



Optimization of Aircraft Maintenance Process

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ABSTRACT

This paper examines and analytically reviews maintenance process with the aim of enhancing maintenance of aircrafts in order to meet the demands of passengers on manufacturers and airline operators to design good aircrafts with pushed out maintenance schedules which are fast, efficient and reliable for safety purpose. As a result of the increasing number of aircrafts in operation, the rate of maintenance activities increases. Hereby making customers require more in respect to the minimization of the maintenance service lead time. The objective of this work is to investigate optimization process of aircrafts maintenance. The aim of the optimization process is to minimize total make span time. Based on the analysis carried out and the result obtained from simulating the maintenance of oil pressure sensor, DIT-10, it was found that the maintenance service lead time can be reduced by changing the structure and order of the maintenance process.

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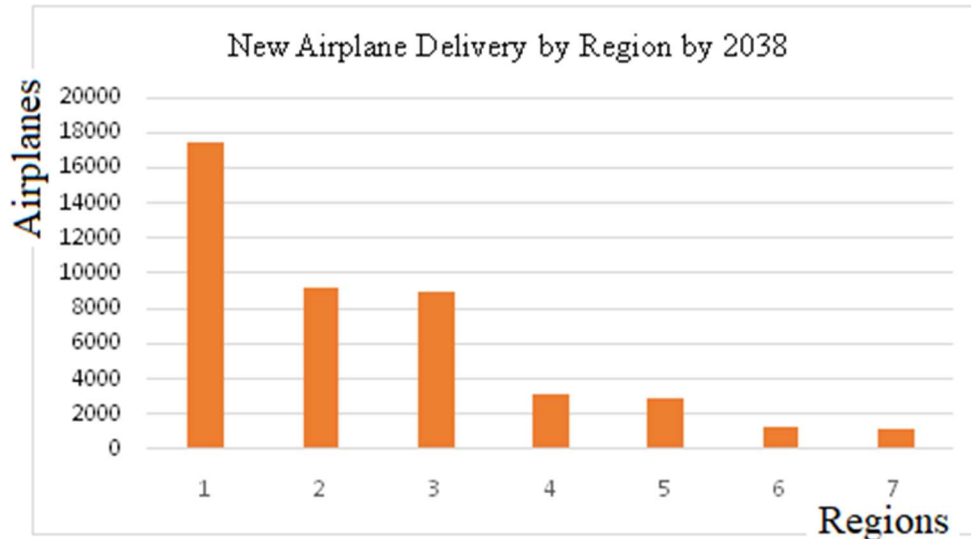
INTRODUCTION

Aircraft maintenance is the overhaul, repair, inspection or modification of an aircraft or aircraft systems, components and structures in an airworthy condition [1]. Regular maintenance prevents aircraft components and systems failures during operations. It takes place when an aircraft undergoes certain flight hours, flight cycles or calendar months. There are three major types of maintenance: A-check, C-check and D-check. A typical A-check includes inspection of the interior or exterior of the airplane with selected areas opened such as, checking and servicing oil, filter replacement and lubrication [2][23][24][25]. They are performed approximately every 2 to 3 months. The C-check requires thorough inspection of individual systems and components for service ability and functionality. This is planned within an interval of 18 to 24 months. The D-check otherwise known as structural check uncovers the airframe, supporting structure and wings for inspection of most structurally significant items; it is carried out every 6 to 10 years [3]. Many airlines merge D-check into C-check and label it as a heavy C-check [4]. During a C-check or D-check,

the aircraft has to be grounded for several weeks and removed from the revenue schedule [30][32].

The aircraft maintenance process is a significant and important part in the safe operation of an aircraft. It is one among the major decisions an airline has to make during its operation [26][27]. As a result of the increasing number of aircraft in operation, the rate of maintenance activities is also on the rise [28][29]. Hereby making the customers require more concerning the minimization of the maintenance service lead time. According to ICAO's preliminary compilation of annual global statistics, the total number of passengers carried on scheduled services rose to 4.3 billion in 2018, which is 6.4 percent higher than the previous year, while the number of departures reached 37.8 million in 2018, a 3.5 per cent increase [5]. The 4.3 billion airline passengers carried in 2018 are expected to grow to about 10.0 billion by 2040. The number of passengers in commercial aviation in the last 15 years has doubled. Additionally, more than 24,000 commercial aircraft took off around the world, making over 38 million flights; in just one year [5]. The world's major manufacturers delivered

1,606 new commercial aircraft in 2018 and recorded 1,640 new aircraft net orders [6].



1- Asia Pacific; 2- North America; 3- Europe; 4- Middle East; 5- Latin America; 6- Russia and Central Asia; 7- Africa

Fig 1.0 New airplane deliveries by region by 2038 [6]

LITERATURE REVIEW

The maintenance of components, especially of the engine of an airplane, is very important and difficult [35]. The engine is complex, subject to wear and failure, safety-critical and expensive. Therefore, the optimization of the policy for maintenance and the maintenance scheduling of engines, which arbitrates the balance cost/safety, is a considerable problem. Most of the airline companies fly with various aircraft families, characterized by a specific engine type for each airplane. The inspection and repairs of the engines are usually done at the airline special facility for engine maintenance [36]. As a result of its complexity, including many parts and repair routings, a job shop environment is implemented in a component or engine maintenance facility, in for example [36-38]. Almgren et al. [37] and Kleeman et al [36] consider the maintenance scheduling problem for aircraft engines. Almgren et al. [37] describe an opportunistic replacement problem with single objective of minimizing the total maintenance cost. The components are bound, though to a maximum time interval without replacement. Via Mixed

Integer programming, MIP and polyhedral analysis, the replacement problem is solved. The results show significant savings compared to simpler maintenance policies. Kleeman et al [35] describe a multi-objective genetic algorithm. They have two goals: the minimization of the time needed to return engines to mission capable status and the minimization of the associated cost by limiting the number of times an engine has to be taken from the active inventory for maintenance [35]. This planning problem is usually dealt with through Linear Programming, LP/Integer Programming, IP/Mixed Integer Programming, MIP [37-39]. Dietz et al [37] combine the determination of the optimal level of specialisation and optimal task allocation for maintenance workforce. They use a sequential LP algorithm to obtain good results and the model can be easily applied to problems with the objective to maximize the operational efficiency of military aircraft. Safaei et al [39] address the maximization of the availability of a military airplane. Pre and after flight checks must indicate if repair is necessary and the plane therefore needs to be stationed at the repair shop. In the shop, the jobs need to be assigned to a limited number of



technicians in such a way that next missions can take place as planned. A network structure is used to simulate the flow of the planes between missions and the repair shop. MIP provides results for this scheduling problem.

Quan et al [40] study multi-objective preventive maintenance tasks scheduling with evolutionary algorithms aiming for a schedule with a minimum number of technicians to perform these tasks. Quan et al [40] achieved this by minimizing worker idle time. However, the tasks need to be completed as fast as possible to make equipment available again. Hence, the completion time needs to be minimized as well, leading to a trade-off between both a smaller workforce to lower the idle time and a larger workforce to lower the completion time. Evolutionary Algorithm, EA is used to find pareto-optimal solutions.

Studies from Moudani et al [41], van Buskirk et al. [42] and Bajestani et al [43] were conducted to consider the maintenance scheduling for aircraft in combination with aircraft or fleet assignment. Moudani et al [41] mixed two techniques to find solutions: dynamic programming for the fleet assignment and a heuristic approach for the maintenance scheduling. Van Buskirk et al. [42] describe a military application and a system which operates in two stages. In the first stage, the qualified planes are assigned to missions. The second stage addresses the usage-based and calendar-based maintenance action scheduling. A greedy search algorithm and constraint programming are used to find better-scheduled preventive maintenance activities. Bajestani et al [43] also address a military aircraft maintenance scheduling problem in which the goal is to meet aircraft requirements for a number of missions in the presence of breakdowns. An optimal solution requires both the assignment of airplanes to missions and scheduling the repair jobs while coping with limited capacity. Different approaches are suggested for solving the problem. Experimental results show that a logic-based Benders' decomposition combined with integer and constraint programming outperforms the hybrid heuristic. The latter, though, can compute feasible schedules in a very short time, so advantages and disadvantages need to be considered, depending on the user's interest.

Kozanidis et al. [43-48] and Feo et al [47] combine the flight and maintenance planning. After a certain number of flying hours since the last check, a plane is grounded to come in for maintenance. This problem requires planning with the objective of maximum utilization of the planes over time. Kozanidis and Skipis [45] report a mixed integer bi-objective optimization model. The first objective is to minimize the total residual flight time. The second is to maximize the total number of available aircraft. The residual flight time is the remaining time that an aircraft can fly before it is grounded for a maintenance check [49]. Therefore, minimizing the residual flight time is equal to maximizing airplane utilization.

METHODOLOGY

Arena Simulation Software was used to simulate the maintenance operation of the oil pressure sensor of AN-124. The Antonov An-124 Ruslan is a large, strategic airlift, four-engined aircraft that was designed in the 1980s by the Antonov design bureau in the Ukrainian SSR, then part of the Soviet Union (USSR). The An-124 is the world's 2nd heaviest gross weight production cargo airplane and heaviest operating cargo aircraft, behind the destroyed one-off Antonov An-225 Mriya (a greatly enlarged design based on the An-124) and the Boeing 747-8.[33] The An-124 remains the largest military transport aircraft in service.[34] The lead designer of the An-124 (and the An-225) was Viktor Tolmachev.

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Rockwell Software's Arena Simulation System can protect your business by predicting the impact of new ideas, rules and strategies before putting them into practice without disrupting customer service [9][11][17]. Simulation modeling in the Arena simulation system means creating a computer model of a real or supposed system (physical, technological, financial, etc.) and carrying out experiments on the constructed model in order to describe the observed results and / or predict future results [10]. Obviously, replacing a real experiment with simulation modeling allows you to reduce the costs necessary for conducting research. In addition, in some situations, experiments on real systems can be extremely dangerous or impossible [15][16]. When the fate of the enterprise is at stake, Arena helps you choose the most profitable strategies and gives you confidence to go live, while eliminating unnecessary costs, minimizing your investment and strengthening customer relationships [31].

Arena has enabled organizations in different countries to:

- Avoid costly mistakes caused by the implementation of highly intuitive solutions; [20][21]
- Develop processes to deal with dead ends and uncertainties caused by randomness and volatility in systems; [14][18]
- Discover hidden reserves and eliminate inhibiting factors in existing implementations and internal processes; thereby helping to strengthen relationships with customers through the improvement of services quality and the delivery speed. [12][13]

The Simulation process for a maintenance operation of the oil pressure sensor, DIT-10, of AN-124in Arena Simulation System involves inputting all the steps taken in accessing the oil pressure sensor and the action of maintenance into selected boxes and the observing the outcome of the process. The pictorial representation of the process is shown below:

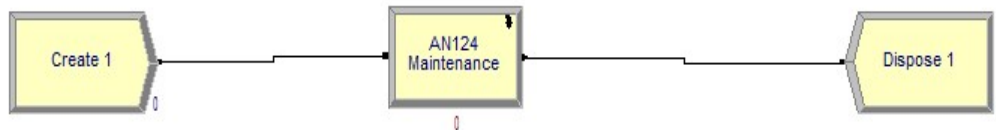


Fig 1: Initial model of the maintenance

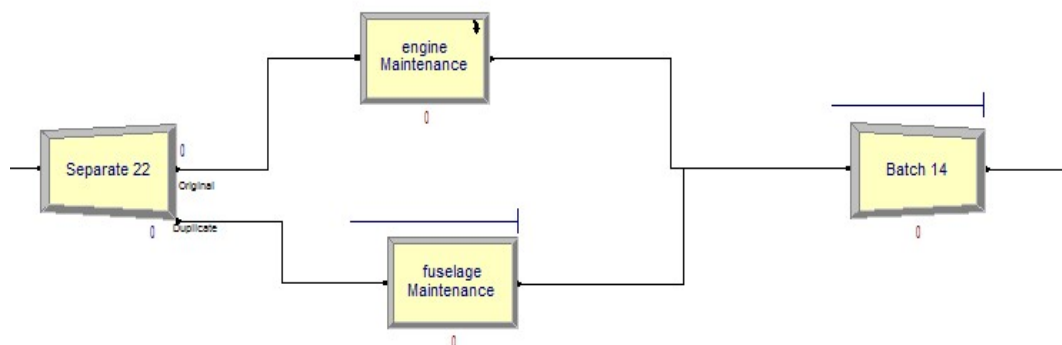


Fig 2: Initial model of the AN-124 maintenance

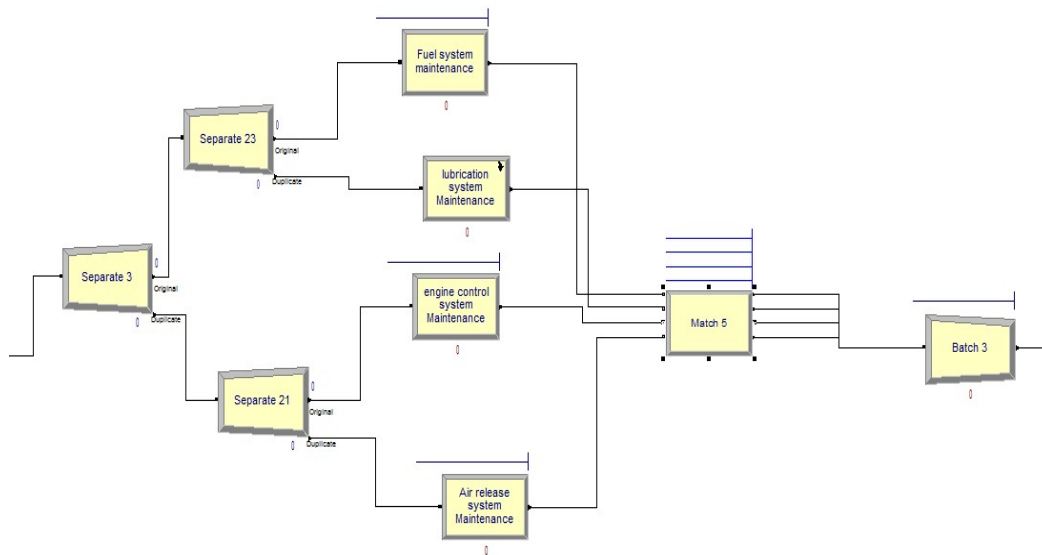


Fig 3: Initial model of engine maintenance

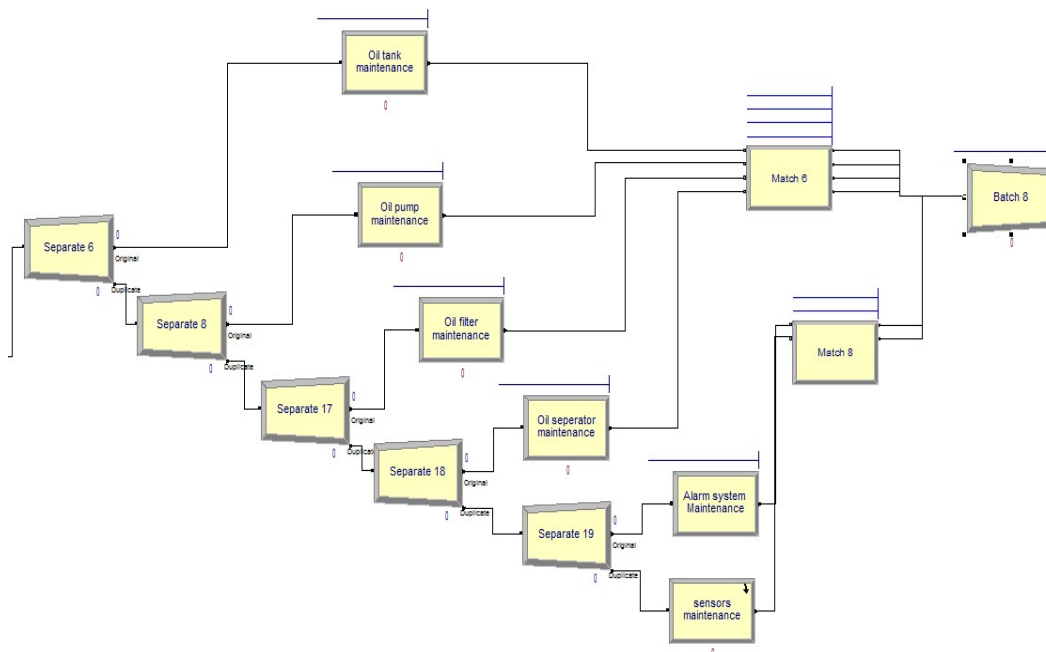


Fig 4: Initial model of lubrication system maintenance

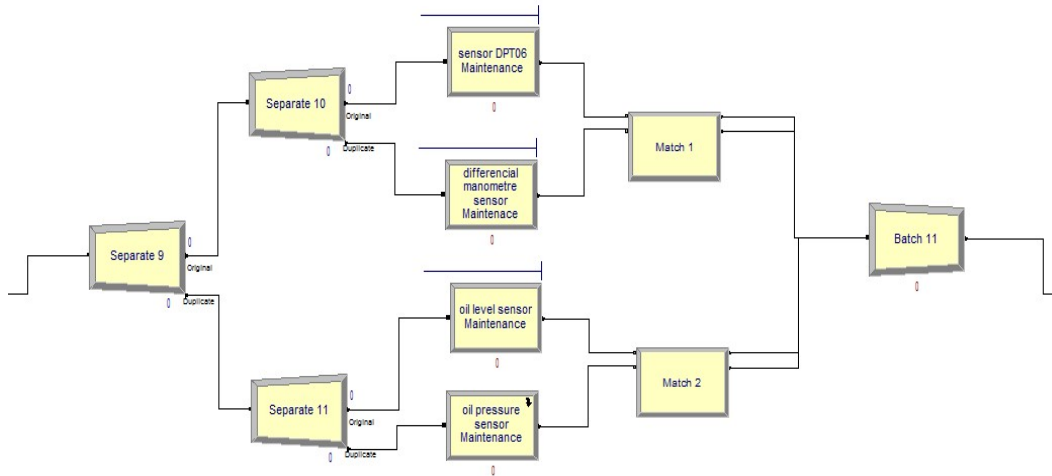


Fig 5: Initial model of oil pressure sensor maintenance

To minimize service lead time, the structure and order of the maintenance of the oil system and the oil pressure sensor was changed. In this new structure, the operations that were done separately were performed at the same time by a way of matching them. Which means that

more man power will be required. The operation of the proposed model is not limited to the Aircraft used in this work – it can be implemented on any aircraft. The pictorial representation of the changed process is shown in the figures below:

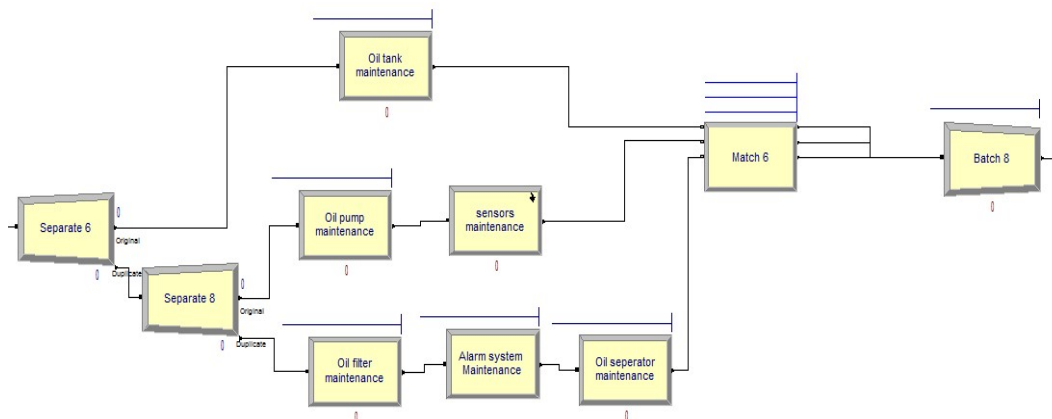


Fig 6: Changed model of lubrication system maintenance

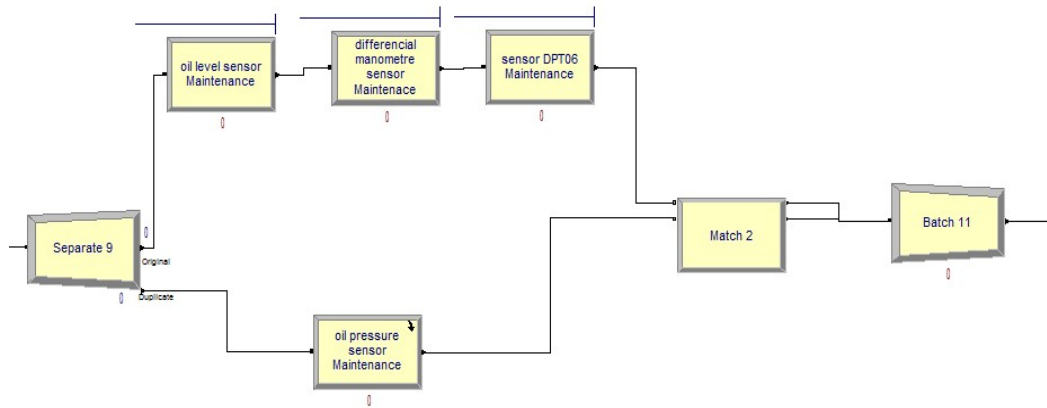


Fig 7 Changed model of the oil pressure sensor maintenance

RESULTS AND DISCUSSION

The time taken to maintain the oil pressure sensor of AN 124 using the initial model is shown in the tables below:

Table 1: Time spent on maintenance of AN-124 (initial method)

AN 124 Oil Pressure Sensor Maintenance Key Performance Indicators Time units: hours		
Time per entity		
Average	Minimum	Maximum
16.2849	14.3464	18.6633
Wait time per entity		
Average	Minimum	Maximum
15.2560	10.1848	63.0596

Table 2: Time spent on maintenance of AN-124 (changed model)

AN 124 Oil Pressure Sensor Maintenance Key Performance Indicators Time units: hours		
Time per entity		
Average	Minimum	Maximum
15.4352	6.6982	23.9844
Wait time per entity		
Average	Minimum	Maximum
5.6743	1.8739	35.6292

From tables 1 and 2 above, a significant difference is observed in the waiting time per entity. With the initial structure and order, the average waiting time was about 15 hours; and after the structure and order was changed, the

average waiting time reduced to about 6 hours. In the same way there was a significant drop in the minimum and maximum value of time taken to maintain the aircraft using the changed model. Which means that compared to the initial model,



more aircraft can be maintained using the changed model.

CONCLUSION AND RECOMMENDATION

Aircraft maintenance and repair is a critical operation that enhances the operation and lifespan of the aircraft. The implementation of maintenance models as used in this work requires detailed, accurate information on the maintenance processes. A maintenance process involves the steps taken in maintaining a system or a component. In the case of this work, the object in consideration is the oil pressure sensor of AN - 124. The model presented in this work focuses on changing the structure and order of maintenance by a way of changing the order of the tacks and then increasing the number of Technicians to tackle the tasks. However, the data used in the model presented in this work could be improved to better fit dedicated situations. Rockwell Software's Arena Simulation System is a good option of a software than can be used to simulate different ways of changing the structure and order of maintenance process in order to make maintenance of aircrafts more efficient and less time consuming. And when the time required to maintain aircrafts is reduced, more aircrafts can be maintained within a given time resource, thereby making more aircrafts available for operation.

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