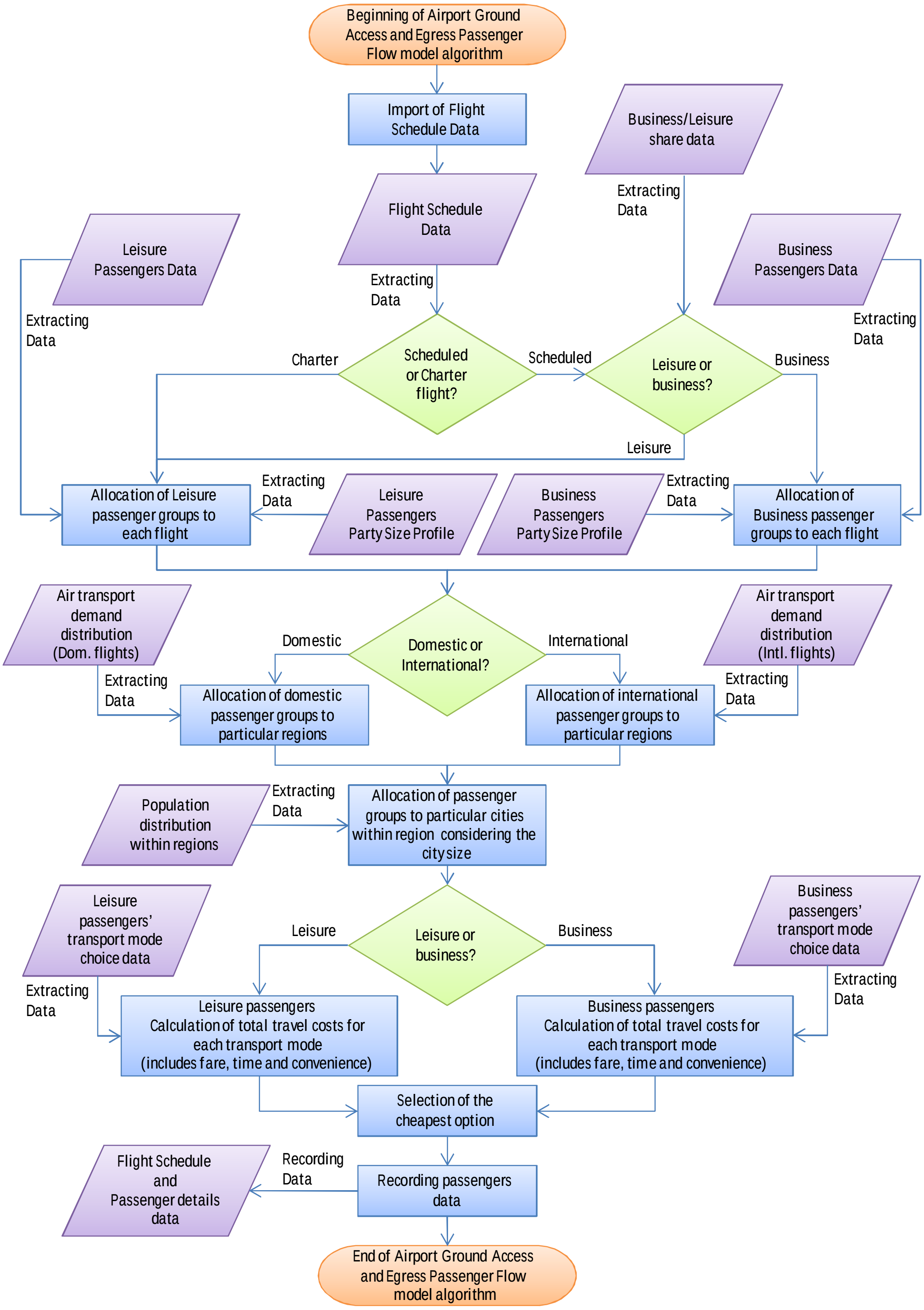

Figure 1: Airport Ground Access and Egress Passenger Flow model Algorithm

In the first step of the algorithm, the model generates the sizes of passenger groups. The air passengers often travel in groups of various sizes (e.g. families, couples, friends, business partners etc.). The group sizes are different for business and leisure passengers. Each passenger type has a probability distribution of the group size. These probability distributions are used to generate passenger groups for the flight. The algorithm generates the groups in the cycle until the number of passengers reaches the actual number of passengers in the each particular flight from the flight schedule.

In the second step, the model assigns the place of trip origin/destination to each group of passengers. The region of the trip origin/destination is randomly assigned to each passenger group based on probability distribution that reflects the distribution of air transport demand within the airport's catchment area. The city of the trip origin/destination is randomly assigned to each passenger group based on the population distribution within particular region. The assignment of region and city of passenger's origin/destination is proportional. It means that if a particular region has higher air transport demand than another one, the probability that the passengers are from this region is proportionally higher. Same analogy is used in the case of city assignment. It means that if a city within particular region has higher population than another one within the same region, the probability that the passengers are from this city is proportionally higher.

B. .Passenger transport mode choice module

The algorithm of passenger transport mode choice that is used in the AGAP model is based on evaluation of the perceived costs of each transport mode. Thanks to this approach, it is possible to consider both quantitative and qualitative factors influencing the passenger mode choice. The AGAP model automatically selects for each passenger the most favourable option in terms of price, travel time and convenience.

The perceived costs of transport consist of the financial costs, time costs and transfer costs. The financial costs represent the money value needed to get from the place of origin to the airport and back including all related charges such as parking fees in case of car transport etc. The time costs represent a perceived value of in-vehicle travel time and excess travel time (i.e. waiting, walking, transfer time, etc.). The transfer costs represent a perceived value of additional physical and cognitive effort resulting from the transfer, and perceived value of risk of missing the connection.

The AGAP model evaluates perceived costs of the following airport access/egress transport modes:

- Individual car – 'Kiss and drive':
- Individual car – 'Park and fly'
- Taxi
- Public city transport
- National public transport + Taxi
- National public transport + Public city transport

Before AGAP model starts to calculate the perceived costs for particular airport access/egress modes, it has to calculate distances, travel times, waiting times and number of transfers for each airport access/egress option.

In the case of access/egress trips by individual cars (i.e. 'Kiss and drive' and 'Park and fly'), model gathers all the required information regarding distances and travel times from the database containing comprehensive information on road network within airport's catchment area. The time when passenger arrives at the airport before STD (Scheduled Time of Departure) of his/her aircraft is randomly generated by the model using normal probability distribution. The time when passenger leaves the airport after ATA (Actual Time of Arrival) of his/her aircraft is defined by fixed value that is estimated based on analysis of the arrival processes at particular airport.

The information related to access/egress trips by taxi are calculated and processed using same approach as in the case of individual car trips. The only difference is that in the case of taxi trip, the model randomly generates time that passenger spends by waiting for a taxi.

The information regarding national/urban public transport between particular parts of catchment area and airport are gathered from the actual public transport timetable database. The public transport timetable database contains information regarding travel times, service frequency, departure/arrival times and number of transfers for all public transport connections within the airport catchment area. The model selects the most favourable outbound and inbound connections from the database, considering the following factors:

- Passenger's itinerary defined by departure/arrival time of his/her flight;
- Price of the connection;
- Total travel and waiting times;
- Number of transfers.

The time when passenger arrives at the airport before STD of his/her aircraft is given by the public transport itinerary of particular passenger. The time when passenger leaves the airport after ATD of his/her aircraft is given by the arriving processes at the particular airport and by time that passenger spends by waiting for the public transport connection (calculated based on the public transport itinerary).

When the model compiles a set of traffic flow related information (i.e. distances, travel times, waiting times, transfers, dwell times in terminal etc.) for each airport ground access/egress option considering a specific needs and requirements of each particular passenger, it is ready to calculate perceived costs. The value of perceived costs for all of above listed airport access/egress transport modes is calculated using the following equation (1).

$$Perceived\,Costs = Financial\,Costs + Time\,Costs + Transfer\,Costs \quad [Eur] \tag{1}$$

Assuming that airport access/egress ground transport mode with the lowest perceived costs would be the passenger's choice the AGAP model assigns the cheapest transport option to particular passenger.

The main data output from the Airport Ground Access and Egress Passenger Flow model is an Excel spreadsheet where the information about the passengers is stored. It includes the passenger ID number, place of origin, group size, transport time etc. The most important aggregate information includes:

- Total travel time
- Total distance travelled
- Travel costs
- Arrival earliness distribution of passengers

The travel time, distance travelled and travel costs are used as performance indicators necessary for the analysis of passenger flows within the airport catchment area and for comprehensive operational, economic and environmental assessment of the airport ground access/egress solutions. The arrival earliness pattern is key information for assessing the impact of airport ground access/egress on the airport terminal operations.

The capabilities of the AGAP model have been tested on the Bratislava airport case study. Using the AGAP and PaxSim models, we have compared current design of airport ground access/egress system at Bratislava airport with innovative concept based on dedicated minibus network serving the entire catchment area. The minibus network has been designed for collection, transportation and distribution of air passengers. Operation of minibuses within this network is based on the analogy of collection, transportation and distribution of consignments within express carriers' regional distribution network. This principle allows introducing a high-level coordination and synchronisation between air and ground transport. This airport access/egress concept is referred as *pick-up/drop-off concept* in further text.

The main aims of the Bratislava airport case study were to perform operational and environmental assessment of both airport ground access/egress concepts and to investigate their impact on passenger and baggage flows in the Bratislava airport terminal building.

IV. AGAP MODEL VALIDATION

During the design process of the model we have created a sample of 100 passengers (randomly generated). For these 100 passengers, we have calculated all the parameters manually (e.g. group size, place of origin/destination within airport's catchment area etc.). During entire development process the functionality and accuracy of the AGAP model has been verified using this testing sample of 100 passengers. Thanks to this verification process, we have reduced the probability of creating the software bugs.

In order to validate used algorithms and verify assumptions that have been taken into account the simulation results have been compared with actual operational data. The AGAP model validation showed that the simulation results approximate the real operations. The simulation results accuracy has been verified by means of the following parameters:

- Arrival earliness distribution of passengers (see Figure 2)
- Proportion of airport ground access/egress transport modes (see Figure 3)

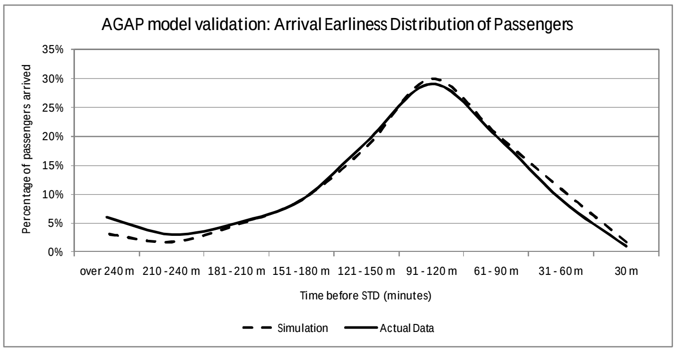

Figure 2: AGAP model validation: Arrival earliness distribution of passengers

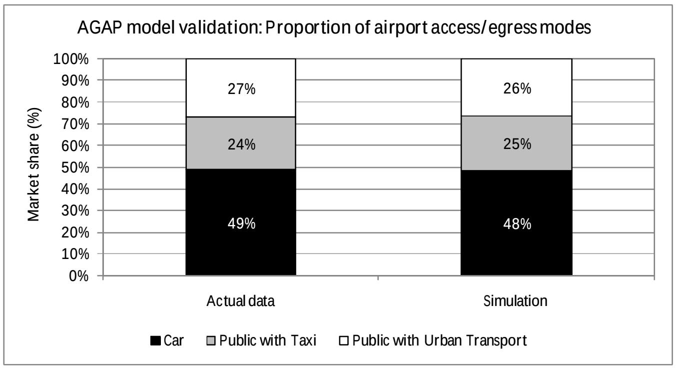

Figure 3: AGAP model validation: Proportion of airport access/egress transport modes

As can be seen from the charts the simulation results correspond to the actual operational data.

I. BRATISLAVA AIRPORT CASE STUDY

In order to perform operational and environmental assessment of the airport access/egress concept based on collection, transportation and distribution of passengers within dedicated minibus network, it was necessary to define simulation scenarios.

At this stage, our research did not focus on the traffic flows optimisation within dedicated minibus network. However, we assumed that by means of optimisation, it would be possible to achieve high load factors and consequently high efficiency of traffic flows.

In our study, we assumed that there is a reciprocal relationship between average minibus load factor and price per passenger-kilometre. This relationship is mathematically expressed by equation (2).

$$\underset{[EUR/pax.km]}{Minibus\ Dist.Rate} = \frac{\underset{[EUR/km]}{Price\ of\ minibus}}{\underset{[Number\ of\ Seats]}{Seat\ Capacity} \cdot \underset{[\%]}{Average\ Load\ Factor}} \qquad (2)$$

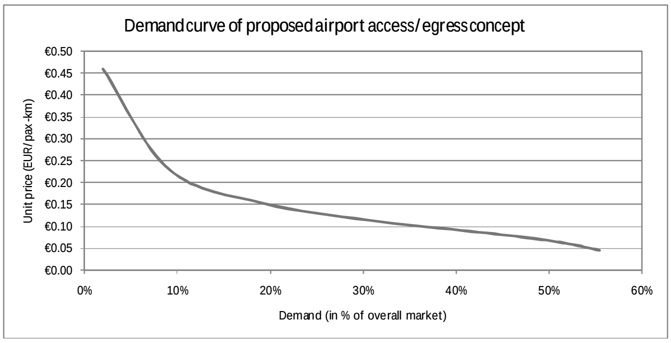

Figure 4: Pick-up/drop-off concept: Price elasticity of demand

The chart in Figure 4 demonstrates the price elasticity of demand for services associated with collection, transportation and distribution of air passengers.

As it has already been mentioned, average load factor is directly dependent on level of traffic flows optimisation within dedicated minibus network. For this reason, we decided to consider three various load factor values in our simulations, in order to answer the question, what average load factor needs to be achieved through traffic flows optimisation to make the proposed pick-up/drop-off concept viable.

In all 4 scenarios, we consider the traffic flows according to flight schedule from 8th July 2008 (the busiest day in 2008). According to data that were provided by Operation Division of Bratislava airport, 49 arrivals and 45 departures of commercial passenger aircraft took place at Bratislava airport on 8th July 2008. These aircraft movements generated passenger flows of 5,497 departing and 5,900 arriving passengers, who passed through the terminal at Bratislava airport on that particular day. On 8th July, share of leisure passengers was 73% and share of business passengers was 27%.

For the purposes of operational and environmental assessment of the proposed pick-up/drop-off concept, we have defined the following 4 scenarios:

- **Baseline scenario:** This scenario considers current status of ground access/egress at Bratislava airport, without any coordination between air and ground transport.
- **Scenario40:** This scenario assumes that the proposed pick-up/drop-off concept has been introduced at Bratislava airport. This scenario also assumes that by means of traffic flows optimisation, 40% average load factor has been achieved across entire dedicated minibus network.
- **Scenario60:** This scenario assumes that the proposed pick-up/drop-off concept has been introduced at Bratislava airport. This scenario also assumes that by means of traffic flows optimisation, 60% average load factor has been achieved across entire dedicated minibus network.
- **Scenario 80:** This scenario assumes that the proposed pick-up/drop-off concept has been introduced at Bratislava airport. This scenario also assumes that by means of traffic flows optimisation, 80% average load factor has been achieved across entire dedicated minibus network.

For all 4 simulation scenarios, we assumed the following configuration of passenger and baggage processing facilities in the Bratislava airport terminal:

- **Check-in resources:** In all scenarios, we assumed 15 check-in counters opened and operated using the common check-in concept (i.e. passenger can check at any counter). In the case the baggage check-in is considered to be an integral part of the proposed pick-up/drop-off concept, 5 counters are used for self-service drop-off and 10 counters are used for classic check-in.
- **Security checks:** In all scenarios, we assumed 4 central security checkpoints to be in operation.
- **Departure passport control:** In all scenarios, we assumed 4 departure passport control counters to be in operation.
- **Arrival passport control:** In all scenarios, we assumed 4 arrival passport control counters to be in operation.
- **Baggage carousels:** In all scenarios: we assumed that 4 baggage carousels in main terminal building, and 2 baggage carousels in arrival terminal C are in operation.

In order to achieve results reflecting actual operation, we have run each scenario three times. Considering the fact that during each simulation, the AGAP model generates unique passenger sample, each scenario has been simulated and analysed using three different passenger samples. Average values of the particular outputs of these three iterations were then calculated and consequently used for further analyses.

II. SIMULATION RESULTS

A. *Market shares of the proposed pick-up/drop-off concept and other transport modes*

This part is aimed at analysing the impact of proposed pick-up/drop-off concept on the overall efficiency of traffic flows within airport's catchment area.

The introduction of synchronised and coordinated airport ground access/egress is anticipated to primarily influence the proportion of particular transport modes used by air passengers. One of the principle targets of air-ground intermodality is to reduce share of individual car access/egress trips.

Proposed pick-up/drop-off concept significantly reduces market share of other airport access/egress modes. It means that pick-up/drop-off concept is able to compete with both individual and public airport access/egress transport modes. It is necessary to point out that proposed concept does not serve city of Bratislava, which is estimated to generate as much as 34.5% of the overall passenger throughput at Bratislava airport.

The simulation also showed that proposed pick-up/drop-off concept would be as attractive for leisure passengers as for business passengers:

- **Scenario40:** 29.9% of leisure passengers and 32.1% of business passengers would use the services of dedicated minibus network to travel to/from the airport.
- **Scenario60:** 47.0% of leisure passengers and 47.0% of business passengers would use the services of dedicated minibus network to travel to/from the airport.
- **Scenario80:** 53.2% of leisure passengers and 52.8% of business passengers would use the services of dedicated minibus network to travel to/from the airport.

B. *Traffic flows efficiency*

The simulation results also proved that proposed pick-up/drop-off concept would have a positive impact on efficiency of traffic flows within airport's catchment area. The introduction of the pick-up/drop-off concept into operation would lead to reduction of wasted times related to travelling to/from the airport including passenger dwell times in terminal. In comparison with baseline scenario, the average wasted times related to outbound trips would be reduced by 15.6% in the case of Scenario40, by 24.9% in the case of Scenario60, and by 26.3% in the case of Scenario80. The average wasted times related to inbound trips would be reduced by 10.6% in the case of Scenario40, by 16.7% in the case of Scenario60 and by 16.3% in the case of Scenario80.

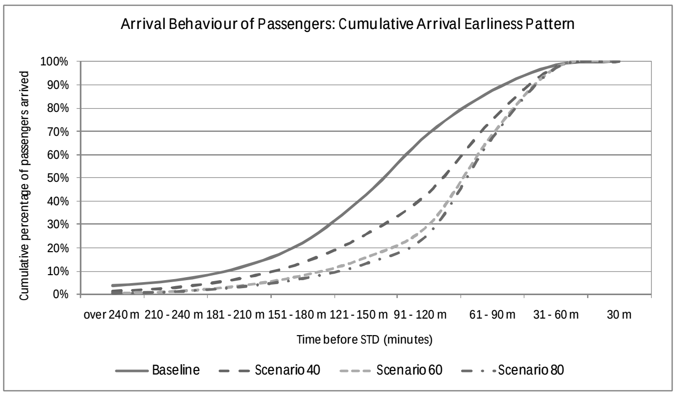

Figure 5: Cumulative arrival earliness distribution of passengers according to particular simulation scenarios.

The chart in Figure 5 depicts how the proposed pick-up/drop-off concept would contribute to the reduction of passenger dwell times in airport terminal. According to simulation outputs, in the case of Scenario40, the departing passengers would spend 23.5% less time in the airport terminal compared to baseline. In the case of Scenario60, the dwell time reduction would be 35.8%, and in the case of Scenario 80, it would be as much as 38.7%.

The fact that proposed pick-up/drop-off concept would considerably contribute to increased efficiency of door-to-door transportation is reflected in a significant reduction of average number of transfers per access/egress trip. The average number of transfers per access/egress trips would be reduced by 44.1% compared to baseline in the case of Scenario40, by 69.0% in the case of Scenario60, and by 72.0% in the case of Scenario80.

On the other hand, faster and more convenient transport mode would be more expensive in terms of direct financial costs. However, the advantages in terms of convenience and time savings surpass higher travel costs. It means that proposed pick-up/drop-off concept is still cheaper in terms of perceived costs.

C. *Environmental assessment*

The simulation results that has been analysed in previous chapters proved that the proposed pick-up/drop-off concept is able to compete with private cars in terms of travelling speed and convenience, and thus contribute to the reduction of share of individual car access/egress trips. Consequently, if the proposed pick-up/drop-off concept reaches certain market share it could also contribute to the reduction of air pollution related to ground traffic generated by the airport.

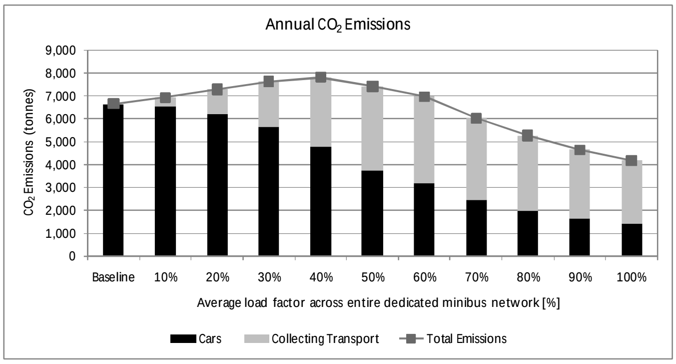

Figure 6: Annual CO2 emissions caused by individual car access trips and by dedicated minibus network operation

However, the fast-time simulation of traffic flows within airport's catchment area showed that significant reduction in CO_2 and SO_2 emissions (for CO_2 see Figure 6) would be achieved only if average load factor reaches 70%. In terms of NO_x emissions, the introduction of the proposed airport access/egress mode would lead to their increase regardless the minibus traffic flows efficiency. This results from the fact that diesel minibuses produce significantly more NO_x emissions compared to commonly used cars. On the other hand, we expect that even lower intensive utilisation of minibus fleet would contribute to reduction of local air pollution related to cold starts of private cars.

D. *Airport terminal operations*

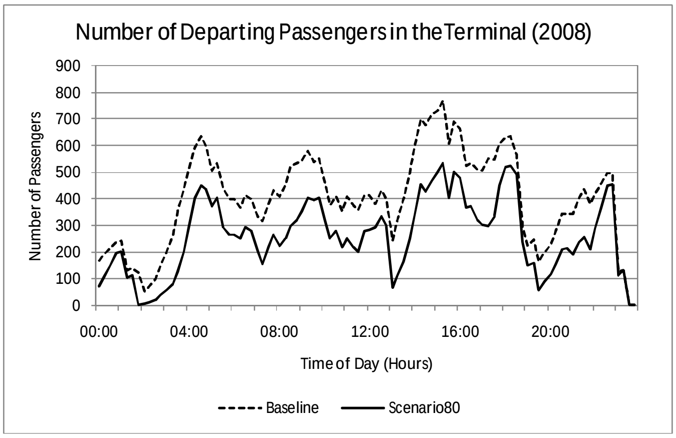

Figure 7: Number of departing passengers in airport terminal building during the day

Fewer passengers in terminal pose fewer requirements on the size of the airport terminal building and thus increasing investment efficiency. According to the simulation outputs, introduction of synchronisation between airport ground access and airport traffic would lead to significant reduction of number of departing passengers in the terminal. In the case of Scenario40, the average number of departing passengers in the terminal would be 21.0% lower compared to baseline. In the case of Scenario60, the average number of departing passengers would be reduced by 33.0%, and in the case of Scenario60, the average number of departing passengers would be reduced by as much as 35.7% (for baseline and Scenario 80 see Figure 7).

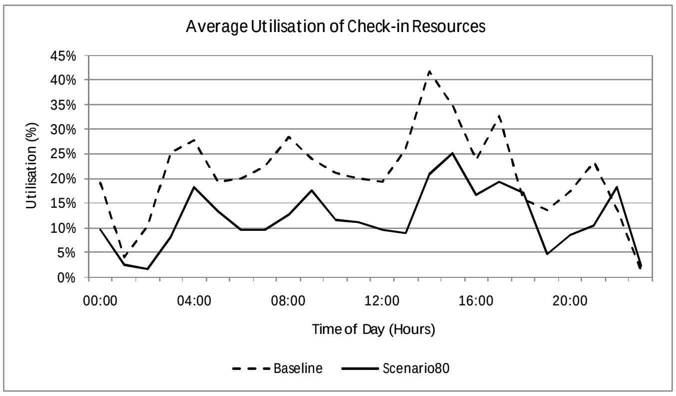

Figure 8: Average utilization of check-in resources

The average utilisation of terminal processing resources would only be affected if the baggage check-in is an integral part of the proposed pick-up/drop-off concept. Moreover, this applies only to utilisation of check-in resources. The impact of the pick-up/drop-off concept on utilisation of other processing facilities is insignificant. According to simulation results, if the baggage check-in is an integral part of the proposed pick-up/drop-off concept, it would be possible to handle same number of passengers using 25.4% less check-in resources in the case of Scenario40, 37.8% less check-in resources in the case of Scenario60, and 43.2% less check-in resources in the case of Scenario80 (for baseline and Scenario 80 see Figure 8).

The impact of the proposed pick-up/drop-off concept on other terminal processing facilities (i.e. security checks, passport control counters, etc.) is insignificant.

III. CONCLUSIONS

This paper describes and demonstrates a new method for evaluating the capacity of airport terminals as well as for operational and environmental assessment of airport ground access/egress system. This new method is based on fast-time simulation of door-to-door passenger flows and thus enables to see the airport terminal as an integral part of regional, national or international transportation network. Thanks to this fact, it is possible to analyse the interactions between airport ground access/egress and passenger and baggage flows inside airport terminal building. The new method reveals an innovative approach to performing comprehensive operational and environmental assessments of future airport ground access/egress concepts.

Using this new approach, we have performed an operational and environmental assessment of innovative airport access/egress concept based on the intermodality principles that are widely used within integrated intermodal networks of parcel companies. Thanks to microscopic simulation of door-to-door passenger flows we were able to conduct initial feasibility assessment of the proposed pick-up/drop-off concept and identify its potential benefits.

IV. FUTURE WORK

At this stage of research and development it is not possible to use developed simulation models as decision making support tools in real operations. It is necessary to perform a more comprehensive validation of outputs.

Within further research, we will also focus on the following issues:

- Development of more sophisticated algorithms of passenger transport mode choice (e.g. current model assigns each passenger with the cheapest transport option, which does not fully reflect the actual passenger preferences);
- Integration of algorithms reflecting the probability of delay in both, air and ground transport.

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