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Ground Handling Operations Management: An Agent-Based Modelling Approach

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Abstract- This work addresses the resource allocation-routing problem in the aircraft Ground Handling (GH) context. This problem is classified as one of the challenges that most of the ground-handling operators face nowadays. It consists of allocating a number of resources including workers and vehicles to aircraft of different service requirements and specifications. The allocation deals with the assignment of *m* teams of *n* skilled workers to *k* special purpose vehicles to serve *i* aircraft on the air-side area, while the routing is to determine the optimal route used by a group of workers integrated with vehicles when serving one or more aircraft. Both the allocation and routing tasks are affected by a number of constraints including different aircraft types and sizes, different aircraft service times, and various GH operation details based on flight types.

Keywords: *resource allocation, routing, aircraft, ground handling operations, autonomous system, algorithms, simulation.*

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Ground Handling Operations Management: An Agent-Based Modelling Approach

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Abstract- This work addresses the resource allocation-routing problem in the aircraft Ground Handling (GH) context. This problem is classified as one of the challenges that most of the ground-handling operators face nowadays. It consists of allocating a number of resources including workers and vehicles to aircraft of different service requirements and specifications. The allocation deals with the assignment of *m* teams of *n* skilled workers to *k* special purpose vehicles to serve *i* aircraft on the air-side area, while the routing is to determine the optimal route used by a group of workers integrated with vehicles when serving one or more aircraft. Both the allocation and routing tasks are affected by a number of constraints including different aircraft types and sizes, different aircraft service times, and various GH operation details based on flight types. Therefore, the main aim of this research is to develop an autonomous system to deal with the allocation, planning, and scheduling of resources. The methodology followed involves a number of algorithms that act and interact with one another towards achieving the best allocation and routing process. The simulation results have shown a net decrease in the service time and an overall team utilisation of 92%.

Keywords: resource allocation, routing, aircraft, ground handling operations, autonomous system, algorithms, simulation.

I. Introduction

With over 3 billion passengers and millions of flights every year, aviation is one of the busiest sectors in the world. Air transport is an economic engine that has globalised the world's economy and facilitated tourism and business between different countries and continents (ATAG, 2014).GH operations embody the airside activities at airports (Fitouri-Trabelsi et al., 2015). They comprise all the services required by aircraft between landings and take-offs (CAPA, 2014). Most of these operations require the use of special vehicles that are specific to each type of operation.They are usually categorised as: ramp, on-ramp, or on-board services. Each of these categories include a number of services. However, airline companies may opt for another schema to follow depending on a number of factors such as the total budget of GH operations and the number of available workers.

In this research paper, the issue of aircraft GH resource allocation, scheduling and routing is investigated. Because GH operations consist of many distinct tasks that not all ground handlers can perform, workers of different skills are required. Moreover, the different operations to be completed depend on two parameters the aircraft size and the flight type. There are three aircraft sizes: large, medium, and small, and two flight types: international and domestic. Furthermore, a number of vehicles are required to perform all the tasks. These vehicles are categorized based on their specialisation and may be needed for one or more tasks. Likewise, workers have different skills; however, some of them can perform more than one operation and therefore can be used

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accordingly. Workers will be assigned not only based on their skills, but also depending on their idle time. The worker with the least utilisation will be called in first. Following the same logic, the aircraft that is taking off first will be given priority.

This paper is organised as follow: section II presents the work context followed the multi-agent based modelling section where the algorithms used are explained. The simulation and results are explained in section IV, followed by the conclusion and future works sections.

II. Work Context

GH operations refer to all the operations needed to service an aircraft between the period of landing and take-off. Figure describes the main GH usually needed:

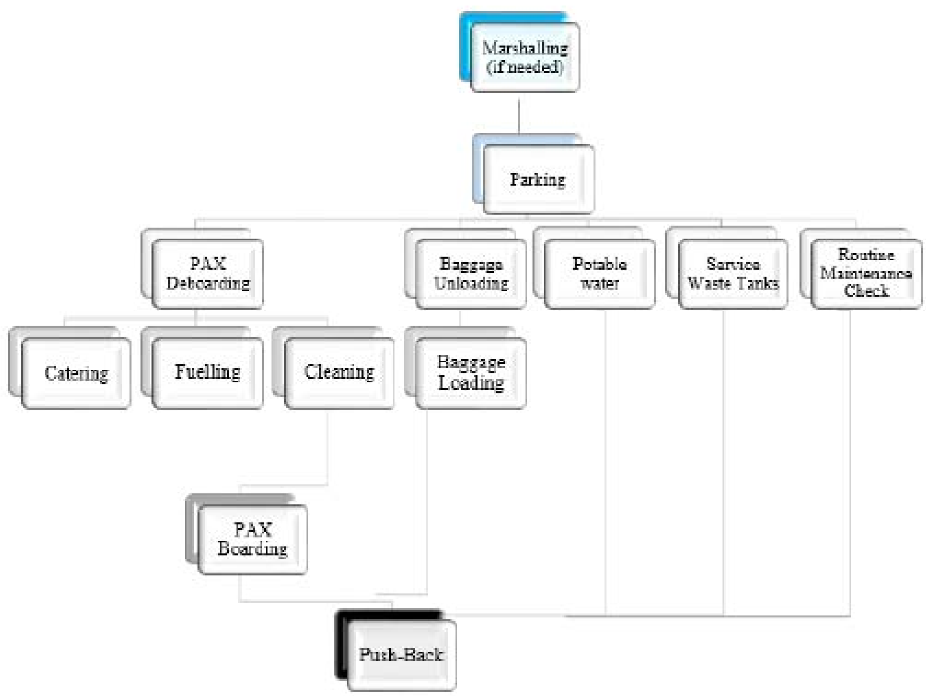

Figure 1: GH Operations

Several vehicles are needed to complete GH operations. Some of the vehicles are represented in the diagram below:

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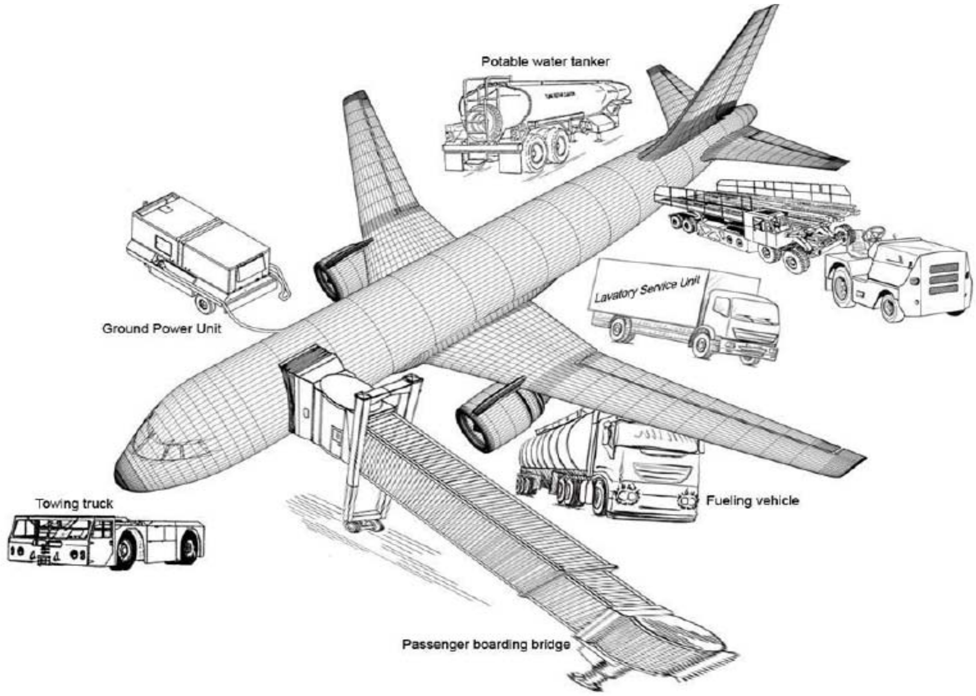

Figure 2: Vehicles needed in GH

In this research, the issue of aircraft GH resource allocation, scheduling and routing is investigated. Because GH operations consist of many distinct tasks that not all ground handlers can perform, workers of different skills are required. Moreover, the different operations to be completed depend on two parameters the aircraft size and the flight type. As mentioned above, there are three aircraft sizes: large, medium, and small, and two flight types: international and domestic. Furthermore, a number of vehicles are required to perform all the tasks. These vehicles are categorized based on their specialisation and may be needed for one or more tasks.

GH operations have been studied for decades and great advances in the GH processes were made. Nonetheless, some aspects of GH operations have not been improved, and on-going research is still being carried out. One aspect of the turnaround processes, however, was not investigated to this date. It is contended that the benefits of combining vehicle routing with the workers' availability and skills should be exploited by managers to optimally allocate crews to aircraft.

In the light of the above, the question driving this research is:

Can GH resource allocation, scheduling and routing be fully optimised? The following parameters are taken into account: workers' availability and skills, vehicles' availability and specialisation, aircraft inter-arrival, and due times.

III. Multi-Agent Based Modelling

The system architecture is a conceptual diagram that demonstrates how the system operates. The purpose behind this system is to allocate, plan, and optimise ground-handling resources efficiently by calculating the shortest paths for vehicles and implementing intelligent search and optimisation algorithms.

The core of this system are Multi-Agent based model along with a number of embedded algorithms including Hamiltonian Cycle, Fibonacci Heap, and Genetic Algorithms.

These algorithms have been developed to optimise allocation of resources including both workers and vehicles to different GH operations. These algorithms are implemented in the back-end and are not accessible through the GUI.

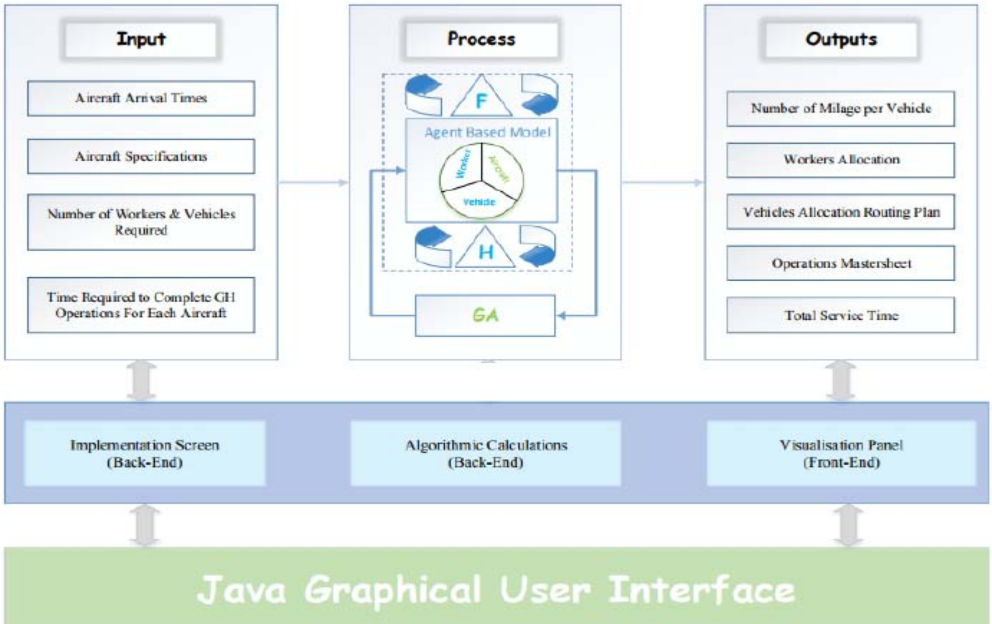

Figure 3: Conceptual Model

A number of inputs are used and fed into the system. These inputs include aircraft inter-arrival times, aircraft specifications, number of workers and vehicles required, and finally the time required to complete all GH operations. Several algorithms embedded within the ABM are developed to optimise resources allocation of GH operations. Hamiltonian Cycle with Fibonacci Heap algorithms are used to optimise the vehicles routing plan, while a Genetic Algorithm is used to optimise the required number of workers and vehicles.

Every time a random number of aircraft is generated, the Hamiltonian graph changes. The nodes and edges of the graph are directly linked, and therefore dependent, of the number of aircraft generated. Furthermore, the KPIs for GH operations include optimised routes, optimised GH operations, optimised number of vehicles and workers, and an optimised GH operations planning and schedules. These are the outputs of the system.

An Agent-Based approach along with a number of algorithms as components are used to process inputs and turn them into the required KPIs. The Agent-Based approach is used to mimic the GH operations and a number of algorithms are integrated with the developed ABM to optimise the performance of the allocated resources including workers and vehicles.

IV. Simulation & Results

A 7-day simulation was run to test the system and get the results that are presented within this section.

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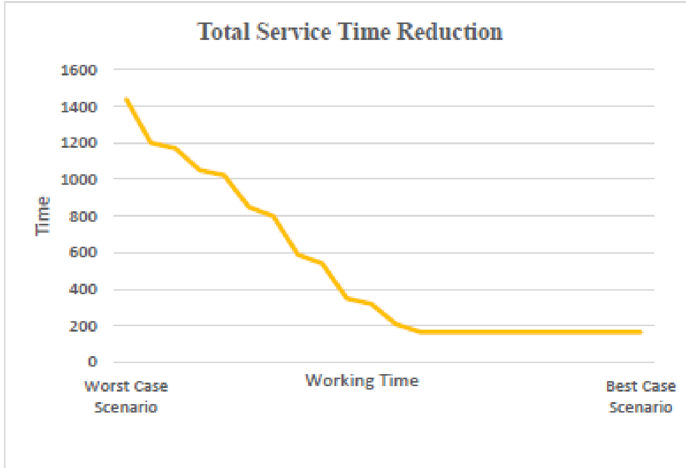

Figure 4: Total Service Time Reduction

The total service time reduction shows the worst case versus the best case scenarios. The Genetic Algorithm (GA) used was run for about 5 hours to get these results.

Concerning the vehicles working hours for vehicles serving international aircraft, it is higher than the ones serving local flights. This is due to the fact that more time is allocated to international flights as a number of things must be checked thoroughly before take-off. For instance, routine maintenance check for local aircraft may take 10 to 30 minutes, while the same operation takes between 30 and 50 minutes for international flights.

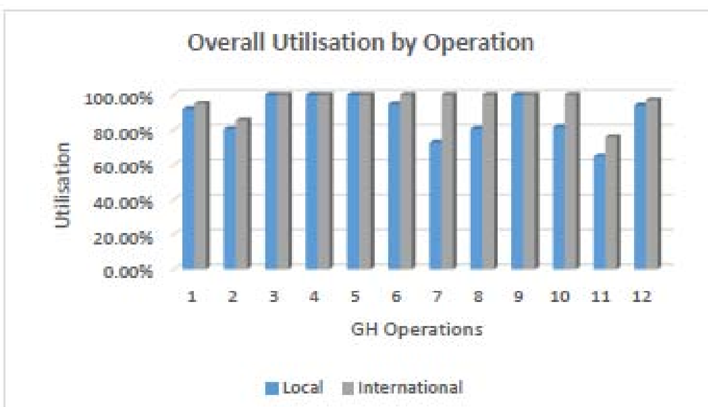

Figure 5: Overall Utilisation by Operation

An overall utilisation of over 92.26% was achieved, as shown in the below graph.

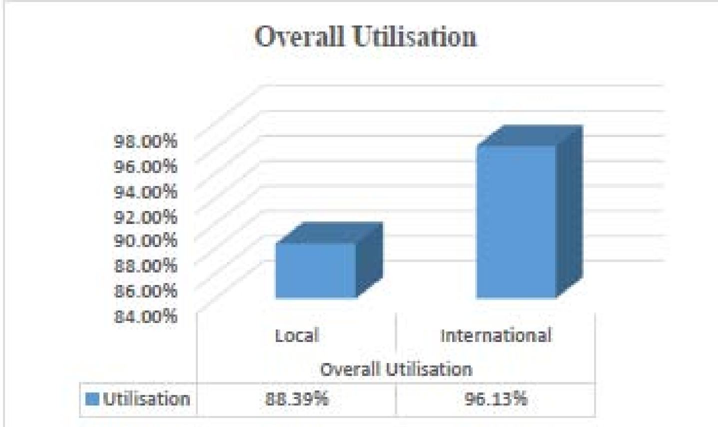

Figure 6: Overall Utilisation

The graph below shows both the total service time for vehicles serving both local and international flight types.

Figure 7: Total Service Time

We notice from the graph that international flight destinations are given more time. Nonetheless, one should keep in mind that the total number of aircraft of international destinations and those of local destinations are randomly generated. This may have impacted the total service time for some days. For instance, 52% of the aircraft generated on day 1, and 81% of the aircraft generated on day 4 are of international flight type.

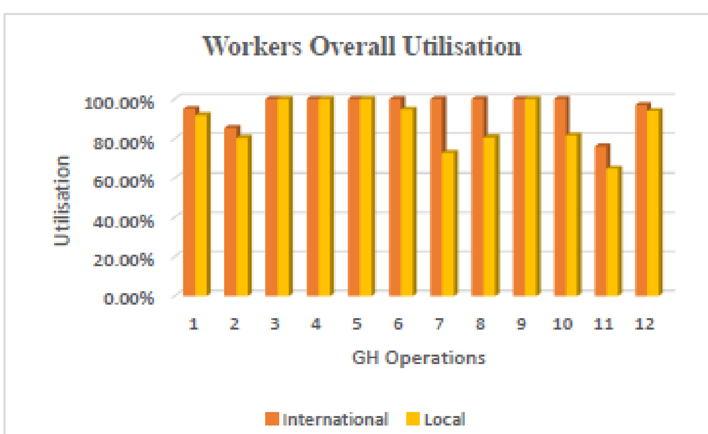

Figure 8: Workers Utilisation

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The overall utilisation for workers serving local and international aircraft is high. The overall utilisation of the workers serving international aircraft is higher than the one of workers serving local aircraft.

To determine the resource allocation plan, a 7-day simulation was run from Monday to Sunday to randomly generate workers, vehicles, and aircraft. Most of the workers and vehicles are used every day. This is what makes the utilisation very high. Both workers and vehicles have very little idle time and work all day long serving different aircraft.

V. Conclusion

Optimally allocating workers to vehicles and assigning them to one or more aircraft while taking into account the availability of resources and aircraft arrival and due times is the problem addressed within the scope of this research. An attempt to solve this problem was made through implementing a multi-agent based simulation model.

A thorough analysis of the results, routing tables, and allocation tables of 103 aircraft was carried out. A number of graphs were generated to show the total working hours, the vehicles utilisation, the total service time, the workers utilisation, and the total service time reduction.

The simulation results are promising as the overall vehicles utilisation is 92% and the total working hours are very high. This implies that all resources are well allocated, optimised, and used.

VI. Future Works

Finding the optimal resource allocation and routes was the main purpose behind this study. Different aircraft models and types were taken into account. Two aircraft models were studied: Boeing & Airbus; different sizes were considered as well: large, medium, and small aircraft. The simulation study consisted of generating a random number of aircraft of different destination types: local or international where 103 aircraft total were studied.

For future works, adapting this system to other problems in other areas of study, such as supply chain where using the vehicle routing section of this research to solve the dynamic allocation of vehicles in logistics, is being considered. Furthermore, adding more rules to achieve better agents' interaction is considered as well.

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