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Integrated Decision Making for Ground Handling Management

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Summary- In this paper a hierarchical structure for the management of airport ground handling activities is proposed. The main decision making processes in charge of the managerial units composing a proposed ground handling management organization are considered. The global objective is to turn available the ground handling resources so that arriving and departing flight are serviced with as little delay as possible. Two operational situations are considered: a normal one where small delays are coped with when arriving and departing traffic is globally on schedule, and a disrupted situation where arriving or departing traffic suffer very large delays.

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Integrated Decision Making for Ground Handling Management

Salma Fitouri-Trabelsi [α], Felix Mora-Camino [σ], Carlos Alberto N. Cosenza [ρ] & Li Weigang [ω]

Summary- In this paper a hierarchical structure for the management of airport ground handling activities is proposed. The main decision making processes in charge of the managerial units composing a proposed ground handling management organization are considered. The global objective is to turn available the ground handling resources so that arriving and departing flight are serviced with as little delay as possible. Two operational situations are considered: a normal one where small delays are coped with when arriving and departing traffic is globally on schedule, and a disrupted situation where arriving or departing traffic suffer very large delays.

I. Introduction

The sustained global economic growth of the last decades has been possible with the development of improved means of communication and of transportation of people and goods. It has been particularly the case with air transportation where, during the last forty years, the number of passengers has been multiplied by seven. This increase of passenger volume has generated a permanent challenge for civil aviation authorities, airlines and airports to supply sufficient capacity to provide a safe transportation service with acceptable quality standards (Santos et al., 2010). In the last decade, new traffic management practices, such as Airport Collaborative Decision Making (A-CDM) (Eurocontrol, 2011), based on multi-agent and collaborative decision making concepts have been introduced at airports. Among the many activities which contribute to the safety and efficiency of air transportation, airport ground handling plays an important role even if it has remained in the shadow of other traffic activities in the Operations Research literature. While among the overall airport operations costs, ground handling costs represent a rather small portion, their dysfunction can generate huge extra costs for airlines and airports as well as high discomfort for passengers (Pestana, 2008).

In this study a hierarchical structure for the management of airport ground handling activities is considered. The global objective is to turn available the ground handling resources so that arriving and departing flight are serviced with as little delay as possible. Two operational situations are considered: a normal one where small delays are coped with when arriving and departing traffic is globally on schedule, and a disrupted situation where arriving or departing traffic suffer very large delays.

In the first situation a ground handling coordinator produces an estimate of the necessary resources from each ground handling service provider while these service providers assign the available resources to the scheduled ground handling activities. At both levels, the formulation of corresponding optimization problems leads to NP-complete problems while a new solution should be at hand whenever new operations conditions appear. So, heuristic approaches have been developed to generate working solutions to this overall problem. While in the case of normal operations these heuristics consider the flights according to their nominal schedule, in the disrupted operations, flights are treated in accordance with an estimated degree of criticity computed by the

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ground handling coordinator. The proposed approach is illustrated with traffic data from a large European airport.

II. Hierarchical Structure for the Management of Ground Handling at Airports

When considering ground handling organization in different airports, it appears that this organization depends strongly on the size and the physical organization of the airside as well as on the volume and composition of traffic. Then, a large diversity of actual ground handling organizations is found in major and medium size airports. Then it does not appear desirable to propose a general paradigm to organize airport ground handling since the resulting efficiency can be quite unequal from an airport to the next. However, when some key characteristics are met, delimiting a specific class of ground handling situations, common organizing principles can be of interest.

Here some assumptions with respect to airport ground handling characteristics, which are frequently encountered in medium to large airports, are adopted. They are the following:

Here is considered the case of airports in which ground handling is performed by a set of specialized operators working in parallel under the management of the airport authorities.

The ground handling process is supposed to follow pre-established sequencings and to be performed at the parking stands. It is supposed that the parking stands are assigned to arriving flights by the airport and communicated through ATC, while the status of the parking stands is monitored by ATC which is in charge of driving the aircraft out of the parking position. It is also supposed that the arriving parking position is its departure parking position for the next flight. This last assumption introduces constraints on the ground handling activities.

From the considerations developed in the previous paragraph, it appears interesting to consider that the airport ground handling operators do not interact directly within the A-CDM framework (Eurocontrol,2011) , but through a ground handling coordinator.

The introduction of the GHC led to a hierarchical structure for the ground handling management as it showed in Fig.1.

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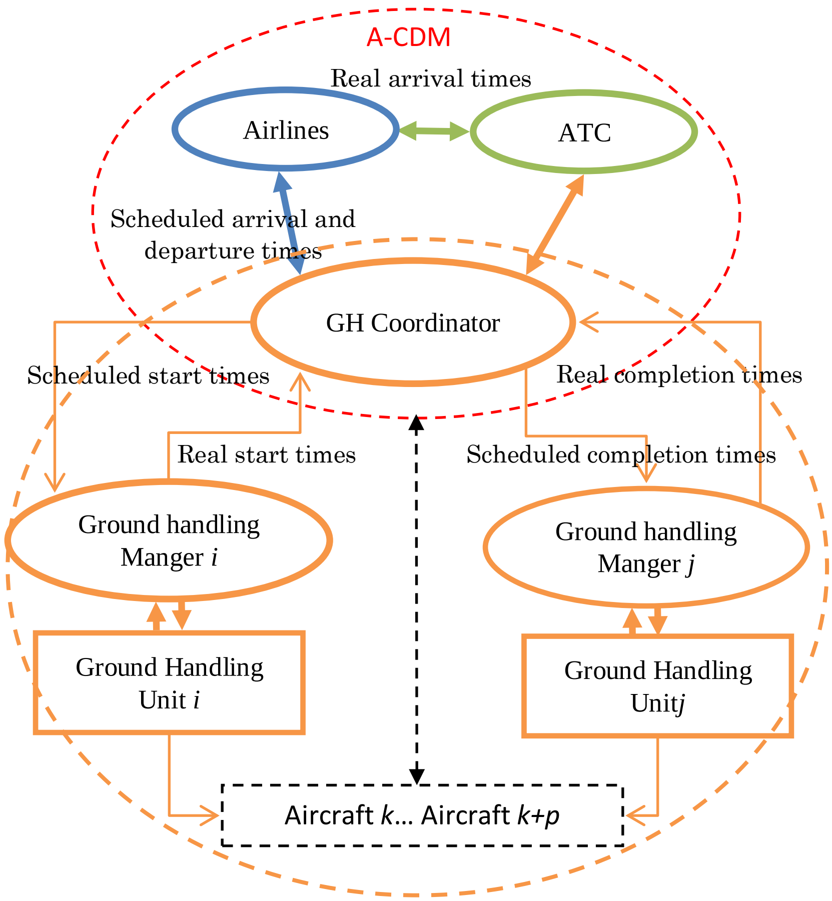

Figure 1 : Connection of A-CDM with Ground Handling

a) Ground Handling Coordinator

This coordinator will be a communication interface between the other A-CDM partners and the ground handling managers.

The principal functions of the GHC are:

- To provide to the other airport partners:
  - predictions of ground handling delays
  - Generation of milestones
- To provide to the ground handling managers:
  - Predictions about activity levels
  - required ground handling resources per period

i. *Ground handling milestones monitoring*

The ground handling activities around an aircraft can be divided in two set of operation:

- The set of arrival ground handling operations, A_i^{gh} , which includes all the ground handling activities which must be performed to conclude properly the current commercial flight. The main arrival ground handling activities are de-boarding passengers, unloading baggage, performing cleaning and sanitation.
- The set of departure ground handling operations, D_i^{gh}, which gathers the ground handling activities which must be performed to prepare the next commercial flight. The main departure activities are passengers boarding, baggage loading, fuelling, catering.

The possible milestones monitored by the ground handling coordinator are:

- time of start of arrival ground handling activities :

$$T_i^{agh} = \min_{k \in A_i^{gh}} \left\{ t_{ik}^{agh} \right\} \tag{1}$$

- time of completion of arrival ground handling activities :

$$\tau_i^{agh} = \max_{k \in A_i^{gh}} \left\{ t_{ik}^{agh} + d_{ik}^{agh} \right\} \tag{2}$$

- time of start of departure ground handling activities :

$$T_i^{dgh} = \min_{k \in D_i^{gh}} \left\{ t_{ik}^{dgh} \right\} \tag{3}$$

- time of completion of departure ground handling activities :

$$\tau_i^{dgh} = \max_{k \in D_i^{gh}} \left\{ t_{ik}^{dgh} + d_{ik}^{dgh} \right\} \tag{4}$$

Here t_{ik}^{dgh} is the start time of ground handling activity k on departing aircraft i, d_{ik}^{dgh} is the duration of the ground handling activity k on aircraft i. All these time related variables and parameter adopt two values: their estimated value which can evolve and their effective value at completion.

ii. *Global planning of ground handling resources*

The planning of ground handling resources should be performed at start for a whole day of operation by considering as basic input information:

- the time schedule of arriving and departure flight,
- the operational characteristics of these flights.

The prediction of the necessary GH resources (vehicles and work force) over the operations period is performed in three steps:

- *a global ground handling assignment* (GGHA) problem is solved for a nominal schedule of flights. A fast heuristic solution is proposed (greedy approach)
- *totalization of necessary resources* is performed for each time interval. Here a time interval within the operating period is chosen for the resources used by task t :

$$u_t = \max\left\{\text{Timing}, \min_{j \in K} s_j^t \right\} \tag{5}$$

- *margins are added to the estimation of necessary resources:*

For arrival ground handling activities:

$$r_i^k = n_i^k + p_A^k A_i^k \tag{6}$$

For departure ground handling activities:

$$r_i^k = n_i^k + p_D^k D_i^k \tag{7}$$

where: n_i^k is the nominal number of teams (vehicle and staff) of type i necessary at period k to process scheduled arrivals/departures, r_i^k is the computed required number of teams of type i necessary at period k, to process schedules arrivals/departures, included reserve, A_i^k is the number of teams of type i necessary to handle flight arrivals at parking stands during the previous half an hour which are supposed to be processed before period k , D_i^k is the number of teams of type i necessary to handle flight departures at parking stands during the previous half an hour which are supposed to be

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processed before period k and, p_A^k is the probability that an arrival scheduled within half an hour before period k is delayed and should be processed at period k and p_D^k is the probability that a departure scheduled within half an hour before period *k* is delayed and should be processed at period *k*.

b) Ground Handling Manager

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The ground handling manager has two principal functions:

- Planning operations
- Managing operations

i. *Planning operations*

To achieve this function the ground handling manager has to:

- Solve its *pairing problem* to cover all planned demands for its services: during the current operations period. Result: list of duties which will be performed by its GHU's.
- Create the ground handling units by *assigning* its resources to its duties (a resource roastering problem).

ii. *Managing operations*

Managing operations consists in the first time to update the assignment of his ground handling resources to aircraft considering the information received from the GHC has in case of:

- perturbation at the level the aircraft's arrival times
- perturbation at the level of the duration of performing of the tasks
- weather conditions (strong rain, snow, strong wind, etc.)

It consists also in monitoring the GHUs. A ground handling unit can be in the following states:

- *deactivated:* either the equipment is not ready (under repair or maintenance) or the operators are not available,
- *waiting for assignment:* the unit is enabled but has not been assigned to flights,
- *assigned:* the unit has been assigned to one or more flights, but the realization of the activity on the first of these flights is planned far in the time horizon,
- *made ready to perform its next activity:* this happens when the planned time to perform a ground handling activity is near. This corresponds either to the time necessary to adapt the resource to the flight to be served or to a minimum time delay to inform the operators of the next operation,
- *operating:* the unit is performing the activity (transfer operations and processing at aircraft or terminal).

III. Nominal Decision Making Processes with the Proposed Approach

a) The ground handling coordinator level

The decision making considered at this level is to solve the global ground handling assignment which is the first step of the global planning of ground handling resources.

A fast heuristic solution is proposed (greedy approach) which consists in. this approach will ensure the feasibility of all ground handling operations. The idea of the porposed heuristic is to rank arriving and departing aircraft according to their planned start time of the corresponding ground operations (either arrival ground handling tasks or departure grand handling tasks). Then the GHC will process in this order each aircraft ground handling activity by linking each task to a route to build a ground handling duty:

- To cover task j at aircraft k it will search between the already created routes of type j , which one can cope with it, within the planned interval and at lower transportation cost.
- If none of the existing route provides a feasible solution
  - and there are remaining capacity of type j at the corresponding base, a new route of type j starting at this base is created with first stop at aircraft k.
  - and there are no remaining transport capacity at base of type j, add this task at the route of type j which minimizes the mix of resulting delay for aircraft k and of distance travelled to reach it with the weight λ.

Then repeat with all the expected ground handling tasks j at an arriving or departing aircraft.

This will produce feasible sets of duties (routes) to be performed by the different ground handling fleets and workforce. Then this data will be used by the ground handling coordinator to compute, according to the process proposed in the previous chapter, the level of resources that each ground handling manager must provide at each time period. These resources will be afterwards either effectively used to process aircraft and passengers or will remain as a warm reserve to face perturbations and incidents.

b) The ground handling manager level

In a nominal situation, the ground handler fleet managers will assign a vehicle and a work team to each route. This vehicle may be changed by another to pursue the duty in accordance with operational considerations (refueling need, mechanical failure, etc) while work teams will be shifted according to labor and safety regulations.

Here it is supposed that there are enough spare vehicles and work teams to meet operational perturbations.

The proposed heuristic consists in:

- For each ground handling manager:
  - Order the aircraft in accordance with their arrival/ departure time, depending on the type of the ground handing fleet service.
  - Assign to each aircraft taken in order a vehicle considering:
    - Availability of all vehicles of the fleet.
    - The distance from its current position to the considered aircraft

This is a rather simple greedy heuristic which provides for each fleet facing the current service demand a complete solution through a reduced computational effort. So there is no limitation in calling back this solution process any time a significant perturbation occurs.

In the case of ground handling fleets involved in unloading/loading activities at parked aircraft, aircraft will be duplicated considering their current scheduled arrival time at the parking position and their current scheduled departure time from the same parking position. Then each duplicate will be ordered according to increasing time.

From the solutions of the assignment problems solved by each ground handling manager , the ground handling coordinator forward the milestones corresponding to the completion of ground handling activities to the airlines and the ATC to produce if necessary new estimates for the departure schedule of the aircraft.

c) Case of study

To validate the proposed ground handling organization and the associated decision making processes real traffic data from Palma de Mallorca Airport was considered. Palma de Mallorca Airport is, with respect to aircraft and passengers traffic, the third largest Spanish airport. During the summer period it is one of the busiest airports in Europe, and was used by 22.7 million passengers in 2011. The airport is the main base for the Spanish carrier Air Europa and also a focus airport for German carrier Air Berlin. It occupies an area of 6.3 km2 (2.4 sq mi). Due to rapid growth of aircraft traffic and passenger numbers, additional infrastructure has been added to the

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two first terminals A (1965) and B (1972). It is composed now of two runways, four terminals and 180 parking stand (27 of them at aprons) (PDM, 2012). It can handle up to 25 million passengers per year, with a capacity to dispatch 12,000 passengers per hour.

To evaluate the proposed approach, we tested it using aircraft traffic for a 24h period (01/08/2007) with 690 arrivals and departures distributed between the four parking areas related with the four terminals of Palma de Mallorca Airport. Except for aircraft staying at night at the airport, all ground handling operations are done in the context of fast turnaround operations. Different sizes of ground handling fleets have been considered. The resulting earliest departure time for aircraft have been compared with the real time departure data, showing that with rather reduced ground handling fleets at each terminal, the proposed heuristic, coded in Java, does not generate additional delays. Fig.2 displays the hourly traffic of arriving and departing aircraft on a typical summer day at this airport. It appears that aircraft traffic remains intense from early morning until the beginning of night hours.

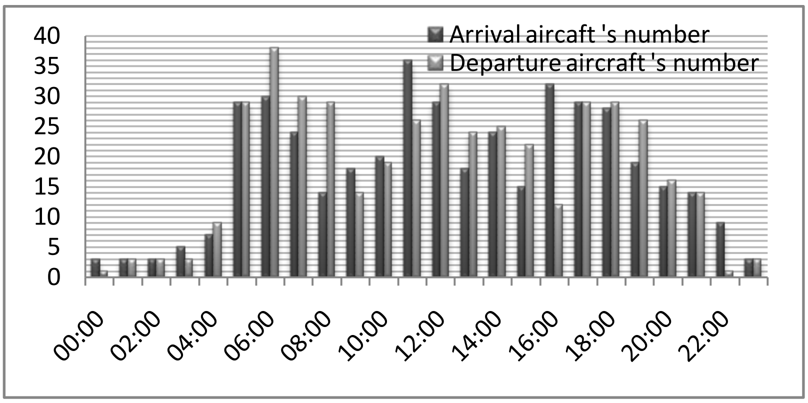

Figure 2 : 01/08/2007 PDM Airport aircraft hourly traffic

The proposed heuristic approach has been tested for the aircraft traffic with the ground handling fleets of Fig.3.

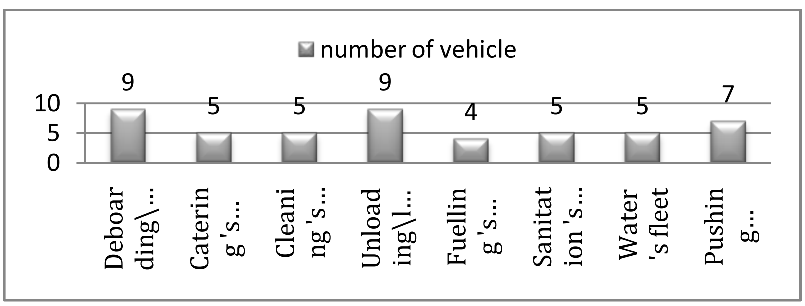

Figure 3 : Nominal composition of ground handling fleets

i. *Implementing the global planning of ground handling resources*

This approach is proposed to calculate the nominal number of resources required for each ground handling manager during a day of traffic. The solution of this approach is given in the Table 1. It represents the number of the aircraft which will be performed by each ground handling unit of each ground handling service provider.

Ground handling activity	GHU1	GHU2	GHU3	GHU4	GHU5	GHU6	GHU7	GHU8	GHU9
De-boarding/ Boarding	71	58	43	38	32	25	19	12	6

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passengers									
Unloading/ Loading baggage	133	95	93	85	66	79	60	51	28
Catering	86	80	66	58	55				
Cleaning	97	77	60	61	50				
Refuelling	103	92	84	66					
Sanitation	144	94	59	34	14				
Water Supply	103	82	66	53	41				
Push back	118	112	84	37	31				

Table 1 : Solution of hierarchical approach

Using this solution, only 14 aircraft will have a delay at the level of the departure times with a maximum delay of 14 minutes. The 14 aircraft that would leave their parking stand later that which it had been predicted their departure times match with busiest flight traffic period.

This global planning of ground handling resources as it has been described is composed of three steps:

For the first step, it has been supposed that the nominal number of each ground handling resources is presented in the figure.

In the second step, the unit time period which has been considered has been taken equal to the maximum between 5 minutes and the smallest duration of a ground handling operation, including transfer time according to the formula (5).

Ground handling activity	Duration (min)
De-boarding passengers	5
Catering	5
Cleaning	5
Boarding passengers	5
Unloading baggage	5
Fuelling	5
Loading baggage	5
Sanitation	5
Potable water supply	5
Push-back	5

Table 2 : The unit time period of each ground handling operation results

The third step of the estimation of the necessary resources at a given time for all ground handling managers is performed by adding margins to the nominal level of demand of scheduled arrival and departure flights. This is done according to formula (6) and (7).

The figures presented below provide the size of the resources required for each ground handling manager to perform their corresponding ground handling tasks in case of perturbations that can occur during the day. As it can be seen, the number of reserved resources increases in the busiest flight traffic period (arrival/departure aircraft) according to the Fig-4.

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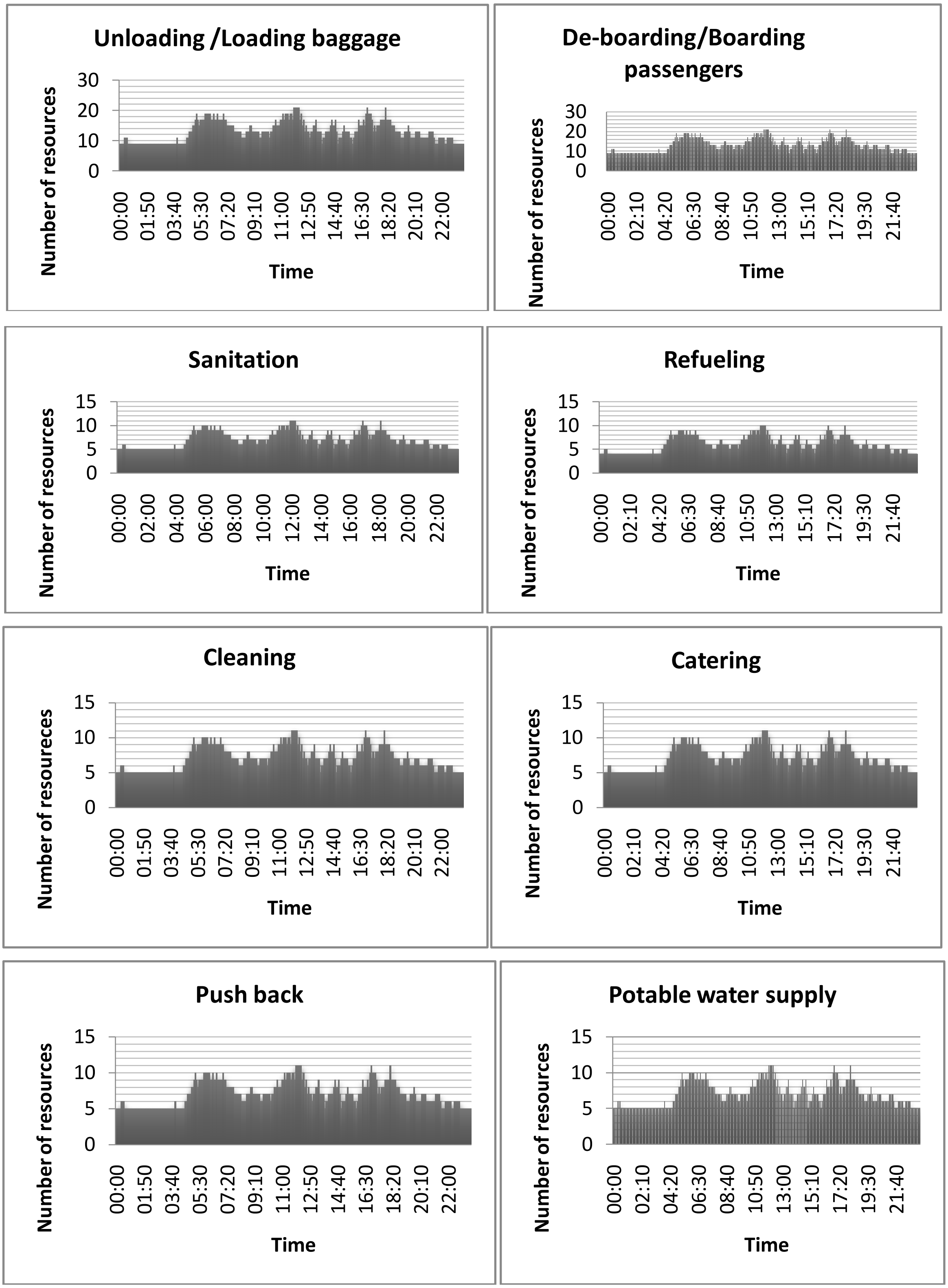

Figure 4 : Number of the resources required for each ground handling activities each of period of time

ii. *Implementing the heuristics for on-line GHFA*

To test the efficiency of this approach, the accurate arrival times of each considered flights are supposed to be communicated to the ground handling managers thirty minutes before the effective landing. Here, this allows the ground handling managers to reassign the ground handling resources by considering the updated arrival times at the parking stands of the flights announced to land within the next half hour. Aircraft within five minutes to land have been supposed to maintain the previous assignment solution. No flight directed towards the considered airport has duration less than forty minutes. Then the real departure times where compared with the ones obtained through the proposed heuristic approach. The considered ground handling resources were the ones effectively existing at that airport.

The application of the proposed heuristic approach to the nominal schedule of arrivals during the considered reference day provided a feasible assignment for each ground handling manager in at most 0.3 seconds. These solutions led to delays with respect to scheduled departure schedule involving only 36 aircraft, with a maximum delay of 16 minutes. The average delay among delayed aircraft has been of 7 minutes. Fig.5 displays the hourly distribution of delayed aircraft at departure resulting from the application of the proposed decentralized approach. Clearly, the occurrence of these delays corresponds to the busiest aircraft traffic periods at the airport where ground handling resources become short. The proposed heuristic could be restarted using higher ground handling resource levels provided by the ground handling coordinator to improve the expected delay performance of the system.

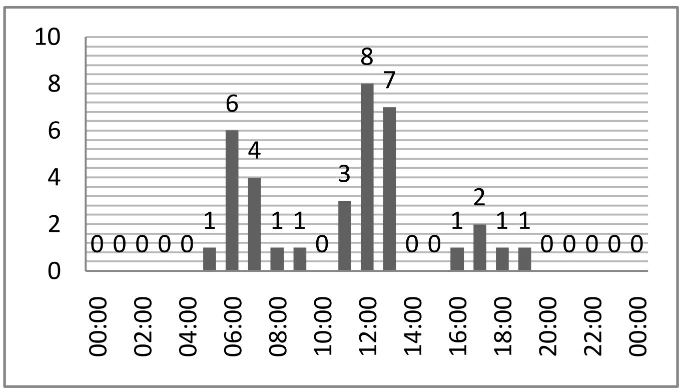

Figure 5 : Hourly delays distribution resulting from the proposed heuristic

Historical data from 01/08/2007 at Palma de Mallorca Airport indicate that about 244 aircraft departures where delayed for multiple reasons, including one of the main reasons, ground handling delays. The maximum observed delay is about 520 minutes and the average delay among delayed aircraft has been of 30 minutes. There is information about the use of a particular system to manage ground handling at that airport.

It is clear, that in theory, the proposed heuristic approach provide significantly improved results with respect to departure delays. Then it can be expected for this particular airport that, even if the implementation of the proposed heuristic approach is not perfectly performed, some noticeable improvement with respect to the current practice will take effect. This is quite noteworthy since the proposed heuristic has not been particularly improved with respect to a basic greedy approach.

IV. Ground Handling Management Under Disruption

To our knowledge there exists no specific definition for airport disruption while some recent works refer to this situation (Ploog, 2005) and (Tanger and al, 2013) without providing any definition. According to the British Standards Institute (Business continuity management, 2006), "a disruption is an event which causes an unplanned, negative deviation from the expected delivery according to the organization's objectives". According to this definition, the term disruption could be perceived as equivalent to the term perturbation. The ground handling services are delivered in a changing environment with many operational uncertainties. For example, the expected arrival times for flights are subject to frequent delays, the duration of ground handling

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tasks is sensitive to unexpected events such as additional travel time due to traffic congestion on airside service ways or machine breakdowns. Then it could be considered that ground handling management tackles in permanence disrupted situations.

a) *fuzzy heuristic for on-line ground handling management problem*

The problem for each ground handling fleet is here to assign ground handling vehicles to arriving or departing aircraft so that each aircraft is serviced by a vehicle while, according to the current operational situation, no delay or a minimum delay is produced. For that, the airline ground station managers generate resources requests to the ground handling fleet managers. The produced schedules are based on the predicted arrival times as well as the scheduled departure times. These schedules take not only into consideration the possible variation of the ground handling tasks durations by using a fuzzy dual formalism (Cosenza, 2011; Cosenza, 2012), but consider also the criticality of the flight. This criticality depends on the current predicted delay as well as the operational consequences on other flights. Then more critical flights may get their ground handling solution treated before earlier less critical scheduled flights. The following notations are adopted: Each task of the turnaround process $t \in \{1,\ldots,T\}$ is carried out on an aircraft a(i) associated to a flight i, i∈I, (I=IA∪ID, IA is the set of arriving flights and ID is the set of departing flights) by a specific service provider $k \in \{1,\ldots,K\}$.

b) *Fuzzy-based ranking of flights*

The first step of the proposed heuristic consists in performing an initial ordering of the flights in accordance with their current predicted arrival time $\hat{t}_i^a$ at their assigned parking amended by considering their criticality. To each arriving flight i ∈ I, can be assigned the difference $\Delta t_i^a = \hat{t}_i^a - \bar{t}_i^a$ between the predicted arrival time $\hat{t}_i^a$ and the scheduled arrival time $\bar{t}_i^a$. Here $\hat{t}_i^a$ and $\bar{t}_i^a$ can be either real numbers or fuzzy dual numbers, where $\hat{t}_i^a$ is provided by the ATC. Each arriving flight must cope with two types of operational constraints:

Connection constraints when arriving passengers must reach without delay another departing flight.

Departure schedule when the arriving aircraft must be ready to start a new flight with a tight schedule..

When considering connection constraints, let C_i be the set of departing flights connected to arriving flight i. The time margin between fight i and each flight j in C_i is given by:

$$\tilde{m}_{ij}^a = \bar{t}_j^d - \hat{t}_i^a - \max\left\{ \tilde{d}_{db}^{\,i} + \tilde{T}_{ij}, \tilde{d}_{ul}^{\,i} + \tilde{\theta}_{ij} \right\} \quad j \in C_i \tag{8}$$

Here $\tilde{T}_{ij}$ and $\tilde{\theta}_{ij}$ are respectively the connecting delay for passengers and luggage between flights i and j. The margin between arrival flight i and departure flight j serviced in immediate succession by the same aircraft is:

$$\tilde{m}_{ij}^a = \bar{t}_j^d - \hat{t}_i^a - \tilde{D}_{ij} \text{ with } j = \sigma(i) \tag{9}$$

where $\tilde{D}_{ij}$ is the minimum fuzzy dual duration of ground handling around arrival of flight i and departure of flight j. Here $\sigma(i)$ provides the number of the next flight serviced by the aircraft operating flight i. Then:

$$\tilde{D}_{ij} = \max\left\{ \begin{array}{c} \tilde{d}_{ul} + \tilde{d}_{fu} + \tilde{d}_{ll} \\ \tilde{d}_{db} + \tilde{d}_{ca} + \tilde{d}_{bd} \\ \tilde{d}_{db} + \tilde{d}_{cl} + \tilde{d}_{bd} \\ \tilde{d}_{sa} + \tilde{d}_{wa} \end{array} \right\} + \tilde{d}_{pb} \tag{10}$$

Then, the fuzzy margin of arriving aircraft i is given by:

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$$\tilde{m}_i^a = \min_{j \in C_i \cup \sigma(i)} \tilde{m}_{ij}^a \tag{11}$$

The amended arrival time for flight i is then given by:

$$\tilde{\tilde{t}}_i^{\,a} = \hat{t}_i^a + \tilde{m}_i^a \tag{12}$$

To each departing flight I ∊ ID, can be assigned the difference $\Delta t_i^d = \hat{t}_i^d - \bar{t}_i^d$ between the predicted departure time $\hat{t}_i^d$ and the scheduled departure time $\bar{t}_i^d$. Here also, $\hat{t}_i^d$ and $\bar{t}_i^d$ can be either real numbers or fuzzy dual numbers. Symmetrically, each departing flight must cope with operational constraints related with successive flights by the same aircraft and flight connections for passengers and cargo.

In the case in which the ground handling tasks are relative to a departing flight j, the amended predicted time to start grand handling activities at the corresponding parking position is now given by:

$$\tilde{\tilde{t}}_j^{\,d} = \bar{t}_j^d - \min_{i \mid j \in C_i \, and \, i = \sigma^{-1}(j)} \tilde{m}_{ij}^a \tag{13}$$

with

$$\tilde{m}_{i\sigma(i)}^a = \max \begin{Bmatrix} \tilde{d}_{fu} + \tilde{d}_{ll} \\ \tilde{d}_{ca} + \tilde{d}_{bd} \\ \tilde{d}_{wa} \end{Bmatrix} + \tilde{d}_{pb} \tag{14}$$

Then, to each flight *i*, either arriving or departing, is assigned a time parameter τ_i such as:

For arriving flights:

$$\tau_i = \left\| \tilde{\tilde{t}}_i^{\,a} \right\| \tag{15}$$

For departing flights:

$$\tau_i = \left\| \tilde{\tilde{t}}_i^{\,d} \right\| \tag{16}$$

where $\| \ \|$ is the fuzzy dual pseudo norm. Then the flights, either arriving or departing, present in the considered period of operation can be ranked according to an increasing τ_i index. Let the integer ra (i) be the amended rank of flight i.

c) Ground Handling Fleets assignment to flights

Then flights are processed in the produced order ra(i) where ground handling vehicles are assigned to the corresponding aircraft. In the case of an arriving flight, ground handling arrival tasks (unloading luggage, de-boarding, cleaning and sanitation) are coped with by assigning the corresponding vehicles in accordance to their previous assigned tasks with other aircraft, their current availability, and their current distance to the considered aircraft. Here the common reference time schedule for the ground handling arrival tasks is $\hat{t}_i^a, i \in I_A$. In the case of a departing flight, ground handling departure tasks (fuelling, catering, luggage loading, boarding, water and push back) are also coped with by assigning the corresponding vehicles in accordance to their previous assigned tasks with other aircraft, their current availability, and their current distance to the considered aircraft. Here the common reference time schedule for the ground handling departure tasks is $B^{low}(\tilde{\tilde{t}}_i^{\,d}), i \in I_D$.

In both cases it is considered that the whole set of different ground handling vehicles necessary at arrival or departure is assigned by considering the common reference time schedule. This assignment of vehicles to flights either arriving or departing is performed on a greedy base by considering the closest vehicle available to

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perform the required task. This will make that at the start of ground handling activities for an arrival or departure flight, all necessary resources will be nearby the parking place and that scheduling constraints between elementary ground handling tasks will be coped with locally without need of communication between the different ground handling fleet managers. This is a rather simple greedy heuristic which provides for each fleet facing the current service demand a complete solution through a reduced computational effort. So there is no limitation in calling back this solution process any time a significant perturbation occurs.

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d) Illustration of the proposed approach

To evaluate the proposed approach, the data used on the case of study of the previous part has been modified to create artificially a disruption situation. Here it has been considered that for any external reason, for exemple some severe weather conditions, a part of earlier scheduled arriving flights in the morning have been delayed and the airport operates under a concentrated arriving traffic at capacity between 11a.m. and 1 p.m.. Then, the effective arrivals and scheduled departures are those of Table.3.

It is considered that during and after this period the airside capacity of the airport is insufficient, including taxiing capacity with the appearence of queues of taxiing aircraft, parking positions with apron congestion and saturated ground handling capacity. In that conditions, transfer times for aircraft and ground handling units activities durations are subject to large uncertainties. Here it has been considered two scenarios for the uncertainty: in the first one additional delays are between 0% and 40% of the original duration between 11a.m. and 2 p.m. with return to nominal situation afterwards, in the second scenario additional delays are between 0% and 40% of the original duration between 11a.m. and noon, between 20% and 60% of the original duration between noon and 1:30 p.m., between 0% and 40% of the original duration between 1:30 p.m. and 2:30 p.m. with return to nominal situation afterwards.

	10h→11h	11h→12h	12h→13h	13h→14h	14h→15h	15h→16h
Arrival traffic	20 + 30	34 +15	25	7	15	15
Scheduled departures	17	19	28+15	17+20	17+10	17

Table 3 : Effective arrivals and scheduled departures

In the case of this airport, there are no connections between the flights since in general this airport is a final destination for most of the passengers, so the arrival and the departure priority lists coincide. The priority list is calculated here by taking into account the predicted departure date of the flight j, which is the flight serviced by the same aircraft than for flight i. Here $\tilde{D}_{ij}$ is the minimum fuzzy dual duration of ground handling around arrival of flight i and departure of flight j and the real arrival date of the flight i respecting the considering degree of uncertainty. This duration $\tilde{\Delta}_{ij}$, which is a fuzzy dual number, can be expressed by:

$$\tilde{\Delta}_{ij} = \left(\tilde{D}_{ij} + \hat{t}_i^a - \bar{t}_j^d\right) \tag{17}$$

This application provided a feasible assignment for each ground handling manager in at most 0.4 seconds each updating of the priority lists.

The numerical results show that the delayed aircraft get in general the highest priority on the list. During the period of time between 11a.m and 2:30 p.m. ground handling achieves to serve 200 flights (arrival and departure of aircraft). The main numerical results are displayed in Table.4.

	Scenario 1	Scenario 2
Mean delay for GH processing at arrival	7.36 min	8.86 min
Maximum delay for GH processing at arrival	27 min	30 min
Mean delay for GH processing at departure	45.1 min	59.4 min
Maximum delay for GH processing at departure	195 min	197 min

Table 4 : Statistical results for disruption scenarios

Notes

Fig.6 displays the hourly distribution of delayed aircraft at departure resulting from the application of the proposed approach for the two scenarios. It appears that the impact of arriving traffic delays has resulted in an airport disruption situation which has extended in the afternoon. In the first scenario it can be considered that the disruption situation ends around 5 p.m. and in the other case it ends around 8 p.m. It appears then, that the more uncertainty about airside operations delays, the less the available ground handling capacity is able to cope with this disruption situation. Then insuring predictability of airside delays through fluidity of operations even in heavy activity levels situations emerge as an important objective.

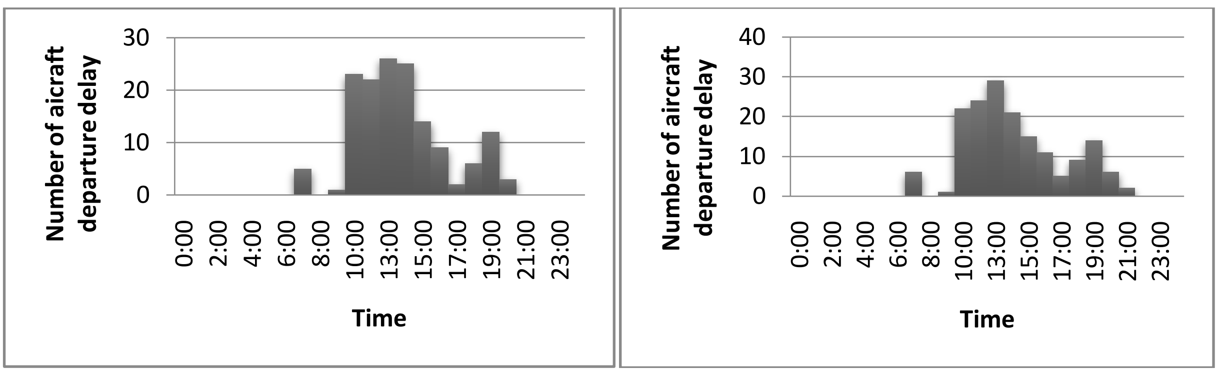

Figure 6 : The hourly distribution of delayed aircraft at departure for the scenario 1 and the scenario 2

V. Conclusion

In this paper, an organization for the ground handling management has been proposed. This proposed organization is based on the introduction of a ground handling coordination which has the role of a communication interface between the ground handling manager and the other airport partners. The solution of the different assignment problems solved by the ground handling coordinator and ground handling managers has been considered. A heuristic approaches has been developed in that case. In the case of the pairing problems faced by the ground handling managers, a heuristic approach has been developed.

The whole process has been illustrated by considering a case study with real traffic where it has been assumed that flight arrival times are perfectly known half an hour in advance. Even if scheduled and effective arrival times are different, the adopted traffic situation can be considered as normal. Also the ground handling management has been considered in the case of a huge traffic perturbation characterizing an airport disruption. The operations planning procedures performed within the proposed management structure of ground handling have been revised by adopting temporary new objectives and taking into account the uncertainty with respect to activity delays in this situation. During the disruption period, the ground handling coordinator takes over the direction of the ground handling management by imposing to the ground handling managers, priority lists of flights to be processed. The computation of these priority lists makes use of fuzzy dual calculus to take into account delays uncertainty. The feasibility of the proposed approach is displayed by considering the case of a disruption at Palma de Mallorca airport.

Notes

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