Development of New System for Spare Parts Repair to Reduce AOG Situations in SAUDIA Special Flight Services Division

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.*Abstract:-* The Special Flight Services is a division of Saudi Arabian Airlines – SAUDIA, that operates small private jet aircrafts to serve government top officials and its distinguished guests, as well as charter flights for business companies. The SFS division has experienced lately a serious problem called AOG or Aircraft On Ground, which is the inability of the aircraft to fly due to a technical problem caused by the unavailability of the required spare parts to fix it. This paper summarizes the study that was conducted to resolve this problem. The goals of the study were to minimize the frequency of the AOG occurrences and to reduce the average AOG duration when they occur. The procurement and Stores departments were studied and their processes were analyzed to determine the root causes of the problem. The repair cycle of the spare parts was reengineered to make it shorter and more efficient; the critical spare parts were identified, their demand and their optimal stock quantity were estimated. The existing repair cycle was reduced from a total of 23 activities taking an average total time of 149 days to only 15 activities requiring an average repair time of 30 days; an enhancement of almost 80% in average repair time was achieved by reengineering the repair cycle. Seventeen critical parts were identified and few additional numbers of each part were needed to be on stock. These measures improved the problem and made it within acceptable normal level.

Key-words: - Inventory Management, Spare parts procurement, Aircraft Maintenance, Aircraft on ground (AOG)

1 Introduction

Special Flight Services (SFS) division was established in 1976 by Saudi Arabian Airlines specifically for providing fleet services to the government officials and VIPs. Presently, SFS employs 15 aircrafts and is considered as an independent company in terms of airlines standards. It has all departments that are usually found in an airline, such as flight operations, flight services, maintenance, planning, etc. The Special Flight Procurement and Store (SFPS) is one of the departments that ensures the availability of the right quantities of material at the right place and at the right time. It is mainly responsible for repair and maintenance of the aircrafts. SFPS consists of two major departments i.e. Procurement and Stores. The objective of procurement is to buy two types of parts i.e. repairable and expendable. In the event of malfunctioning of the aircrafts these parts are needed for their proper maintenance. Repairable parts are those which are repaired either within the kingdom or outside and expendable parts are those which are used only once and after their use they are disposed off. The responsibility of the store is to maintain adequate stock of the purchased parts to make them readily available as soon as they are demanded. It has been observed that SFPS management frequently encounters the problem of Aircraft on Ground (AOG). The term AOG represents a situation where an aircraft becomes unexpectedly idle and is unable to fly due to either some technical problems or failure of its a few critical repairable parts. In case an AOG occurs, the aircraft comes to a halt, becomes out of service for a considerably long time and cannot resume service unless defects are removed. If the parts required to replace the failed parts of the aircraft are not available in the store, SFPS management strives hard to procure them as soon as possible and at any cost. It has been also observed that the basic reason for long waiting time of AOG is the unavailability of parts required to replace the broken parts of the aircraft in the store. In this situation the maintenance people can do nothing with the defect except wait for the required parts. As long as the aircraft waits for the replacement of the failed parts, its schedule is cancelled and its load is transferred to another aircraft. It has been further observed that the main factor responsible for long waiting time of AOG is the complex nature of the repair cycle being followed by the SFPS management to fix the repairable parts. It is believed that the frequency and the duration of AOG may be minimized by reengineering and simplifying the processes within the repair cycle.

1.1 Literature Review

The literature is rich with numerous studies on spare parts planning and management. This problem has great importance because of its impact on the operation of equipment and the productivity of the relevant processes and systems. The financial investments and the inventory management of spare parts are two other dimensions that make this problem of vital importance for many companies, particularly those that have some critical operations. Spare parts procurement and inventory management were the topics of many studies in the literature [1-5]. Sigrid L.N. studied the problem of finding the optimal inventory level for components in an assembly system where multiple products share common components in the presence of random demand [6]. In another study, Strijbosch L. W. G. et al, examined the performance of two different (s, Q) inventory models; namely a simple and an advanced model, for spare parts in a production plant of a confectionery producer in the Netherlands. The results of this study showed that the advanced approach yields a service level close to the desired one under many circumstances, while the simple approach is not consistent, in that it leads to much higher inventories in meeting the desired service level for all spare parts [7]. Other studies focused on the maintenance planning and management and highly considered the importance and availability of spare parts on equipment operation and the smooth execution of the maintenance activities [8-9]. In a study by Sheut C., et al, a decision model was proposed to assist in a comparative evaluation of alternative corrective maintenance policies. A simulation model was developed to predict inventory costs and delivery performance of a corrective maintenance policy in various production systems. The results of a case study demonstrated the decision model's capability to assist managers in selecting the best corrective maintenance policy [10]. Some other studies used simulation as a technique to study the problem in an integrated system context; the procurement function, inventory, demand and spare parts usage and the maintenance function were considered collectively in the simulation studies [11-12]. In a study by Duffaa S.O. et. al., the elements of an integrated simulation model for effective planning of maintenance operations for SAUDIA was described. The integrated model consisted of several modules; mainly, planning and scheduling, organization, supply, quality control and performance measures. The study also outlined the utility of such a model for SAUDIA [13].

2 Problem Descriptions

The Special Flight Services (SFS) is a division of Saudi Arabian Airlines – SAUDIA. It is considered as a small independent airline within Saudia because, it has all technical and operations departments like the main airline and it is managed independently. The division has 15 small jet aircrafts, mainly 13 Gulfstream and two Falcons. This fleet serves mostly government top officials and distinguished guests. The fleet also operates charter flights to companies and businessmen.
Aircraft On Ground (AOG) is a situation where an aircraft is incapable to fly due to technical malfunctioning of one or more of its parts and due to the unavailability of these parts on stock for its replacement. SFS fleet has experienced lately a high number of AOG situations within the last two years. The average duration of AOGs when they occur has also been increasing. When an AOG occurs SFS management tries very hard at any cost to find the needed parts to remedy the situation to get the grounded aircraft flying again back on schedule. This problem not only causing a great embarrassment to SFS top management with the government, its distinguished passengers and Saudia top management, but also lots of interruptions in the flight schedule and a continuously increasing maintenance and operations costs.

2.1 The Scope of the Study
To study this problem which the SFS division was facing, the procedures of the aircraft maintenance departments were studied and all relevant data was collected. The procedures of the procurement and Stores Departments were also be studied and all relevant data was collected. Data on the broken parts that were causing the problem as well as data on the AOG situation were collected. Data on the repair procedures and the spare parts inventory werw collected as well. The operations department was not be considered in studying this AOG problem.

2.2 Goals of the Study
Two goals were set for this study , these were mainly:

a) to minimize the number of the occurrences of the AOG situations per year.
b) To decease the average duration of the AOG situations when they occur.

By achieving these two goals, it is hoped that the impact of the AOG problem will be minimized and that SFS Division will have a smoother flight schedule and lower maintenance and operation costs.

2.3 Objectives of the Study
To achieve the goals of the study the following objectives were defined:

1. To study and analyze AOG situations to identify the critical parts that were causing the AOG.
2. To track the usage of those critical parts to determine their real demand.
3. To study the repair procedures to determine the average cycle time for repairable parts.
4. To study the stores department procedures and inventory management of the spare parts to determine the optimal quantities of the critical parts.

It is believed that accomplishing the above objectives will lead to achieving the goals of the study.

3 Methodology

To accomplish the objectives of the study and achieve its goals the following methodology was devised:

1. Study and analyze all relevant processes related to the aircraft maintenance.
2. Study and analyze all relevant processes within the Stores Department.
3. Study and analyze all relevant processes within the Procurement Department.
4. Identify and collect necessary data of major activities and all relevant processes.
5. Study and analyze current repair cycle to fix any problems and improve any deficiencies.
6. Redesign and improve all relevant processes to shorter and more efficient.
7. Design a complete solution to implement all improvements, results and recommendations.

By executing the above methodology, it is believed that the root causes of the problem would be discovered. The proper solutions to those different problems would be developed and the main problem will be resolved.

4 Current System

The current aircraft maintenance system was thoroughly studied and four main relevant processes were identified. These are:

1. Air craft maintenance process to replace all defected parts that grounds and halts the aircraft from flying. All relevant processes in the air craft maintenance should be identified and the major ones should be studied in details to understand all the steps within the process, the kind of work being performed in a step, the time required to execute it and the total time taken to complete the process. All resources such as manpower, equipment, spare parts and material that were used in every step of the process should be identified and recorded.
2. The inventory management processes in the stores section of the Materials management Department. Major processes in the Stores department were identified and thoroughly analyzed

in order to find how well the department was performing its role within the aircrafts maintenance and the fleet operation. Some of the most important data collected was the fast moving spares, the slow moving parts and their average stock level. The critical parts, are those parts that are fast moving and their stock level is so low or almost out of stock for long durations of time in such a way that is not meeting the actual demand and therefore, causing the AOG situations. The reorder points, reorder quantities and the lead times of those critical parts were determined.

3. The main processes of the spare parts procurement in the Materials management Department were studied and analyzed. Policies and procedures were reviewed, vendors records and parts records were studied and repair orders were traced. Inefficiencies were identified and unnecessary delays were detected. Vendors' performance was evaluated and orders data were collected.
4. The repair cycle process with all its sub-processes were also studied and analyzed to determine steps involved, work performed and time required to execute every step. Policies and procedures were also identified and reviewed and recommended changes and improvements were made.

4.1 AOG Data

Data on AOG situations were collected over a one year period. Data on a total of 232 AOG situations were collected. The data collected included: date of AOG occurrence, AOG log number, number of parts required to resolve the AOG, aircraft number, aircraft type, aircraft model, part description, part stock ID number in SPFS, name of the system where the part belongs to, number of the system where the part belongs to, number of purchase order(s) used to resolve the AOG, AOG end date and AOG duration.

These data were statistically analyzed and the parts with the most repeated failures were identified. The number of times each part and the percent of times in relation to the total number of AOG failures over one year period were estimated. The total number of those critical parts was seventeen and their total percent failure was estimated at 30% over one year period. If the same part failed repeatedly on the same aircraft, a further special investigation was conducted on the aircraft itself and its operation. If the same part recorded repeated failures on different aircrafts, this triggered further investigations on the part itself; its reliability, maintenance and installation procedures.

AOG statistics for each aircraft over one year were estimated. Those statistics included; number of times an aircraft experienced AOGs, number of parts that caused the AOG, the number of parts that recorded repeated failures, the average AOG duration for each aircraft and the overall average AOG duration for all of the 15 aircrafts.

Table 1 – Summary Statistics of so important AOG variables

	Failure Occurrence	**Failure Frequency**	**Time Between AOG Occurrence**	**AOG Duration**
Distribution	Exponential	Weibull	Gamma	Exponential
Expression	0.5+Expo(0.868)	0.5+Weib(1.98,1.32)	0.5+Gam(7.38,1.45)	-0.5+Expo(1.92)
Square Error	0.003199	0.003831	0.016556	0.002357
Test Statistic	2.38	7.21	63.5	2.91
P-Value	0.0944	0.0281	0.005	0.577
No. Of Data Points	269	227	209	250
Min. Data Value	1	1	1	0
Max. Data Value	4	11	57	18
Sample Mean	1.37	2.31	11.2	1.42
Sample Std. Dev.	0.693	1.51	10.6	2.13

The full year data set was statistically analyzed to identify the distributions of some important variables, such as, Failure Occurrences, Failure Frequencies, Time between AOG Occurrences and AOG Duration. Table 1 shows the summary statistics of these variables

4.2 Current Repair Cycle

The current repair cycle to fix defected repair spare parts was studied and thoroughly analyzed. Each activity in the cycle was identified, analyzed and its time was estimated. The cycle consisted of 23 activities that are executed in a total average time of 149 days. Table 2 shows all 23 activities with their average durations and the overall cycle time. Figure 1 shows the flowchart of the current repair cycle.

Table 2: List of activities along with their time.

Step No.	Activity performed	Time consumed (Days)
1	SFS technicians removed the broken parts from the air craft. This is the starting point of the repair cycle and the time consumed in other steps was recorded from this point.	0
2	The removed parts were delivered to the repair control section (R&R) of the SFPS.	6
3	Repair control section (R&R) sent information about these parts in the form of tags to SFPS administration.	1
4	Administration recorded the information and sent the tags and to SFS engineering section.	1
5	Engineering section decided where to send the parts for repair and returned tags back to SFPS.	5
6	SFPS administration updated records and sent tags to R&R	1
7	The R&R section forwarded the tags to SFPS procurement-repair section.	1
8	Repair section placed repair order and waited for purchase order (PO) documents.	5
9	PO documents were sent to R&R.	1
10	R&R section handed over parts and documents to shipping section.	1
11	Shipping section transferred parts to Saudia cargo and shipped on first available flight (FAF).	14
12	Contractor carrier delivered parts to the discrepant vendor.	16
13	Vendor evaluated the parts and sent estimated repair cost quotation to regional procurement office (RPO)	24
14	RPO agent updated maintenance and engineering management system (MEMIS) and faxed the quotation to SFPS repair section.	3
15	RPO sent quotation to SFS technical to get approval.	3
16	RPO received and updated MEMIS with repair charges.	5
17	Vendor completed repair and dispatched parts to RPO.	15
18	RPO received and shipped parts to Saudi Arabia.	14
19	Saudi custom cleared shipment from the divisional custom.	7
20	Main receiving cleared materials management's parts	7
21	SFPS received/collected SFS materials.	5
22	SFS inspector tested and accepted the parts.	5
23	Inspector closed the PO and transferred the repaired parts to SFPS store.	9

From the study and analysis of the processes of the current system the following findings were revealed:

1. The Maintenance department with all its subsections was performing their work satisfactorily and was not causing any delay in maintenance that might result in an interruption to the aircraft flying schedule.
2. The main reason that is causing the AOG situation is the unavailability of spare parts that are needed by maintenance to replace the broken parts on the aircraft and that what was causing AOG. It was further found that the parts were classified into two categories:
   - Disposable Parts – those are the parts that are not repairable and are disposed of after their broke down
   - Repairable parts – those are the parts that gets repaired after they broke down and are used again
3. The stocks of some disposable parts are not available in optimal quantities, because of the nature of use of these parts.
4. The average repair cycle time to repair broken repairable parts is very large.
5. Some of the repairable parts can be fixed locally but the majority are shipped to Europe and USA for repair
6. Several departments are involved in the process of parts repairs; mainly Maintenance, Stores, Engineering, Procurement and Shipping.
7. No accountability on delays in any of the departments including vendors; therefore follow-up and control almost does not exist.
8. Lack of communication between all departments, vendors and all parties involved.
9. No tracking system available to follow up the broken parts in their repair process.

These findings have clearly explained the causes of creating the AOG situations in such a frequent manner and the average long duration of an AOG when it occurs.

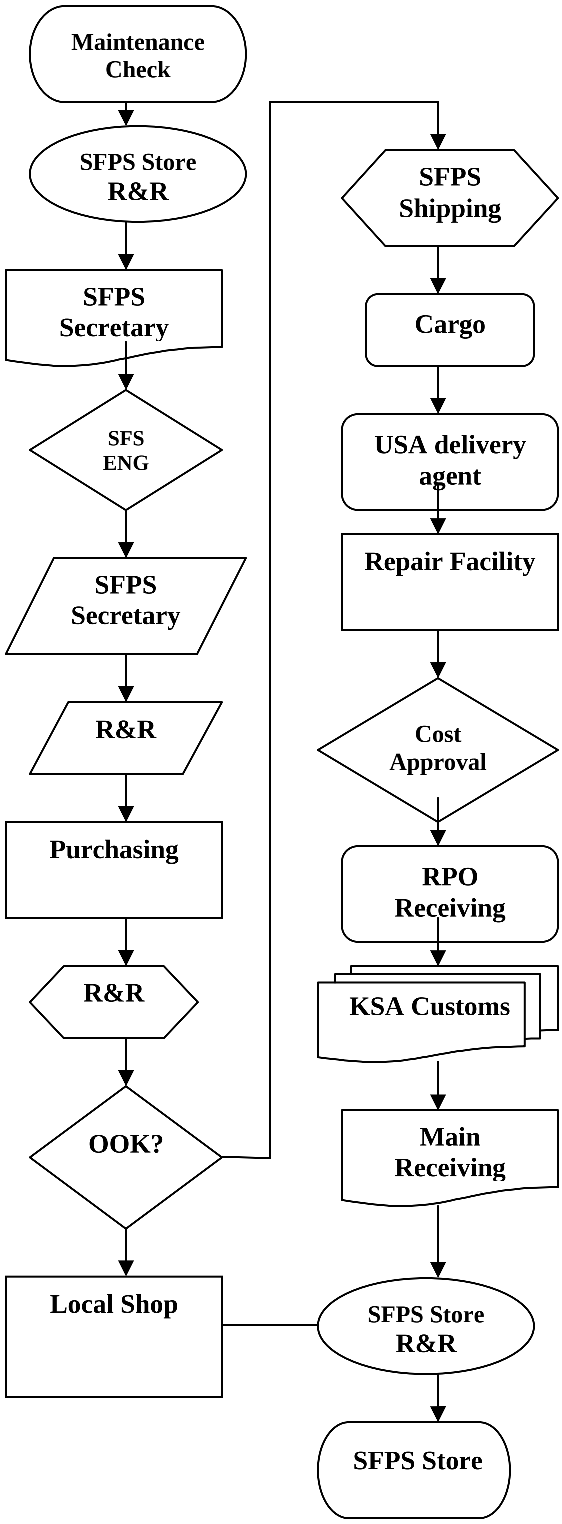

Fig.1- Existing Repair Cycle

5 New System

After the current system was thoroughly studied and reasons that were creating AOG situation were identified, all relevant processes were reengineered to make them more efficient by eliminating some unneeded activities, combining some, shortening the remaining ones, and setting a standard time for the duration of every activity in all relevant processes. solution To develop a solution for the AOG problem the following five techniques were used:

1. Reengineering the Spare parts repair cycle.
2. Developing a Repair cycle Tracking Application (RCTA)
3. Estimating the optimal stock quantity of the critical parts that were causing the AOG in both categories; the disposable and repairable parts.
4. Setting some new policies, standards and developing new procedures.
5. Improving communication channels and network within and outside SFS

5.1 The Proposed repair Cycle

The existing repair cycle was reduced from a total of 23 activities to only 15 activities in the new cycle. Further, the time duration of each activity in the proposed cycle was estimated and standardized. All relevant procedures were clearly stated and the whole process was smoothly tuned. The new reengineered cycle consisted of 15 activities that can be executed in a total average time of 30 days. The reengineering effort has reduced the cycle by 8 activities and the average cycle time by 80%. Figure 2 shows the flowchart of the proposed repair cycle. The activities of the new proposed repair cycle were arranged into four phases:

Phase I – SFPS administration issues orders to complete all documents required for shipping the defective parts out of kingdom for repair. The time required to complete the activities of this phase was estimated and standardized to three days only. The major activities of this phase are:

- The maintenance technicians have to return the broken parts that have been removed from the affected aircraft in a maximum time of 8 hours.
- The stores personnel have to record immediately the parts relevant data and send the parts to packing for shipping.
- Purchasing department is notified to place the repair order

Phase II – The failed parts should be delivered to the vendor within seven days.

- Prior notification and coordination of shipment delivery with carrier agent
- Daily follow up and update on shipment status

Phase III – The vendor ships back the repaired parts in a maximum of fifteen days.

- Prior communication and coordination with vendor to schedule work of defected parts
- Fast receipt of repair quotation and processing of work authorization
- Periodic follow up and updates on parts repair status

Phase IV – The repaired parts should be received at SFPS store within five days.

- Prior scheduling of the delivery date of the repaired parts
- Prior coordination the shipment delivery with the carrier agent
- Monitoring and expediting shipment of repaired parts.

5.2 Repair Cycle Tracking Application

As part of the new solution for the AOG problem, an application was developed to automate the processes of the reengineered repair cycle, to track and monitor all activities in the different sections of SFPS. The application was developed using MS Access and the Structured Query Language (SQL) programming language. The main Screen of the application contains five branches representing five programs; these programs are developed for the four sections of SFPS, mainly, Stores, Procurement, Shipping and Receiving; and the fifth program in the application was designed for Reports generation. The RCTA was designed to generate 10 reports and more reports can be easily added as needed by users. The RCTA database was designed to contain all data related to the repair orders of the defective parts. Each order data has all movement data of the defective parts in the repair cycle. The application users in the different sections are supposed to enter data of the undertaken activities relevant to the defective parts in their respective sections. A repair order is a record in the RCTA database. A repair order is considered open in a section of SFPS until all activities of the part being processed in that section are complete. When the processing of all activities are completed the repair order is considered closed for that section. In this way, the RCTA is recording the time each section takes to complete the process of a defective part and thus monitors all delays caused by any section. Some of the benefits that was realized from the development and implementation of the RCTA include:

- It linked all relevant sections of the repair cycle and integrated their work
- It generated the needed information at the right time with the right quality
- It helped the users to make the right decision and take necessary actions at the right time
- It preserved all data of the repair orders in a central reservoir and made it sharable to all respective users.
- It saved lots of time by eliminating paper work and automated the processes
- It improved communications links among all parties involved and increased SFPS sections efficiencies and effectiveness.

5.3 Critical Parts Analysis

After the implementation of the RCTA for one full year, data on the repaired parts was collected. This data along with the original data – one year data – which was collected on AOG, was analyzed to identify the parts that caused the AOG. These critical parts are those parts that are causing frequent AOG's because their quantities in stock were not enough to prevent a zero stock situation in the store. After the critical parts were identified additional data relevant to these parts were collected. The additional data included the following:

- Number of AOG's caused by these parts
- Number of spares for each of the critical parts SFPS has in stock to support the maintenance of the fleet
- The number of units of each critical part used by an aircraft and the number of aircrafts that use that part.

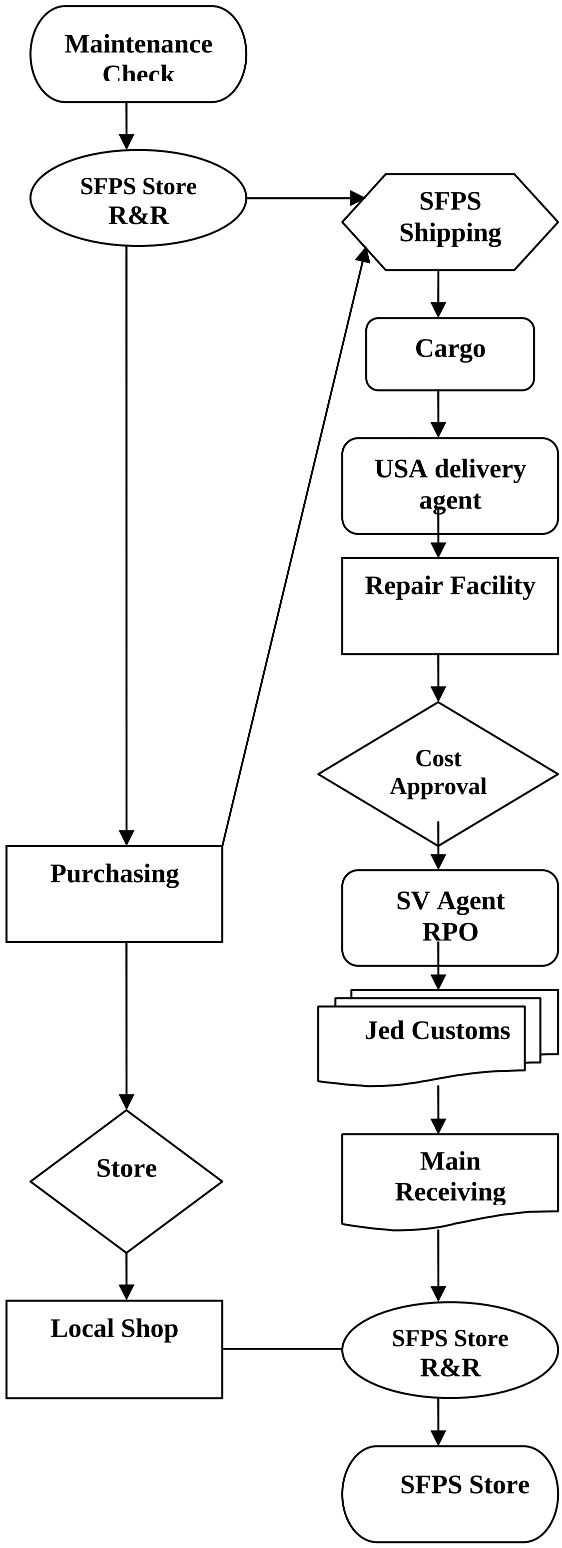

Fig.2- Proposed Repair Cycle

- The average Repair Cycle Time (RCT) for each of the critical parts; that's the average time that the part takes for repair from the time it is shipped out to the vendor till it is received in the Stores section.

The above information was used to calculate the additional number of parts required to be added to the current number of units in the stock for each of the critical parts. The new stock level for each of the critical parts should be sufficient enough to prevent a stock out event on these critical parts as much as possible. From this study and analysis – of two years data – seven parts were identified as critical and the total number of additional units that were required to be added to the stocks of these parts were determined to be 21 units.

5 Results

The study and analysis of the relevant process of the aircraft maintenance in the Special Flight Services Division of Saudia to identify the causes of the frequent occurrence and long durations of the AOG situations revealed the following findings:

1. In the new system, the repair cycle became shorter, simpler and more efficient which reduced the shortage of spare parts that caused the AOG. This was realized by reengineering the current repair cycle which would have a great impact on the AOG problem which is the main problem of this study.
2. This study streamlined the daily processes and created better environment for the employees and increased their productivity. This was realized by revising, improving and setting relevant policies and procedure of all departments and processes involved and improving the communications within and among departments.
3. It was easier to identify good and bad vendors. The enhancement of the communication links, prior coordination with vendors on new repair orders and in process jobs along with the implementation of the Repair Cycle Tracking Application [RCTA] have enabled the process of evaluating the vendors' performance and the identification of good and bad vendors.
4. The number of AOG's would be reduced. It is expected that the number of AOG's and the average duration of the AOG's will be greatly reduced due to the availability of the needed spare parts in stock. Availability of the parts was realized because of the faster repairs of the defected parts, due to the shorter more efficient reengineered repair cycle and the replenishment of the additional critical parts needed in stock, achieved by the estimation of the optimal quantities to meet the actual demand.

7 Conclusions

- In this study an attempt was made to reengineer the repair cycle used by the SFPS in order to simplify the repair cycle and to reduce the repair time of the failed parts that caused the AOG.
- The repair time of the broken parts was reduced from 149 days to 30 days i.e. a substantial improvement of almost 80%.
- Other major improvements achieved by reengineering in this study are:
  1. The process of returning the parts that can not be repaired within the kingdom by the maintenance technicians to the store became faster by 80%.
  2. The processing of the defected parts that were the main cause for AOG became faster by 90%.
  3. Recovery of depleted parts stock was improved by 95%.
  4. Shipping process of the broken parts outside Saudia became faster by 80%.
  5. The process of initiating repair order for failed parts became faster by 90%.
  6. The delivery time of the parts to the vendor was reduced by 80%.
  7. The time required for receiving repair quotation from vendor was reduced by 90%.
  8. The delivery time of the repaired parts was decreased by 80%

  The above estimates were calculated by comparing the time duration of the activity in the new improved repair cycle with the time duration of the same activity in the old/current cycle.

- All relevant policies and procedures within all concerned departments related to the AOG problem, spare parts repairs, parts shipping, procurement and stores were revised, enhanced and new ones were developed and implemented.
- All critical parts that were causing the AOG were identified and their optimal quantities were estimated to meet their real demand.
- The development and implementation of the RCTA have made repaired parts data along with the repair cycle data readily available to all relevant staff in all involved departments which made parts tracking, information sharing and decision making very easy.

References

[1] A. Benaouda , N. Zerhouni, M. Mostefai,'A Preventive Interaction Model Applied to the Management of spare Parts,' WSEAS TRANSACTIONS on SYSTEMS, Vol. 4, No. 1, January 2005.

[2] Pao-Long Chang, Ying-Chyi Chou, Ming-Guang Huang,' (r,r,Q) inventory model for spare parts involving equipment criticality', International Journal of Production Economics, Vol. 97, No. 1, July 2005, pp. 66-74.

[3] Thomas R. Willemain, Charles N. Smart, Henry F. Schwarz,' A new approach to forecasting intermittent demand for service parts inventories', International Journal of Forecasting, Vol. 20, No. 3, July-September 2004, pp. 375-387.

[4] Adel A. Ghobbar, Chris H. Friend,' Evaluation of forecasting methods for intermittent parts demand in the field of aviation: a predictive model', Computers & Operations Research, Vol. 30, No. 14, December 2003, pp 2097-2114.

[5] Massimo Paolucci, Roberto Revetria, Flavio Tonelli,' An Agent-based System for Sales and Operations Planning in Manufacturing Supply Chains', WSEAS TRANSACTIONS on BUSINESS and ECONOMICS, Volume 5, Issue 3, 2008, pp 103-112.

[6] Sigrid Lise Nonås,' Finding and identifying optimal inventory levels for systems with common components', European Journal of Operational Research, Vol. 193, No. 1, February 2009, pp. 98-119.

[7] Strijbosch L. W. G., Heuts R. M. J., Van Der Schoot E. H. M.,' A combined forecast : inventory control procedure for spare parts : Modelling and analysis in supply chain mangagement systems', The Journal of the Operational Research Society, vol. 51, No 10, 2000, pp.1184-1192.

[8] Davorin Kralj Drago BOKAL, Marjan SMON,' New Methods of Maintenance of Electricity Devices in Hydroelectric Power Stations and their Influence on Reliability and Costs and Environment', WSEAS Int. Conf. on ENVIRONMENT, ECOSYSTEM and DEVELOPMENT, Italy, November 2005, pp. 66-71.

[9] Ruhul Sarker, Amanul Haque,' Optimization of maintenance and spare provisioning policy using simulation', Applied Mathematical Modelling, Vol. 24, No. 10, August 2000, pp. 751-760.

[10] Sheut C., Krajewski L. J.,' A decision model for corrective maintenance management', International Journal of Production Research, Vol. 32, No. 6, June 1994, pp. 1365–1382.

[11] Masood A Badri,' A Simulation Model for Multi-Product Inventory Control Management', SIMULATION, Vol. 72, No. 1, 1999, pp. 20-32.

[12] Loo Hay Lee, Suyan Teng, Ek Peng Chew, I. A. Karimi, Kong Wei Lye, Peter Lendermann, Yankai Chen, Choon Hwee Koh,' Application of multi-objective simulation-optimization techniques to inventory management problems', Proceedings of the 37th conference on Winter simulation, 2005, pp. 1684 – 1691.

[13] Duffuaa S. O.; Andijani A. A.,'An integrated simulation model for effective planning of maintenance operations for Saudi Arabian Airlines (SAUDIA)', Production Planning and Control, Vol. 10, No. 6, 1 September 1999 , pp. 579-584(6).