A SIMULATION MODEL TO QUANTIFY PERTURBATION EFFECTS OF AIRPORT INFRASTRUCTURES IN AIR CARGO HANDLING OPERATIONS

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ABSTRACT

The optimisation and proper coordination of air cargo transport operations taking into account infrastructure capacity constraints (i.e., interactio of taxiways with pathways), as well as passenger and airline quality factors is considered nowadays a complex problem to be solved that could contribute to a better competitivity of the industrial sector.

The variety of processes, methods, individuals and organizations, in combination with a lack of methodologies to analyze the behavior of the whole airport operation as a combination of the decision taken in each subsystem (ie. handling, airline and airport managers), are one of the main risks that deals with airport and airline delays which have severe cost penalties.

In this paper, a simulation model that considers as a hard constraint the airport dwell time of low cost carriers together with uncertainties in the platform pathways to transport the cargo form the airport warehouse till the aircraft parking to load ULD pallets in the first belly has been implemented. Different policies have been implemented to minimize the handling resources required to satisfy the cargo operations for 4 European destinations.

1. INTRODUCTION

Current scenario in production and logistic fields shows globalization, needs for fast, low cost and reliable transport systems that could provide a competitive answer to fluctuations in market demands.

A particular logistic configuration that relies on an effective but also on a low cost transport system, is the well known supply chain organization, in which competitiveness and profitability require an efficient flexible transport infrastructure.

Low cost air carriers have irrupted in major airline market by offering reduced price air tickets to passengers. Originally these players focused on just serving the ‘‘visiting friends and relatives’’ and the ‘‘ethnic’’ markets, but some of them are changing to embrace more business travelers.

In order to offer competitive travel prices, routes are designed at strategical level to maximize the number of legs per day an aircraft can serve. A critical controllable aspect that can affect drastically at operational level the quality of service of these legs to be flown are the delays generated at the arrival/departure and the turn-a-round time in airports.

The growth in air travel is outstripping the capacity of the airport and air traffic control (ATC) system, resulting in increasing congestion and delays. However, a misunderstanding of the poor utilization of the available infrastructure usually leads to greater investments in additional gates, runways and extensive pavements for taxiways and aprons. In order to avoid this expensive approach, it is important to remove non-productive operations due to poor scheduling approaches.

Different kind of perturbations such as: weather, traffic congestion in some air traffic sectors, and late departures at the origin airport, leads to a typical time window predictibility around [+15 .. -15] minutes with respect to the expected arrival time for more than 40% of the landing operation along the day.

In (Zuñiga, 2010) and (Narciso 2009) two different DES models to minimize delays in the arrival procedures are described. Despite the technological advances in air navigation and the airport manager efforts, such as the well known CDM (Collaborative Decision Making) procedures to minimize delay propagations (Piera 2009), airlines feel weak to preserve route time-tables due to a lack of control on airport infrastructure priorization management rules and handling resources. This is one of the main reasons why low cost air carriers try to minimize/avoid those handling operations that could be a source of delays.

Some aspects that should be considered in a simulation model to design policies to mitigate the propagation of perturbations through the airport subsystems are those involved in the turn-a-round aircraft operation:

- The amount of baggage to be transported by the different handling companies at the different aircrafts that must share the airport pathways at a certain time window.

- The airport pathways capacity to support the movement of handling mobile resources at a certain time window.

- The physical distribution of the parking points (remote and contact points) : Bottlenecks in some pathways affects drastically the handling transport time.

From transport theory, it is well accepted that the speed of mobile handling resources (tracks, air stairs, tow, fuel tracks, buses, push backs, etc) in the airport pathways platform can be maintained around 30 km/h only if the number of resources do not exceed a certain amount of vehicles which can saturate the pathways and force a low average speed around 5 – 10 km/h. Figure 1 shows a typical airport pathway speed profile, in which the exact figure will depends on the characteristics of the airport, the distance from the terminal to the aircrafts parking positions, the interaction between the taxiways and the pathways, etc.

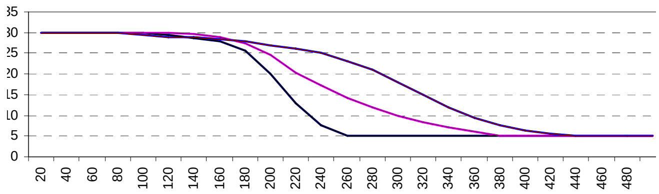

Figure 1: Speed versus Traffic in airport pathways

Despite airport managers try constantly to avoid the saturation of the platform pathways, most slots are concentrated in certain time window periods in which all aircrafts must be attended at the same time, which forces the use of all handling resources to be placed on time in order to avoid any delay in the aircraft turn-a-round time.

On the other hand, the possibility to assign contact positions (ie. fingers) instead of remote parking positions to the scheduled aircrafts is an important factor to reduce the number of mobile handling resources in the airport pathways. Note that 2 air stairs and 2 buses are mandatory to attend passengers of low cost carrier's aircrafts such as A320, B737 when they are assigned to a remote point.

The handling traffic required to attend the aircrafts for a certain period can not always be predicted since it varies according to the number of gates successfully assigned (Narciso 2009) and the amount of luggage's to be transported. On the other hand, the time required for each handling resource to reach the parking position of the aircraft depends also on the amount of mobile resources in the pathways and the interaction between the pathways and the taxiways.

To avoid that these uncertainties could affect the aircraft dwell time in the airport, most handling companies increases the number of resources to be sure that the aircraft will be served at the right time, despite the idleness of their resources is also increased.

In this paper a simulation model that considers the number of extra handling teams to attend at the right time the load/unload cargo operation of the first belly without affecting the rest of handling operations required by the aircraft has been developed at macro level considering the different transport time perturbations.

In section II some characteristics of air cargo operations are introduced. Section III describes the main advantages and handicaps of regional and international airports to implement a low cost cargo operation. In Section IV a case study that considers 4 different destinations from Bcn airport is analyzed.

2. LOW COST CARGO COMPLEXITY

Airline charging costs to first luggage policy contributes to minimize handling operations and at the same time minimize the turn-a-round time in these airports in which luggage transport times from the terminal until the contact or remote parking point is subject of stochastic perturbations due to a lack of capacity in the airport pathways (ie. constant bottlenecks in peak hours).

As a consequence, the first belly of most low cost air carriers flies fully empty. On the other side, logistics operators (ie. OPL) tackle many loosely connected heterogeneous sets of actors, such as suppliers, factories, production firms, warehouses, distribution companies, transport and service providers, retailers, customers and so on to satisfy customer demands under a certain quality service factor and costs. Figure 2 shows a typical sequence of activities to fulfill air transport using cargo aircrafts

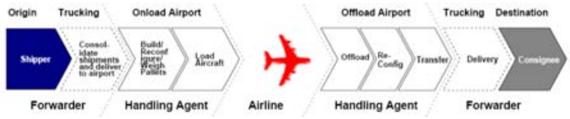

Figure 2: Air cargo activities

To be able to re-use for cargo purposes the first belly of low cost air carriers, it is very important to avoid delay propagation in the airport operations. A deep knowledge about all the events that take place and their interactions in each phase is important. Thus, by considering the Ground Phase, the turn-around handling operations can be formalized as a set of interrelated events which, properly coordinated, will satisfy the aircraft operative needs under certain service quality factors (SQF). With a proper model specification considering its interactions with the shipper the land transport and the cargo receiver, it will be possible to optimize operation efficiency through the proper management of airport re-sources (e.g. airport slots, stands and gates, check-in desks and baggage belts), considering the dynamics and costs of the cargo handling operations.

In the particular case of turn-around operations, it is easy to understand the system dynamics from a discrete event system approach, in which each operation has a certain number of preconditions, duration time estimation, and a set of post-conditions (changes in the state of airport information).

There are several characteristic of the described system that force the development of new methods (Piera 2004) to improve the air cargo operations, such as:

- A hierarchical network-based structure in which decisions at a certain level are propagated upstream and downstream.
- A large number of decision variables which increases the computational

- complexity to deal with an optimal scheduling.

- Emergent dynamics appear when the system behaves as a whole and cannot always be predicted if the interaction between the different subsystems is not considered.

- Multiple performance measures use to force a trade-off solution instead of a global optimal solution.

- The stochastic nature of the arrival and departure times due to atmospheric perturbations is considered a constant source of perturbations.

3. REGIONAL AIRPORTS VS INTERNATIONAL AIRPORTS

Figure 3 shows a layout of Alguaire Airport which is located near by Lleida city in Spain. The runway capacity is below 14 operation/hour but terminal capacity constrains to a maximum of 3 operation/hour.

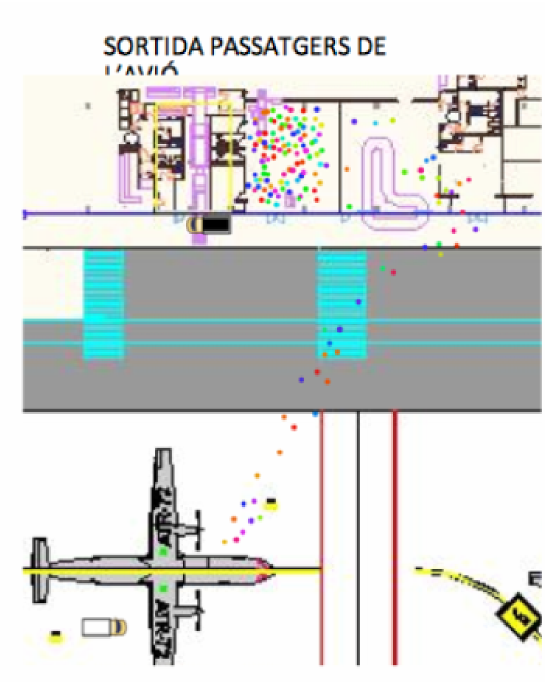

Figure 3: Aircraft parking position at a regional airport.

Now a day, there are 2 low cost carriers that operate in Alguaire airport with 2 scheduled operations in the morning and 2 in the afternoon. Aircrafts are parked just few meters from the terminal, thus passengers walk from the terminal to the aircraft, and there is no bottleneck in the airport pathways. Usually, handling movements from the terminal to the parking position are performed in less than 4 minutes.

Under these ideal operational conditions (absence of perturbations in the airport pathways), handling companies can program low cost cargo operations on the first belly just by a flexible manpower contract policy (Shangyao, 2008). From the airline point of view, the lack of perturbations in the turn-a-round time is a positive factor to sell the first belly for cargo purposes.

The first belly of an A-320 is characterized by a capacity of 12,23 mts3 and a weight constraint of 2 Tn. The extra fuel consumption for a 50 minutes flight when the first belly is full of cargo is just 50 Kg. Under similar circumstances, the extra fuel consumption for a 150 minutes flight is around 140kg. Figure 4 illustrate the extra fuel consume in Kg when the first belly is full with 2 Tn cargo. Thus for short and medium leg distances, first belly capacity can be sold at competitive prices while increasing the airline's benefits.

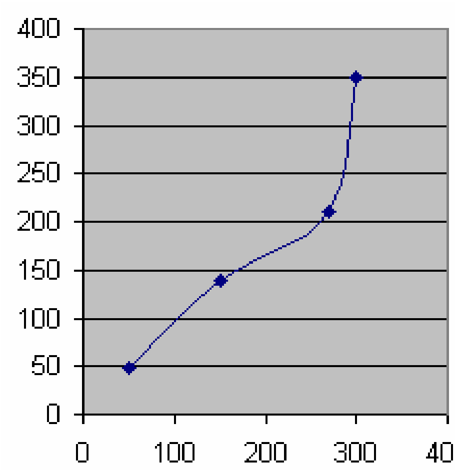

Figure 4: Extra Fuel consumption (Kg) per flight time (min.)

Despite the same costs and benefits should be obtained in international airports, the lack of confidence in preserving the turn-a-round time due to time perturbations on the airport pathways is a determinant factor for low cost carriers to prefer flying with the first belly empty instead of selling the belly capacity for cargo purposes.

Figure 5 shows the Bcn airport layout, in which it is easy to note the cargo warehouses are placed around 20 minutes from the contact parking positions in the new T1 terminal.

Figure 5: Layout of an international airport

It easy also to note that both types of perturbations can affect the cargo handling transport times from the warehouse till the parking position: platform pathway congestions and taxiway/pathways interactions. Furthermore, by considering also that the ETA use to have a perturbation described by a Uniform pdf U(-15, +30) , in order to guarantee that handling transport perturbations will not affect the aircraft turn-a-round time, a cargo handling team should be assigned during a minimum of 3 hours for just one cargo operation, which increases considerably the cost of the cargo operation.

Thus, the advantages of regional airports to support low cost cargo operations are mainly achieved due to lack of perturbations in the handling operative, however they lack of a minimum number of bellies that could be sold to transport a certain number of Tones at a regular frequency is a real handicap for low cost cargo sustainability. On the other hand, international airports can offer a competitive number of bellies, but inner logistic handling transport operations affect considerably the cost of the operation.

4. A CASE STUDY

A macro simulation model has been developed in Bcn airport using the following hypothesis and conditions:

- Only destinations with a minium of 6 flight per day has been considered, so a minimum of 12 Tn or 70 mts^3 could be managent by a transport company in order to attract the attention of freighters:
    - Frankfurt: 6 aircrafts/day
    - Paris: 22 aircraft/day
    - Brussels : 9 aircraft/day
    - Amsterdam: 6 aircraft/day

- Opportunity belly policy: Due to slot concentration in certain time periods, only those bellies that could be attended by an available handling cargo team will be considered. Thus, under this policy it is preferably to miss a belly instead of oversizing the number of cargo handling resources to load goods in all available bellies. Thus a trade-off solutions instead of a global optimal solution can be obtained using a macro simulation model.

Figure 6 shows all the programmed flights to the 4 European destinations distributed according to their ETA.

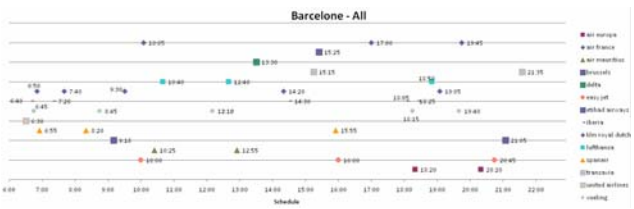

Figure 6: scheduled flights at Bcn airport

A simulation model in Arena has been developed at macro level, in which arrivals are programmed according to ETA's, and different pathways transport times are considered to check the sensibility of the system to handling transport perturbations.

A scenario design has been considered to get a trade-off between the number of extra cargo handling teams with respect to the bellies that could be attended. The model do not considers the perturbations caused by the interation between taxiways and pathways that could appears between the cargo area till the T1 area. A shuttle system transporting ULD's from the cargo terminal to T1 has been modeled together with a cargo area in T1 where ULD's are placed waiting for its final transport to the aircraft parking position.

Figure 7 illustrates the number of aircrafts that can be attended using different number of extra cargo handling teams. Serie 1 represents the number of aircraft attended considering an average time for the cargo handling operation of 55 minutes considering the pathway travel time (go and return) and the load/unload belly operation. Serie 2 and serie 3 show the same information but considering an average time for the cargo handling operation of 65 minutes and 85 minutes respectively.

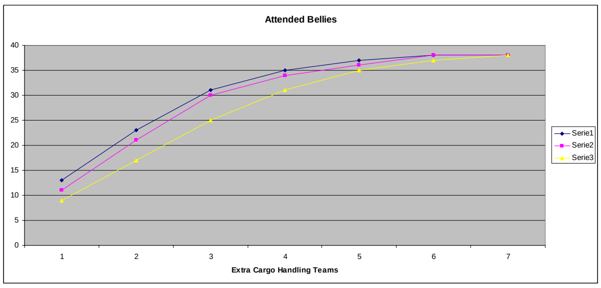

Figure 7: Bellies attended considering different handling cargo teams.

As it can be seen, a poor airport pathways capacity can affect considerably to support low cost cargo operations: increases the idleness of handling resources while at the same time affect the number of bellies that can be successfully loaded during the turn-a-round aircraft time.

According to the results obtained, a good trade-off can be obtained contracting 3 extra cargo teams, which corresponds to an average of 30 bellies per day (ie. 60 tones or 240 mts^3).

5. CONCLUSIONS

The sensitivity of the air cargo logistic systems to the constant perturbations provoked by saturation in the airport platform pathways and the interaction between taxiways and pathways has been introduceded both in regional airports and in international airports.

A simulation model to quantify how perturbations can affect the handling resources to attend cargo operations has been developed in Arena, and the results obtained illustrate the need of new logistic policies to implement low cost cargo transport operations in international airports.

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