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Investigating Rate Increase in Aerospace Factory by Simulation of Material Flow Operations

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Abstract—The main challenge aerospace industries are facing in recent times has been triggered by the remarkable increase in commercial aircraft demand. To address this challenge, aircraft manufacturers need to explore ways to increase capacity and workflow through process optimisation and automation. This study focusses on the optimisation of component flow and inventory during the assembly of the A320 Family wings' at Airbus (Broughton, UK) plant through Discrete Event Simulation (DES).

This research measured the likely impact of future changes in the wing assembly process, using simulation by: mapping of component flow from delivery to the point of use, simulation of current logistics scenario (AS-IS), simulation of future logistics scenarios (TO-BE) that include proposed changes for optimising flow and managing capacity surge, and testing and validation of mapping and simulation. The developed DES model demonstrated the impact of changes planned to be implemented by showing a considerable increase in production capacity growth, by achieving a target of 50% increase of aircraft rate/month within one year. It also highlighted the main problems causing blockages and other non-value activities in the process.

Keywords— Discrete Event Simulation, Aircraft Manufacturing, Witness

1 Introduction

Airbus is a global leader in aeronautics, space and related services. According to Airbus' latest Global Market Forecast 2017, the world's passenger aircraft fleet is set to more than double in the next 20 years, and more than 10 years would be required to meet the current backlog [1]. In order to address this challenge, aircraft manufacturers need to explore ways to increase capacity and workflow through process optimisation and automation. This project utilised simulation for measuring the impact of future changes in the wing/spars' assembly process. The movement of spars, which is the main structural member of a wing, was chosen as the main object of study. Spars are the most structurally demanded components of the wing. They are located perpendicularly to the fuselage, attached to it and expanded towards the wingtip [2]. The single-aisle wings have two spars: the leading edge (LE) or front spar is located close to the front of the wing and the trailing edge (TE) or rear spar is located at two-thirds of the distance to the wing's rear.

Simulation models have the ability to predict behavior with a higher level of detail, making it possible to solve problems before they occur [3]. Discrete Event Simulation (DES), was utilized as a tool for system modelling, analysis and later lean implementation. It provides insight into the performance, capacity and constraints of a factory enabling manufacturers to perform changes to a factory model until the desired performance is achieved, with the expectation that the new-built factory or newly reconfigured production line is "right-first-time" thereby reducing the need to physically prototype the process. The research work involved the following steps:

i. Data gathering and material flow mapping by developing process chart of the LE/TE spar movements, starting from arrival of spar to Airbus plant and finishing at the final assembly points.
ii. Development of four simulation models for current and future scenarios:
   - AS-IS 1: Current scenario (Month 1).
   - AS-IS 2: Included changes suggested and represented shop-floor on Month +6.
   - TO-BE 1: Presented the to-be shop-floor scenario of Month +12.
   - TO-BE 2: Presented the to-be shop-floor scenario of Month +18.
iii. Analysis and evaluation of simulation models considering the Key Performance Indicators (KPIs) and the effect of adding extra shifts on Saturdays and Sundays.
iv. Validation and conclusions.

2 Methodology

2.1 Data gathering and material flow mapping

The spars LE and TE were the selected elements for study, which started with the unloading of the spars from the trailers, and finished when the assembled wings were taken out from the jigs. The on-site data was gathered by:

- Preparing flow-process charts for manufacturing activities, times and specifications
- Informal interviews with operators and documents related to the process.

After on-site data gathering, the material flow was mapped and visualized using process chart. Visualising the work process provided enough information about activities, relationships, flows, and hidden waste. It can bring a deep understanding and major breakthroughs in productivity and other performance [4].

2.2 Simulation models

The simulation models were built in WITNESS Horizon (Lanner Group, UK). The models were based on the data gathered on the floor shop and the information obtained from the logistic team including the tactical plan for the assignation of wings to jigs. The four simulation models are detailed as follows:

1. AS-IS 1 model: It represented the current scenario (Month 1) in the Airbus plant. It contained 212 elements including 130 variables to facilitate required performance of the model. This model was presented to Airbus and the suggested changes were incorporated in AS-IS 2 model.
2. AS-IS 2 model: This model included the suggested changes by Airbus and it presented the shop-floor scenario on July 2017. The main changes were:
   - Arrivals and launches: The number of trailers arriving per week was increased by 16% in one unit. An additional launcher was added in the storage area.
   - Incorporation of the Step Change line 1: Step Change is a fully automated assembly line that works as a jig. It consists of 7 stations, being able to hold 7 wings (14 spars). The number of paths increased by 21% in this model.
   - Shifts: Addition of shifts on Friday night, Saturday and Sunday mornings.
3. TO-BE 1 model: It included the changes that were planned to be implemented in the shop floor in January 2018. The main changes in this model were:
   - Arrivals and launches: The number of trailers arriving was increased by 33% per week. An additional launcher was added in the storage area.
   - Incorporation of the Step Change line 2: The Step Change line 2 is a replication of Step Change line 1. The number of paths increased by 35%.
4. TO-BE 2 model: Represented shop-floor scenario on July 2018. It contained 300 elements with 197 variables and 1164 lines of coding. The main changes were:
   - Arrivals and launches: The number of trailers arriving increased by 50% per week. A third launcher was added in the storage area.
   - Incorporation of Step Change line 3: The Step Change line 3 is a replication of Step Change line 1 and 2. The number of paths increased by 50%.

3 Results

The KPIs taken into account while extracting the results from the models were capacity (number of finished goods or throughput) and Work In Progress (WIP). For the four models, 8-9 different scenarios were tested and the top three displaying best results were chosen for further analysis. For each of these three scenarios, two additional variations were tested:

- Implementing the Saturday morning shift in the shed group (heavy gang, inspection and wing removal operators).
- Implementing the Saturday and Sunday morning shifts in the shed group.

The decision about best scenarios for further testing was a trade-off between the number of finished goods and the WIP. Thus, other parameters were taken into account, such as the percentage of idle time of the jigs and Step Change lines. The scenarios in which the highest idle time percentage was lower than 2% were considered. The maximum time spars spend in the storage area was also a measured index. The results were extracted by simulating for 30 weeks with a warm up period of 4 weeks.

3.1 AS-IS 1 Model

A set of variables was created to calculate the number of wings that went out of the jigs. These variables show the WIP and finished goods at any point while the simulation is running. The finished goods were classified by weeks and by north/south jigs. The results have been summarised in Table 1. The values corresponding to AS-IS 1 are presented in Table 1 as "100 units" and the values corresponding to other models (AS-IS 2, TO-BE 1, TO-BE 2) are presented relative to the AS-IS 1 values. As seen from Table 1, the number of spars waiting to be assembled in the jigs was more than 40% of the total WIP. The remaining 60% were being assembled in the jigs. Even if the percentage of idle time of the jigs was minimum (0.18%), it was noticed that the storage area was full. The average waiting time and maximum waiting time for spars to be transported to the jigs is represented as T and MT days. Upon presenting the model to Airbus for validation, it was suggested that an additional variable was created that would calculate the number of wings assembled per month.

Table 1. Summary of results from AS-IS 1, AS-IS 2 and AS-IS 2 + Saturday and Sunday shifts for 30 weeks. The values corresponding to AS-IS 1 are presented as "100 units" and the values corresponding to other models (AS-IS 2, TO-BE 1, TO-BE 2) are relative to the AS-IS 1 values

	AS-IS 1	**AS-IS 2**	**AS-IS 2 + Saturday shift**	**AS-IS 2 + Saturday + Sunday shift**
Finished Wings	100	122	124	125
Lead Time (minutes/wing)	100	81.6	80.8	80
Work in Progress (spars)	100	106	94	91
WIP Waiting (spars)	100	89	61	53
Jigs idle time (%)	[0 - 0.18]	[0 - 0.45]	[0 - 0.26]	[0 - 0.22]
Spars in storage area	100	100	50	21

Max spars in storage area	100	100	100	100
Average time in storage area (min)	T	0.69T	0.59T	0.56T
Max time in storage area (min)	MT	0.95MT	0.84MT	0.83MT

3.2 AS-IS 2 Model

As suggested by Airbus, this model included the variables that calculated the number of assembled wings per month. In this model, the average assembled wings per month increased by 22% in 30 weeks. Table 1 depicts the results obtained from AS-IS 2 model, AS-IS 2 with a Saturday morning shift, and AS-IS 2 with a Saturday and Sunday morning shift. In AS-IS 2 the lead-time decreased considerably compared to AS-IS 1. With the incorporation of the Step Change line 1, the WIP increased by 6%, and the number of spars waiting to be transported to the jigs decreased by 11%. Furthermore, the WIP decreased considerably when the Saturday morning shift was implemented. The percentages of idle time in both jigs and Step Change were less than 1.2%. With the implementation of shifts on Saturday and Sunday, the shed and storage were less congested, and the average waiting time of spars decreased.

3.3 TO-BE 1 Model

In this model, the average number of wings per month increased to 132, which stands for 66 set of wings per month. This throughput exceeds the 63 aircraft/month Airbus' goal. Table 2 depicts the results obtained from TO-BE 1 model, TO-BE 1 added with a Saturday morning shift, and TO-BE 1 added with a Saturday and Sunday morning shift. A comparison of Table 1 and 2 demonstrates an appreciable 15% increase in WIP. The reduction of WIP with the implementation of Saturday and Sunday morning shifts' was due to operators being able to transport spars to the jigs/Step Change and the wings out of them during the weekend. Hence, the storage areas were less congested, decreasing the average waiting time in the storage area by more than 50% and the maximum waiting time by approximately 16%. The implementation of the Saturday morning shift appeared to have a more significant influence on the results than the latter implementation of Sunday morning shift.

3.4 TO-BE 2 Model

In this model, the average number of wings assembled per month increased by 58%. The WIP rose up by 21%, higher than the data obtained from previous models. However, the number of spars waiting to be transported to the assembly points decreased by 25%. This was a result of the implementation of Step Change line 3, which increased the capacity of the assembly points in 14 spars. Table 2 depicts the results obtained from TO-BE 2 model, adding a Saturday morning shift to the model and adding both the Saturday and Sunday morning shift to the model. The lead-time showed a decrease compared to the previous models, but it did not variate significantly from one scenario to the other. The reason behind the decrease in WIP was that operators were able to transport the spars into the assembly points and the wings out of them during the weekend. In this model, the average time spars wait in the storage area decreased considerably, the storage area was less congested, and the buffer in the shed was not even used. Having more space on the shop floor makes the transport of spars between stations more fluent and blockages less likely to appear.

Table 2. Summary of results obtained from TO-BE 1, TO-BE 1 + Saturday and Sunday shifts, TO-BE 2, TO-BE 2 + Saturday and Sunday shifts. The values corresponding to AS-IS 1 presented in Table 1 as “100 units” and the values corresponding to other models (AS-IS 2, TO-BE 1, TO-BE 2) are presented relative to the AS-IS 1 values

	TO-BE 1	TO-BE 1 + Sat shift	TO-BE 1 + Sat + Sun shift	TO-BE 2	TO-BE 2 + Sat shift	TO-BE 2 + Sat + Sun shift
Finished Goods (Wing	139	140	141	156	157	158
Lead Time (min/wing)	71.7	71.1	70.9	63.9	63.5	63.3
Work in Progress (spars)	115	106	101	121	113	112
WIP Waiting (spars)	85	64	53	75	57	53
Jigs idle time (%)	[0 - 0.45]	[0 - 0.26]	[0 - 0.22]	[0 - 0.45]	[0 - 0.24]	[0 - 0.24]
Spars in storage area	79	50	20	58	41	20
Max spars in storage area	91	88	91	91	83	83
Average time in storage area	0.61T	0.5T	0.48T	0.5T	0.38T	0.37T
Max time in storage area	0.87MT	0.84MT	0.84MT	0.83MT	.74MT	0.74MT

4 Discussion and Validation

The initial AS-IS 1 model was presented to the Airbus logistics' team for validation and the proposed suggestions and expectations for the future scenarios were used as a baseline for the subsequent models. Figure 1 depicts the relative quantities of finished goods after 30 week simulation time. The implementation of the Saturday morning shift appears to make a significant impact on the increase in the throughput. According to Figure 1, by January 2018 (TO-BE 1), the production capacity is expected to increase by 41% as compared to the current scenario (AS-IS 1 model). The final model (TO-BE 2), shows that the production capacity would increase by 58% as compared to the current scenario. Figure 2 depicts the WIP records obtained after 30 week simulation time. The results are classified per model and scenario. The number of spars that can be assembled at the same time increases by 6% in AS-IS 2, 15% in TO-BE 1, and finally increasing up to 21% in TO-BE 2. Therefore, the number of spars in waiting decrease in line with the increase in WIP from one model to the other.

Fig. 1. Finished goods (wings) in 30 weeks per model and scenario

Analysis of WIP depicts an increase from AS-IS 1 to AS-IS 2, however, with the addition of additional shifts in ASIS 2 the WIP decreases. Addition of Saturday morning shift demonstrates a significant influence on WIP reduction, whereas a further addition of Sunday morning shift shows less significant influence on it. The WIP reduction leads to an increase in the idle time of the machines. Based on the results shown in Figure 1 and 2, the implementation of the Step Changes is highly beneficial for the growth of the company. However, a problem that could arise with the capacity increase is a poor management of the WIP, leading to blockages and delays in the production. Therefore, the WIP, more specifically, the amounts of spars waiting in the buffers and footprints should always be maintained to a minimum. The implementation of Saturday morning shift has proved to be the optimum solution as it offers a trade-off between low WIP and low idle time percentage of the jigs and Step Changes.

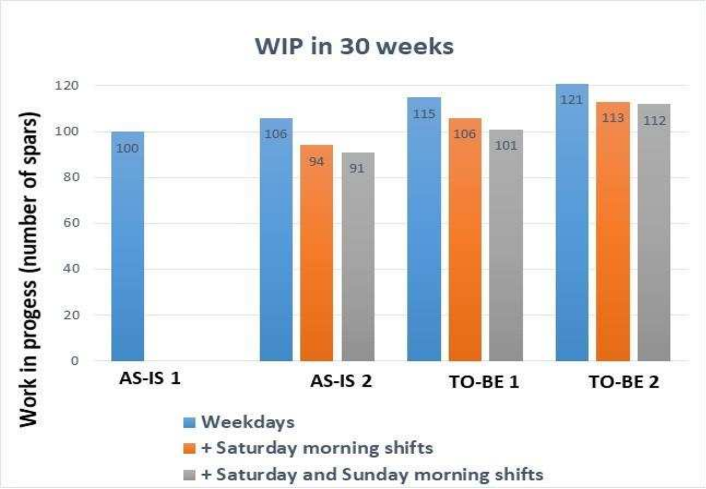

Fig. 2. WIP after 30 weeks of simulation time per model and scenario

5 Conclusions

This research measured the likely impact of future changes in the wing assembly process using material flow mapping and simulation of current and future logistics scenarios. The developed DES model demonstrated an increase in production capacity growth by achieving a target 50% increase in aircraft rate/month within one year. It highlighted the main problems causing blockages and other non-value activities.

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