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OPTIMIZATION OF AIRCRAFT GROUND HANDLING WITH THE HELP OF CRITICAL PATH METHOD

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Abstract. The goal of this paper is development of management control algorithm for optimal aircraft ground handling with the help of mathematic analysis method.

Keywords: optimization, ground handling, downtimes, critical path method, algorithm.

Introduction

The International Air Transport Association (IATA) defines ground handling as an integral part of airline operations and strives to lead the industry toward improved safety and operational efficiency in ground handling by setting standards and assisting in the implementation of global solution. All the recommendations and standards are described in such documents as Airport Handling Manual (AHM), the IATA Ground Operations Manual (IGOM) and the IATA Safety Audit for Ground Operations (ISAGO).

Study area

Efficient ground handling can be defined in terms of total costs and time expenses. They are the main objectives for airports and airlines especially for Low Cost Carriers as they are interested in minimization of expenses per a flight.

Ground handling is the period of aircraft servicing between it arrives to the terminal apron and the time it departs. It can be reached by means of automated equipment, quick and qualitative work of ground handling personnel. Nowadays, highly automated and autonomous equipment are installed in modern airplanes, for example Auxiliary Power Unit (APU), large fuel and water capacity, on-board stairs etc. Nevertheless, downtimes still occur, as there are unforeseen circumstances such as weather conditions, additional non-scheduled flights and human factor, which cannot be predicted.

There are different methods to optimize ground operations at airports. One of them refers to managerial control and planning. Wise planning of the order, means and ways of aircraft servicing can develop the work and foster outcomes. In this paper one of the operations' research methods is used.

In order to develop good plan for ground works few factors should be taken into consideration:

- type of the aircraft;
- level of airport automation;
- number of ground handling workers designated for one flight;
- intensity of flights in an airport.

One more aim of this paper is to make this research considering exactly Ukrainian International air gates – Boryspil and Kyiv. So, all calculations are done according to the average capacity of these airports.

Critical Path Method (CPM)

The method represented in this work is called Critical Path Method.

What is it?

Critical Path Method (CPM) – is an algorithm for scheduling a set of project activities. This method is often used during modeling or planning design, including construction, aerospace and defense, software development, research projects, product development, engineering, etc. It is also the method of mathematic analysis and dynamic programming.

Why can it be used?

As the ground handling consists of many activities with interdependences and special order of their completion, this method can help optimize it and develop the algorithm of actions. This method offers a visual repre-

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sentation of the project activities, presents the time to complete the whole project and tracks critical activities. It can also be used for both sequential and parallel type of tasks (in this paper both types are considered)

What is the input?

It is a set of activities conducted by handling crew.

What is the output?

It is minimization of total costs and time expenses and development of proximate servicing model for one flight.

What are the techniques?

1. A list of all activities required to complete the project (typically categorized within a work breakdown structure).

2. The time (duration) that each activity will take to complete.

3. The dependencies between the activities.

4. Logical end points such as milestones or deliverable items.

The principal of this method is to find out the longest path of planned activities. That's why this path is called "critical" or the longest one. Then other which are not involved in this chain can be distributed, shifted

and completed any time during the whole process. In accordance with this method first of all the total list of activities should be defined. One of the best examples of aircraft type can be Boeing-777 (fig. 1).

It is a large, wide-body twin-engine jet aircraft from Boeing's family with passenger capacity from 314 up to 451. Aircraft possesses modern facilities and highly automated systems: Controls External Power on the Airplane, Main Backup Power which goes to the Left, Right or Auxiliary Power Panels, etc. The common ground handling operations for a commercial flight handling are presented in the Table 1 below.

Table 1. Overview of common ground handling operations for a commercial flight

Ramp services	– Supervision – Marshaling – Start-up – Moving/towing aircraft – Safety measures
On-ramp aircraft services	– Repair of faults, fueling, wheel and tire check – Ground power supply – Deicing, cooling/heating – Toilet servicing, potable water, demineralized water – Routine maintenance – Non-routine maintenance – Cleaning of cockpit windows, wings, nacelles and cabin windows
Onboard servicing	– Cleaning – Catering – In-flight entertainment – Minor servicing of cabin fittings – Alteration of seat configuration
External ramp equipment	– Passenger steps – Catering loaders – Cargo loaders, mail and equipment loading

As it was mentioned above in order to build the algorithm the list of activities, carried out during ground handling should be completed. After completion the list, the next step can be done. It is construction of Network Diagram or CPM Diagram. CPM models activities (Table 2) in the form of network.

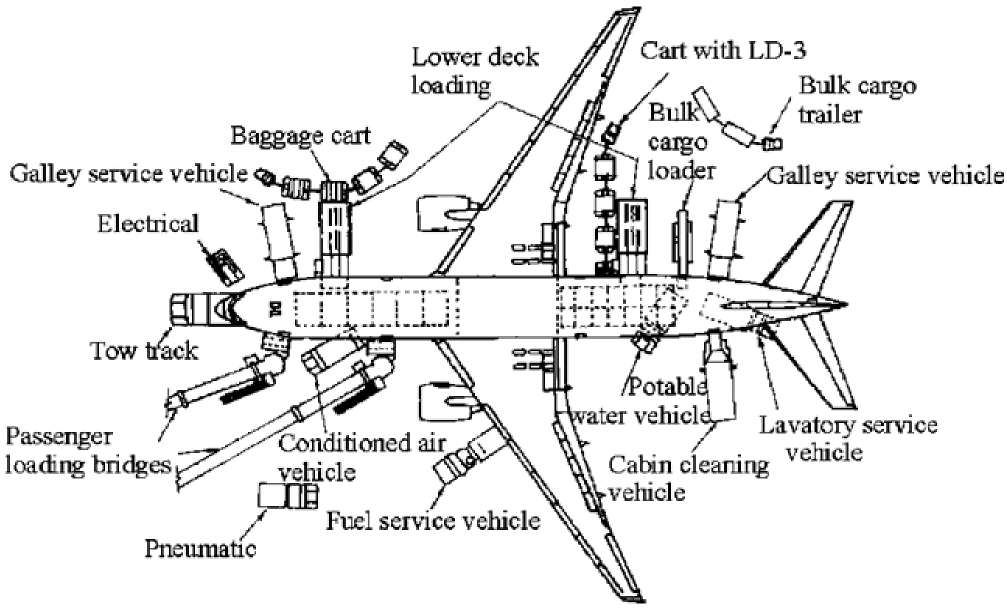

Fig. 1. Scheme of Boeing-777 servicing during turnaround with the help of ground handling support systems and mobile equipment (source: Airport Design and Operation)

Table 2. List of services for ground handling crew per one flight of B-777

Activity	Time, min	Mark	Order of conduction
Position passenger bridges	1	A	–
Supply power	1	B	–
Unload main deck cargo	20	C	after B done
Deplane passengers	15	D	after A done
Unload aft lower lobe	15	E	–
Service lavatories	30	F	–
Service galleys	30	G	after E done
Service cabin	25	H	after D done
Service potable water	12	I	after F done
Fuel aircraft	25	J	after H done
Unload forward lower lobe	10	K	after I done
Load main deck cargo	30	L	after C done
Load forward lower lobe	15	M	after K done
Board passengers	18	N	after G done
Load aft lower lobe	15	O	after L done
Start engines	3	P	after N done
Power supply removal	1	W	after P done
Remove bridges	1	X	after O done
Push back	2	Y	after M done

CPM Diagram

In CPM Diagram we marked all activities as nodes, which are connected with arches (fig. 2). In this case nodes will be marked as 1, 2, 3 and arches – as the designated letters with duration, e.g. A-1 (it means first activity correspondent to position passenger bridges, which lasts for 1 minute). Before diagram construction the order, dependencies and duration of each activity must be reviewed one more time. When the diagram is designed all the nodes should be checked in onward and backward direction. It is done to determine the critical or the longest path. ■ – is node, Δ – is arch or path between node of origin and node of destination.

Onward path:

Node 1: ■1 = 0, this node is always equal to 0 according to the method

Node 2: ■2 = ■1+ Δ 1,2 = 0+1 = 1, the next node is obtained by adding to the node of origin the number (duration) pointed above the arch to the node of destination. Δ1,2 – is the path from the node 1 to the node 2. Then, the same operations should be done until all the nodes will be completed.

Node 3: ■3 = 1
Node 4: ■4 = 15
Node 5: ■ = 30
Node 6: ■ = 16
Node 7: ■ = 21
Node 8: ■ = 35
Node 9: ■ = 42
Node 10: ■ = 51
Node 11: ■ = 63
Node 12: ■ = 41
Node 13: ■ = 66
Node 14: ■ = 52
Node 15: ■ = 67
Node 16: ■ = 69

Then, the inverse procedure should be done in backward direction.

In this case the first node will become the final point and it is already designated as 69, basing on the presented above calculations.

Node 16: Δ15 = 69
Node 15: Δ14 = Δ15 – D14,15 = 67
Node 14: Δ = 52
Node 13: Δ13 = 68
Node 12: Δ12 = 68
Node 11: Δ11 = 65
Node 10: Δ10 = 53
Node 9: Δ9 = 42
Node 8: Δ8 = 47
Node 7: Δ7 = 23
Node 6: Δ6 = 43
Node 5: Δ5 = 30
Node 4: Δ4 = 17
Node 3: Δ3 = 3
Node 2: Δ2 = 28
Node 1: Δ1 = 0

This method has been used with sequential and parallel types of relations. Parallel is used because of simultaneous completion of works by different workers. In the ground handling group for servicing Boeing-777, 4–5 workers and 1 manager are usually involved. So, all the tasks should be distributed in such a way to have the best total costs and time expenses i.e. to have the most optimal scenario.

In order to express all calculated data and show the critical path, the timeline of the whole process has been constructed (fig. 3).

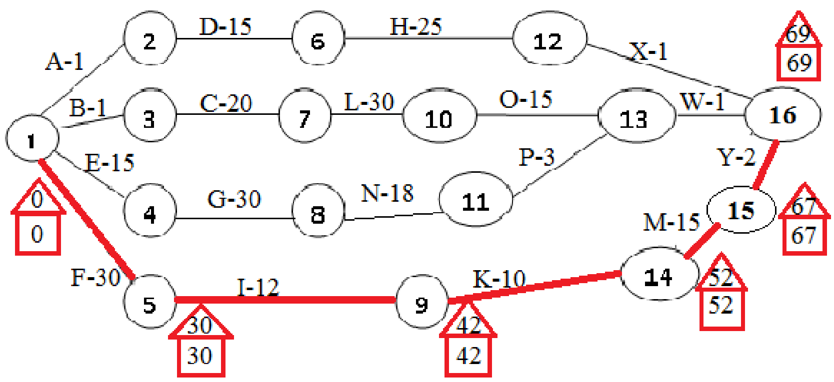

Fig. 2. CPM Diagram

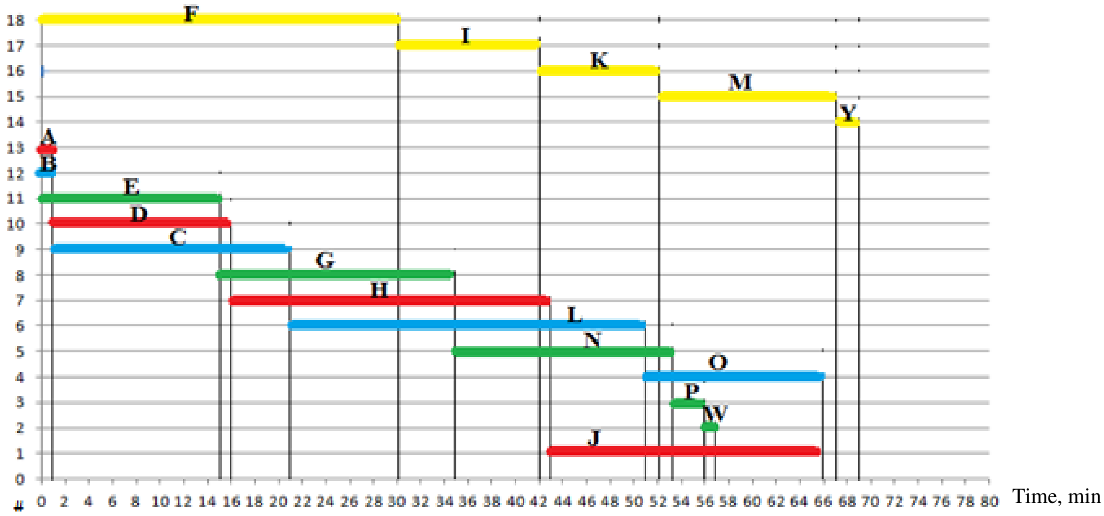

Fig. 3. Time line of the ground handling for a crew from fourmembers

This scheme represents the order and sequence of tasks completion. The critical path is marked with yellow color. It means that this sequence is the longest one and cannot be shifted. Other pathes are movable. 4 colors means 4 different workers. Their tasks designated with letters and the order of their performance is shown according to the color each worker is marked.

Conclusion

As it can be seen, aircraft ground handling is a complex of different tasks, which should be done quickly and qualitatively.

This is a very important to organize the work in such a way, that all the involved members are satisfied and do not bear any losses. It refers to airlines, airports, handling companies and ground handling crew primarily. That`s why mathematical analysis is probable way to solve managerial problem.

The Critical Path Method is a helpful and simple tool for optimization models construction. Benefits that will give the application of this method:

– avoidance of downtimes;

– efficient time and money usage, economy of resources for airlines (especially for Low Cost Carriers);

– good organization and management control of the whole ground handling process;

– clear graphical representation of algorithm;

– simplicity and inexpensive way of optimization both for hub and small airports.

After utilization of this method for ground handling plan creation the optimal sequence of activities was obtained and shown on the diagram (Fig. 3). As it can be seen all actions are completed in 69 minutes. This time is optimal in case of normal circulation of aircrafts (excluding peak hours, when downtowns are unavoidable). This time can be shifted to smaller number taking into account order, but accelerating the process if more workers will be involved or technology will be faster. It also considered a range of factors influencing on the whole process and defined optimal number of workers. Hence 4 workers would be enough for this process completion. This paper included all the ground handling operations from provision of passenger bridges to the end – push back operation. In the studying area the type of aircraft and all constrains, influencing the speed of tasks completion has been described. It is mainly number of workers, level of technologies and equipment used, etc. This paper considers average development for all airports, including Ukrainian one (Boryspol KBP, Kyiv IEV). Average duration of ground handling in KBP within non-peak season comprises 1 hour and 10–30 minutes, which is really significant number. The aim of CPM application is to make this time as small as possible. Optimization also is in the outputs of time and cost minimization avoiding downtimes. In comparison with done calculations 69 min is more optimal than 1 h and 30 min.

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