

Study to Determine the Aircraft on Ground (AOG) Cost of the Boeing 777 Fleet at X Airline

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Abstract

A research was conducted to study and investigate AOG events and cost in X Airline B777 fleet. AOG data was gathered for one year; this set demonstrated that the X Airline B777 fleet experienced 146 AOG events during this period. The critical parts that were causing AOG were distinguished out of this set; 115 parts were causing the AOGs. ABC Analysis was conducted to this set considering three dimensions; Aircraft, part number, and ATA chapter. Regarding first dimension, this analysis shows that the critical AOG Aircraft are 7 aircrafts out of 28 which represented 25% of the number of Aircraft that experienced AOG events had 45% of total AOG occurrences. Regarding ATA chapter, the full set of AOG was sorted by ATA chapters and this analysis showed that 7 chapters out of 26 which represented 27% of the chapters had 50% of total AOG occurrences. As for ABC analysis for part numbers, this analysis revealed that 25 parts were causing 91% of the AOGs cost. A second ABC analysis was led on 25 parts set revealed that 7 parts were the most important that were causing 54% of the AOGs occurrences. All critical part numbers consider as Rotable material. After analysis the data, the average replenishment cost for AOG situations were estimated around \$8,785.36 and the average flight delay cost is \$22753.53. This research was let to comparing X Airline results with other Airlines and tries to know the common and different elements between X Airline and other Airlines in Middle East by sending questionnaire to the Middle East Airlines. The main factors that affect AOG cost were determined and ranked by using AHP (*Analytic Hierarchy Process*) to reduce AOG cost. It was applied based on the method of decision support and questionnaires answered by experts.

Keywords: Aircraft Maintenance; AOG; ABC Analysis; ATA Chapter.

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1. Introduction

The major goal of MRO “Maintenance, Repair, and Overhaul” is to ensure that the aircraft in operative condition before the flight.

Regarding to the importance of the maintenance, it is also desirable to consider the spare parts to be a major component of the maintenance processes. Due to any failure in providing spare parts for the aircraft, this will lead to situation called “Aircraft on Ground” (AOG). AOG is a term in aviation maintenance indicating that a problem is serious enough to prevent an aircraft from flying. Generally to return the aircraft into the service, the airline need to provide the part immediately to fill these requirements, otherwise it will lose its profit and its reputation. AOG applies to any aviation materials or spare parts that are needed immediately for an aircraft to return to service. AOG suppliers refer to qualified personnel and dispatch the parts required to repair the aircraft for an immediate return to service. Mitigation of AOG status when an aircraft "goes AOG" and materials required are not on hand, parts and personnel must be driven, flown, or sailed to the location of the "grounded Aircraft". Whether you have one plane placed in airplane on ground status, or many planes that cannot fly, your business can be affected due to lost revenue, increased commercial airline costs and delays in getting supplies where they are needed. For this reason, it is critical to have an aircraft maintenance partner that can get your planes in the air as quickly as possible. The only thing that can differentiate AOG orders is the urgency, when an order placed under AOG category from procurements, this mean the part must be available as soon as possible. There are several ways to acquire parts through AOG, if there is an existing repair order, the airline must pay more and expedite the delivery, if there is no repair order, the airline search for new purchase order but it must be through AOG desks which are located around the world. The AOG cost can be divided into two sections, the first section refers to technical cost and it includes:

- Part replacement /repair cost
- Part shipping cost
- Sup part replacement cost
- Labor cost

The second section refers to operational cost and it is related to all the cost that Airlines bear due to AOG situation and not related to maintenance cost which includes:

- Taxing cost
- Crew cost
- Transportation cost
- Accommodation cost
- Meal cost
- load/Reload Bags cost
- Catering cost

1.1. Literature Review

Many studies had been published about categorizing the importance of AOG and spare parts. To find the critical part that causes the AOG with most frequency, there are some techniques and categories as shown in below studies.

Azim Baluch, Che Sobry Abdullah, and Shahimi Mohtar , Azizah Aisyati, Wakhid Ahmad Jauhari & Cucuk Nur Rosyidi studied and evaluated best practices in the Maintenance Repairs & Overhauls, discussed the ABC classification scheme. They used ABC analysis to classify the spare parts. ABC analysis classifies the parts into three categories “ A which has low percentage of items and high percentage of usage, B which has medium percentage of items and medium percentage of usage, and C which has high percentage of items and low percentage of usage. The criteria applied based on the cost of the part in the frequent during last years. The parts can be classified into classes; the steps of ABC classification are described as follows:

- Listing the spare parts and their demand.
- Determining the contribution of the spare part by multiplying the demand for each item and the value or price of item.
- Computing the percentage of spare part contribution by dividing the contribution of each spare part with the total contribution of the spare parts.
- Sorting the spare parts so that the percentages of spare part contribution are listed from higher value to lower value. The category of spare part could be found by using the above description from [1].

Seraj Yousef Abed developed a New System for Spare Parts Repair to Reduce AOG Situations in SAUDIA Special Flight Services Division. Minimize AOG achieved by study and diagnose all AOG situations and find the most critical parts that caused most frequent AOG. Analysis of AOG per aircraft, per ATA chapter conducted to find the criticality and statistics applied on aircrafts AOG appearances. The results of the study showed a reduction in the repair time by 80% [2].

T. Rad, N. Shanmugarajan Loblaw examined the Classification of Critical Spares for Aircraft Maintenance. The objective was to concentrate on using so as to order save parts into three gatherings customary, investigative chain of importance procedure ,and data envelopment analysis (DEA) strategies in light of components connected with extra parts unit value, utilization rate, lead time, and unwavering quality. Results demonstrate that it is worthwhile to utilize DEA strategy to arrange the stock [3].

Abdul Qadar Kara, John Ferguson, Karla Hoffman and Lance Sherry studied Estimating Domestic U.S. Airline Cost of delay based on European Model. In this paper, they detail a method for calculating the cost of delays to an airline. The methodology broadens an EU report that ascertained deferrals for three option situations (minimal effort, gauge costs and high expenses) and for short defers (under 15 minutes) and long defers (more than 65 minutes).

This paper shows the reasons of flight delayed in the following points:

- Mechanical problems with the aircraft.

- Schedule disruption due to bad weather or air traffic management initiatives (Ground Delay Programs (GDPs) or Air Flow Programs (AFPs)).
- Misaligned crew/ aircraft due to previous delayed flight [4]

Bacchetti¹, F. Plebani¹, N. Saccani, A.A. Syntetos examined Spare parts characterization and stock administration a contextual analysis. A dialog of various leveled multi-criteria save parts order technique produced for stock administration purposes and tried through an escalated contextual analysis in an Italian family machines fabricating organization. An outlines demonstrated that the scholastic writing worried with characterization related issues for extra parts administration [5]

Azizah Aisyati, Wakhid Ahmad Jauhari & Cucuk Nur Rosyidi studied how to manage the inventory level for spare parts on class A and B which commonly known as important classes. The parts can be classified into classes; the steps of ABC classification are described as follows:

- Listing the spare parts and their demand.
- Determining the contribution of the spare part by multiplying the demand for each item and the value or price of item.
- Computing the percentage of spare part contribution by dividing the contribution of each spare part with the total contribution of the spare parts [6]

Michael MacDonnel, studied Aircraft Rotable Inventory Optimization. The question is how to find an optimization for the planning of spare parts levels used in the support of aircraft operations. In particular, the model addresses the problem of planning ratable inventory [7]

Mark J. Tedone from studied the problem of Repairable Part Management. He described the work conducted by American Airlines Decision Technologies to provide decision support in the area of routable part management. He started by describing if the aircraft landed and a failure occurred to any repairable part, the part will be removed and replaced with a serviceable one from the stock room [8]

2. Problem Description

X Airline incurs a lot of costs due to aircraft maintenance process. Some of which is scheduled for maintenance and the others are non- scheduled maintenance issues. Both of them rendered the aircrafts to become out of service for periods of time. The unscheduled aircrafts come suddenly for maintenance for several reasons e.g. parts malfunctions leading to a situation called Aircraft on Ground (AOG). This situation makes the aircrafts unable to fly and X Airline will bear all the expenses resulted from this situation. This study will help X Airline to estimate and evaluate these expenses in order to reduce or prevent the AOG situation in the future.

2.1. Goal of Study

To determine the average cost incurred due to an AOG occurrence in Boeing 777 Aircrafts at X Airline.

2.3. Objectives of the Study

- Study and diagnose all AOG's cases.
- Identify and analyze all parts that are causing most frequent AOG in each Aircraft.
- Determine the average time for out of service Aircrafts
- Study the cost impact of different AOG's cases.

2.4. Constraints \limitations

- Too much time for collect the data from different departments and questioners.
- Confidential and sensitive information collection.

3. Methodology

To accomplish the objectives of this study, the following methodology was devised:

- Collect the required AOG data.
- Identify the frequency of AOG for each part number.
- Rearrange the data into three categories, Data based on Aircraft, Data based on ATA chapter, and Data based on Part Number.
- Find the repair, purchase, loan cost for each part number.
- Conduct statistical analysis on AOG data.
- Apply ABC analysis to identify the critical parts.
- Analysis the Technical and Operational Cost for AOG situations.
- Apply Questionnaire on AOG situation for Other Airlines.
- Apply AHP (Analytic Hierarchy Process) Technique to determine the main factors that Affect AOG cost.

4. AOG Data

The required AOG data was collected for B777 fleets from maintenance and finance departments for one year. The AOG data include: AOG quantity, Aircraft that affected by AOG, ATA chapter, Type of the part, out of service time, replenishment cost. The total AOGs occurrence for B777 fleet was 146 situations also; the number of parts that caused AOG after remove duplication was 115 parts instead of 146 parts which mean the part failed more than one time.

4.1. Analysis of AOG Technical Cost

The analysis were fully studied and discussed by using ABC analysis technique in order to know the B777 AOGs events based on Aircrafts, ATA chapters and Part numbers for last year. Also, the average AOG technical cost or replenishment cost will be determined in order to know how much money X Airline bear on B777 AOGs situations last year. Analysis Summary of the total Technical AOG Situations include:

- The Average out of service time is 22:54:36
- Average out of service time waiting for a part is 9:51:38
- Average replenishment cost is \$8,785.36

Further analysis of AOG data was conducted based on three factors. These factors were: Aircraft, ATA chapter and Part Number.

4.1.1. Analysis of AOG Data based on Aircraft

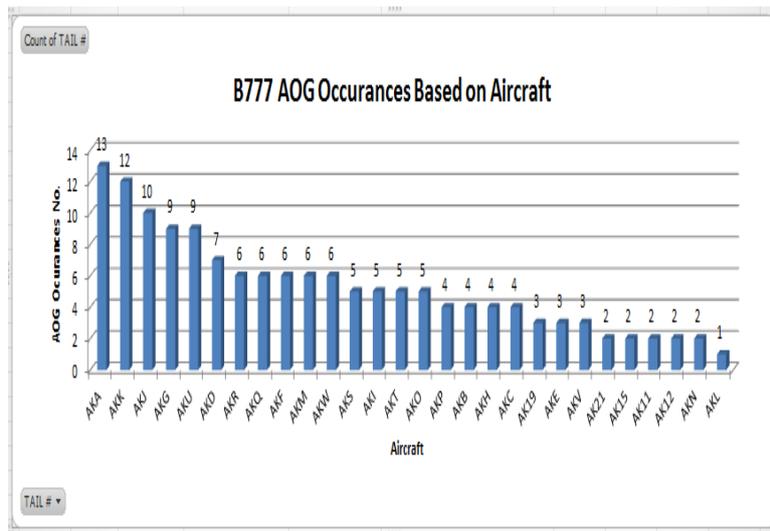


Figure 1: B777 AOG occurrences Based on Aircraft

Figure 1 shows B777 AOG occurrences Based on Aircraft.

The total number of B777 Aircrafts which experienced an AOG is 28 Aircraft. Next an ABC Analysis was applied to find the Aircrafts that have the highest AOG occurrences. Table 1 shows the Aircrafts with high AOG situations.

Table 1: ABC Analysis for B777 AOG occurrences Based on Aircraft

Category	No of Aircraft	% of Critical Aircrafts	AOG Occurrences	% of Aircraft from total occurrences
A	7	25.00	66	45.20
B	9	32.14	48	32.9
C	12	42.86	32	21.9

The Aircrafts with category A, seven Aircraft considered to be critical based on ABC analysis; these seven Aircrafts represent 25.00% of the number of Aircrafts that experienced AOG events.

These 7 Aircrafts experienced 66 AOG occurrences out of the total 146 AOGs situations which occurred to the

28 Aircrafts in one year, up near representing 45% of the total AOG situations.

4.1.2. AOG Data Analysis Based on ATA Chapters

ATA Chapters is a common referencing standard for all commercial aircraft documentation. This commonality permits greater ease of learning and understanding for pilots, aircraft maintenance technicians, and engineers alike.

Figure 2 shows B777 AOG occurrences Based on ATA Chapters:

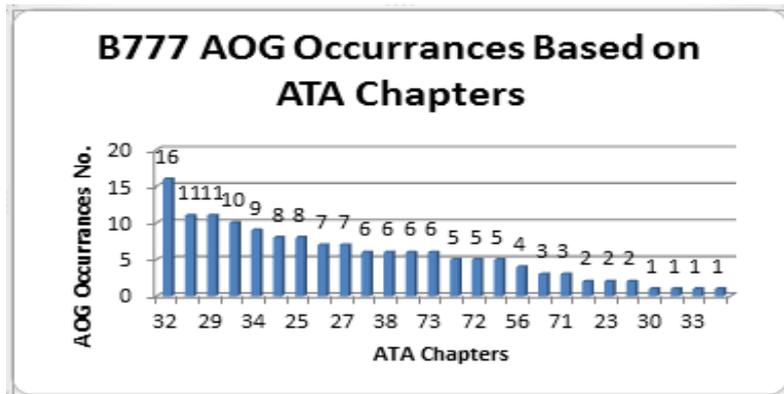


Figure 2: AOG per ATA chapter

The total number of B777 Chapters that appeared with AOG is 26 chapters. After applying ABC analysis to find the most critical chapters that have a big impact on the AOG, table 2 is showing the critical chapters with the number of ATA chapters, percentage of critical chapters, AOG occurrences in the chapters, and percentage of ATA chapters on the total occurrences.

Table 2: ABC Analysis Based on ATA Chapter Seven ATA Chapters considers being critical based on ABC analysis, these seven ATA Chapters represent 27 % of the total ATA Chapters and has an impact on AOG occurrences by 50 %.

Category	No of ATA Chapters	% of Critical ATA Chapters	AOG Occurrences	% of ATA Chapters from total occurrences
A	7	27%	73	50%
B	8	31%	48	33%
C	11	42%	25	17%

4.1.3. AOG Data Analysis Based on Part Number

ABC Analysis was applied to find the most critical Aircraft that has a big impact on the AOG cost; the following table is showing the critical Part Numbers.

Table 3: ABC Analysis Based on Part Numbers

Category	No of Part Number	% of Critical Part Number	Total Cost(\$)	% of Impact of cost
A	25	21.74	1167771.67	91.04
B	40	34.78	99,705.37	7.77
C	50	43.48	15,184.89	1.18

Only Part Numbers with category A will be studied, 25 Part numbers considered to be critical based on ABC analysis 25 Part numbers represent 21.74% of the total part numbers and has an impact on total cost by 91.04 %. The 25 Part numbers which categorized as A class are shown in table 4.

Table 4: Most Critical Parts of Part Family

Part Number	Number of AOG Occurrences	Sum of cost(\$)	%Cost	Material Type
1650M11G16	2	255,063.00	19.89	Rotable
1650M11G17	1	240,735.00	18.77	Rotable
1651M90G05	1	200,526.66	15.63	Rotable
286W0752-006	1	150,750.00	11.75	Rotable
810601-3	4	52,060.78	4.06	Rotable
692D100-13	1	41,231.59	3.21	Rotable
8TJ160AAE1	1	31,250.00	2.44	Rotable
1G2977-2	7	27,274.81	2.13	Rotable
141W7400-31	1	18,408.00	1.44	Rotable
1151474-2	1	18,183.00	1.42	Rotable
692D100-15	1	16,895.00	1.32	Rotable
102L-A2AG	1	15,696.00	1.22	Rotable
HG2040AD03	1	14,514.78	1.13	Rotable
5701-1-1	1	10,651.27	0.83	Rotable
3910013-105	1	10,021.02	0.78	Rotable
3910028-104	2	9,472.65	0.74	Rotable
8061-688	2	9,470.84	0.74	Rotable
822-0195-102	1	7,564.40	0.59	Rotable
1742F6	1	6,800.00	0.53	Rotable
2118860-4	1	5,740.78	0.45	Rotable
3800550-1	1	5,521.30	0.43	Rotable
3A201-0007-01-1	1	5,510.85	0.43	Rotable
119W4103-1	2	5,041.00	0.39	Rotable
810210-2	2	4,750.94	0.37	Rotable
3A201-00007-01-1	1	4,638.00	0.36	Rotable

Twenty five Part Numbers out of 115 were considered as an important for AOG cost. 25 parts belong to rotatable material class. It is believed that based on the previous figure, 21.74 % of Part Numbers have a huge impact up to 91.04% on AOG cost. After the 25 parts based on part number were identified and considered as a critical parts, an ABC analysis was applied on this set (25 parts) to find out the most critical parts based on the number of occurrences (Frequency). Select the first 54% of AOG Occurrences as shown in table 5.

Table 5: Critical Part Based on Part

Part Number	Number of Occurrences	Sum of cost(\$)	%Cost	Material Type
1G2977-2	7	27,274.81	2.13	Rotable
810601-3	4	52,060.78	4.06	Rotable
1650M11G16	2	255,063.00	19.89	Rotable
3910028-104	2	9,472.65	0.74	Rotable
8061-688	2	9,470.84	0.74	Rotable
119W4103-1	2	5,041.00	0.39	Rotable
810210-2	2	4,750.94	0.37	Rotable

Numbers and Frequency of Occurrences Analysis Summary of Critical Parts Based on Frequency of Occurrence includes:

- 7 parts considered as Rotable.
- Total AOG Occurrences is 21 Times.
- Average AOG Occurrences is 3 Times.
- A maximum AOG occurrence is 7 Times.
- A minimum AOG occurrence is 2 Times.

4.2. Analysis of AOG Operational Cost

After analysis the total AOG occurrences, I found Some AOG occurrences caused Delays, Substitution& Cancellation situations and the below figure shows the number of Delays, Substitution, Cancellation and maintenance situation for B777 at X Airline for one year.

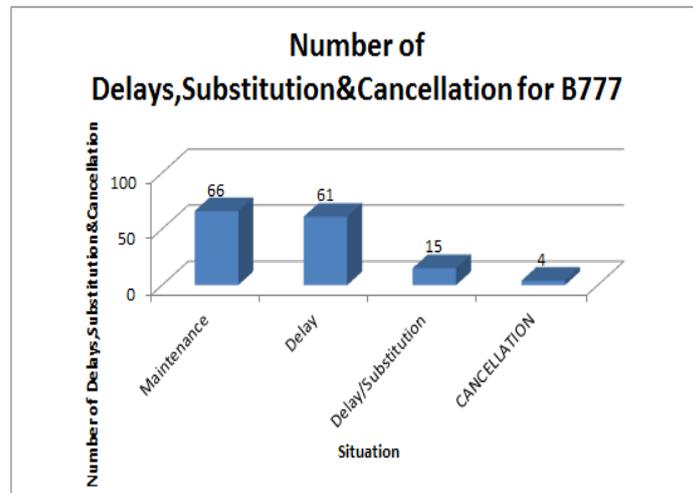


Figure 3: Number of Delays, Substitution, Cancellation and Maintenance Situation for B777

4.2.1. Statistical Analysis for Delay and substitution situations

Figure 4 shows the delay time per minute that were caused by Delay and substitution situations (76 flights).

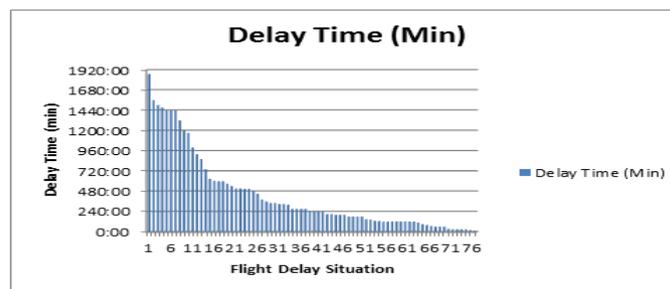


Figure 4: Delay Time per Minute for Each Delay &Substitution Situation

Table 6 shows the Number of AOG caused delay per Interval period.

Table 6: Time Classification of AOG Delays

Number of AOG Caused Delay	Interval Time	
	From(min)	To (min)
24	15	130
15	131	246
10	247	362
2	363	478
7	479	594
4	595	710
1	711	826
2	827	942
1	943	1058
1	1059	1174
1	1175	1290
1	1291	1406
5	1407	1522
1	1523	1638
1	1755	1870

Previous table shows the following observations:

- 64.5% of AOG situations experienced delay less than 6 hours
- 21% of AOG situations experienced delay between 6-16 hours
- 14.5% of AOG situations experienced delay more than 16 hours

4.2.2. AOG Costs Analysis Incurred as a Result of Flight Delays and Substitution

This section is related to cost incurred due to flight delays. When a flight is delayed, the airline bears many costs which can be classified into the following major categories:

- Passengers cost
- Crew cost
- Ground services cost
- Catering cost

Figure 5 shows the total Passengers cost, crew cost, ground services cost and catering cost for 76 delays and substitution situations.



Figure 5: AOG Costs Incurred as a result of Flight delays and substitution

Figure 5 shows the following observations:

- The total Passengers cost=\$877,775
- The total Catering cost=\$427,085
- The total Ground services cost=\$248,189
- The total Crew cost=\$176,218

4.2.3. Total Delay Cost per Flight

The total number of flights that were delayed during the period of study was 76 flights. The total cost of each of these 76 delayed flights was studied and analyzed. Figure 6 shows the total delay cost for all 76 flights.

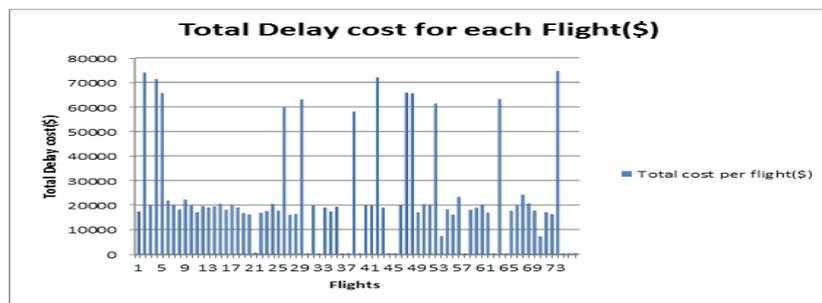


Figure 6: Total Delay Cost for each Flight

Figure 6 shows the following observations:

- The total delay cost of all flights = 1,729,268 Dollars
- The average delay cost of all flight = 22,753.53 Dollars
- The maximum delay cost of all flights = 74,756 Dollars
- The minimum delay cost of all flights = 412 Dollars

4.2.4. The Relationship between Delay Time and Total Cost

Figure 7 shows the delay time intervals and the total cost for 76 flights



Figure 7: Delay Time and Total Cost for 76 flights

As shown in above figure ,the interval 1407 min to 1522 min represent the highest cost which is 344,149 Dollars while, the intervals 711-826 min represent the lowest cost which is 19103 Dollars.

4.2.5. Total Flights Delay Time and Cost against each Part Number



Figure 8: Total Delay Time for Each Part Number

The total delay time& cost for each part that caused delay situations was calculated. Figures8&9 show total delay time and total cost incurred due to failure and unavailability of a spare part.

Figure 8 shows the following observations:

- Part Number BACC2C3E06723EE caused the highest delay time which is 33 hours
- Part Number 2651-278-13 caused the lowest delay time which is 15 min

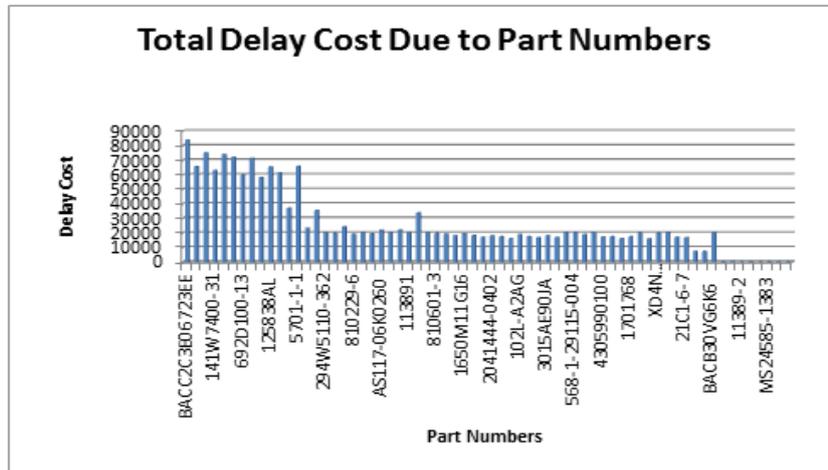


Figure 9: Total Delay Cost for Each Part Number

Figure 9 shows the following observations:

- Part Number BACC2C3E06723EE caused the highest delay cost which is \$84,061.13
- Part Number 2651-278-13 caused the lowest delay cost which is \$441.48

4.3. Questionnaire about Aircraft on Ground (AOG) situations of some Airlines in Middle East

This questionnaire is designed to gather information about Aircraft on ground (AOG) situations for Boeing 777 fleet. It has sent to Middle East Airlines. The main purposes of this questionnaire are comparing X Airline AOG Data with other Airlines and try to know the common and different elements between X Airline and other Airlines in Middle East.

The questionnaire includes ten questions as follows:

- How many Boeing 777 Aircraft in your fleet?
- How many AOG situations your Boeing 777 Aircraft fleet experienced last year?
- What is the average number of AOG per month for the B-777 fleet?
- How many Aircrafts in your B777 fleet experienced the most AOG situation last year?
- What are the part numbers that caused the most AOG situation for B777 fleet last year?
- What are the ATA chapters that caused the most AOG situation for B777 fleet last year?
- What was the average flight delay time due to B777 AOG situations last year?
- What was the average cost due to B777 AOG situations last year?
- What is the average component cost of AOG situation; both technical and operational?
- What was the average time elapsed to procure a part that caused AOG last year?

4.3.1. Comparison between X Airline and Other Airlines

After receiving the three questionnaires properly answered from Y, Z, and k, the results of the research study were compared with those Airlines in order to find the differences with other Airlines.

4.3.2. Boeing 777 Aircrafts for X Airline compared to Other Airlines

Figure 10 shows the number of Boeing 777 fleet for X, Y, Z, and K Airline.

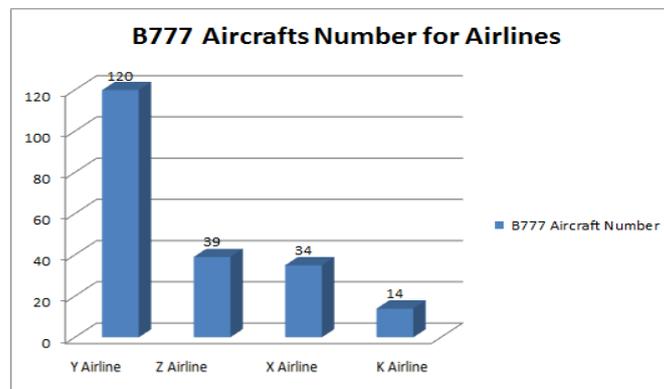


Figure 10: B777 Aircrafts Number for Airlines

Figure 11 shows Y Airline has the largest number of B777 fleets with 120 Aircraft. On the other hand K Airline

has the smallest B777 fleets with 14 Aircraft only.

4.3.3. AOG Situations for Saudia compared to Other Airlines

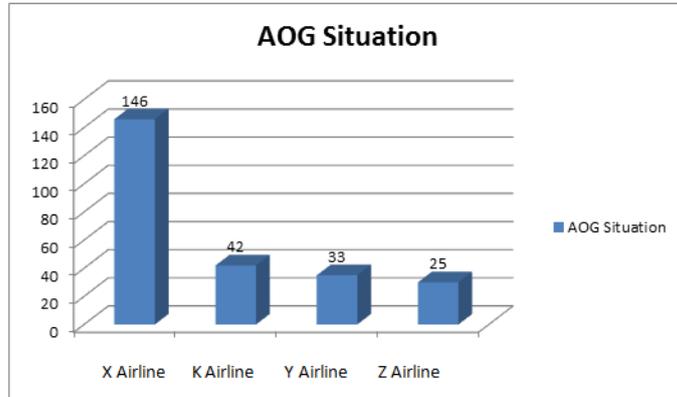


Figure 11: B777 AOG for Airlines

Figure 11 shows X Airlines has the highest number of AOG situation with 146 occurrences. On other hand Z Airline is has lowest AOG situation with 25 occurrences.

4.3.4. Part Numbers that caused the Most AOG situation for X Airline B777 Fleet compared to Other Airlines B777 fleet

Table 7 shows the common part numbers that caused the most AOG situations for X Airline and other Airlines.

Table 7: Common Part Numbers that Caused the Most AOG Situations

P/N 1650M11G16	P/N 692D100-15
P/N 810601-3	P/N 8061-688
P/N 1G2977-2	P/N 1651M90G05
P/N 3910028-104	P/N 5701-1-1

4.3.5. ATA Chapter that caused the Most AOG situation For X Airline B777 Fleet compared to Other Airlines B777 fleet

Table 8 shows the common ATA chapter that caused the most AOG situations for X Airline and other Airlines.

Table 8: Common ATA Chapters that caused the most AOG situations

CH29	CH25
CH52	CH21
CH32	CH79
CH34	

4.3.6. The Average Flight Delay Time Due to B777 AOG situations for X Airline compared to Other Airlines

Figure 12 shows the average flight delay time Due to B777 AOG situations for X, Y, Z, and K Airlines.

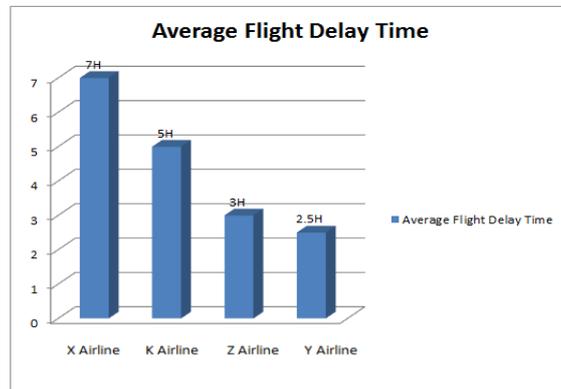


Figure 12: Average Flight Delay Time for Airlines

Figure 12 shows X Airlines has the highest average flight delay time with 7 hours. On other hand Y Airlines has the lowest average flight delay time with 2.5 hours.

4.3.7. Average Cost due to B777 AOG situations for X, Y, Z, and K Airlines

Figure 13 shows that X Airlines has the highest average flight delay cost estimated at \$22754. On other hand Y Airlines has the lowest average flight delay cost at about \$14000

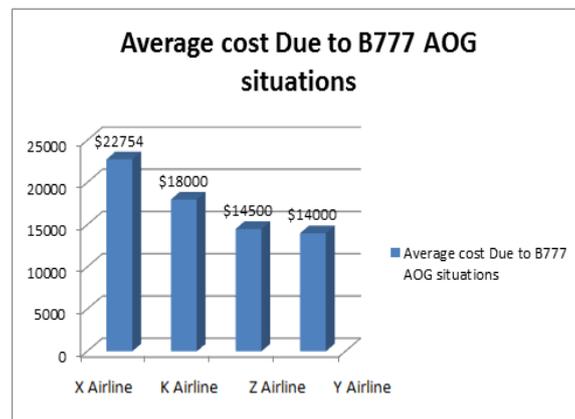


Figure 13: Average Cost due to B777 AOG Situations for Airlines

4.3.8. Average components cost due to B777 AOG situations for X, Y, Z, and K Airlines

Figure 14 shows that X Airline has the highest average component cost at \$8785. On the other hand Y Airlines has the lowest average component cost at \$5000

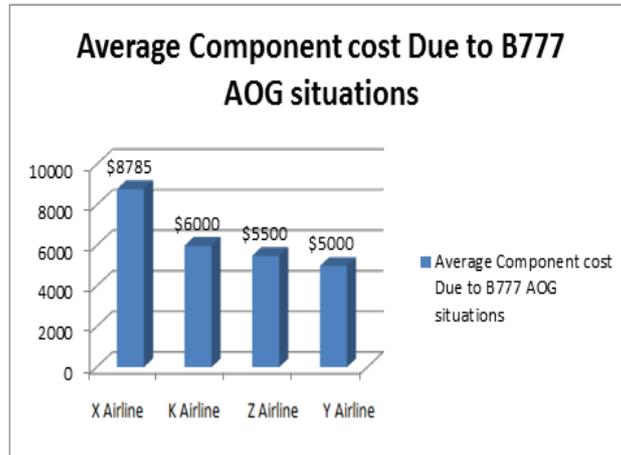


Figure 14: Average Component Cost due to B777 AOG Situations for Airlines

4.4. The Main Factors That Affect AOG Cost by using AHP (Analytic Hierarchy Process) Technique

This section shows the main factors that affect AOG Cost. These factors were presented to experts from Saudia Aerospace Engineering industry (SAEI) through two rounds of questionnaires in sense to be weighed. It was applied AHP (Analytic Hierarchy Process) and the results show that the main important factors that affect AOG Cost. This method can help the decision maker when facing the need of defining priorities to reduce AOG costs [9, 10, 11]

The factors that affect AOG cost are:

- Type of part Agreement or contracts
- The number of passengers
- Components & Aircraft Reliability
- Methods of providing the Parts (Repair-NewBuy-Loan-Exchange)
- Part Forecasting
- Alternative Aircraft
- Maintenance Program for some parts
- Part Capability
- Human error when determining the failure

The methodology adopted in this Paper is based on AHP (Analytic Hierarchy Process) and follows the following steps:

- Determination and definition of the experts to answer the questionnaires;
- Elaboration of questionnaires based on the factors;
- Send the questionnaires to experts;
- Elaboration of the second questionnaires combining the four most voted factors in the first round, in pairs;

- Send this second questionnaire to the same experts;
- Determination of the weights of each factor based on a second questionnaire;
- Creation of a matrix using the factors applying principles of AHP decision support
- Determining the hierarchy of the final cost analysis.

4.4.1. Definition of the factors to be ranked and definition of experts

The questionnaire was sent to six experts, representing the AOG employees in X Airline.

4.4.2. Results of the First Round of Questions

The result is shown in Table 9. Type of part Agreement or contracts, Components & Aircraft Reliability, Methods of providing the Parts (Repair-New Buy-Loan-Exchange) and Part Forecasting were considered relevant by all the experts. It shows the importance of these items to determine the AOG cost.

Table 9: Results of the First Round of Questions

Factors	Votes
1-Type of part Agreement or contracts	4
2-The number of passengers	2
3-Components & Aircraft Reliability	5
4-Methods of providing the Parts (Repair-New Buy-Loan-Exchange)	6
5-Part Forecasting	6
6-Alternative Aircraft	3
7-Maintenance Program for some parts	3
8-Part Capability	2
9-Human error when determine the failure	3

4.4.3. Results of the Second Round of Questions

From the four factors most votes in the first round of questions was then prepared the second questionnaire with the combination in pairs. Experts selected the most relevant factor in each combination. Table 10 shows the results of the questionnaire sent to experts.

Table 10: Results of the Second Round of Questions

Question	Factor	Votes
Question 1	Type of part Agreement or contracts	1
	Components & Aircraft Reliability	5
Question 2	Type of part Agreement or contracts	2
	Methods of providing the Parts (Repair-New Buy-Loan-Exchange)	4
Question 3	Type of part Agreement or contracts	2
	Part Forecasting	4
Question 4	Components & Aircraft Reliability	1
	Part Forecasting	5
Question 5	Components & Aircraft Reliability	2
	Methods of providing the Parts (Repair-New Buy-Loan-Exchange)	4
Question 6	Part Forecasting	4
	Methods of providing the Parts (Repair-New Buy-Loan-Exchange)	2

4.4.4. Construction of the Decision Matrix

Based on the result obtained in the second questionnaire, it was possible to construct the decision matrix that shows the relevance of a factor with respect to another. Each of the four factors was named as follows:

A - Type of part Agreement or contracts

B - Components & Aircraft Reliability

C - Methods of providing the Parts (Repair-New Buy-Loan-Exchange)

D - Part Forecasting

Thus, the decision matrix in which shows the relative importance of each of the factors on the other hand is shown in the table 11, A B C D:

Table 11: Matrix Judgments Obtained

	A	B	C	D
A	1	1/5	2/4	2/4
B	5	1	2/4	1/5
C	2	2	1	2/4
D	2	5	2	1

Normalization was done by dividing each matrix element by the sum of the elements belonging to his column. The normalized matrix is shown in table 12

Table 12: Matrix of Standardized Decision

	A	B	C	D
A	0.1	0.02	0.13	0.23
B	0.5	0.12	0.13	0.09
C	0.2	0.24	0.25	0.23
D	0.2	0.61	0.5	0.45

4.4.5. Hierarchy of the Final Factors

To determine the vector of priority factors, the arithmetic mean of the elements of each row of the matrix was calculated as a standard. The result is shown in table 13

Table 13: Priority of Factor

Factors	Weight
A	0.12
B	0.21
C	0.23
D	0.44

This vector represents the end of the ranking factors. The factor of greatest value in the priority vector is one that has greater relevance in the same way that the lower value is the least among those analyzed. Thus, the final ranking of the factors analyzed was as follows:

- 1- Part Forecasting
- 2- Methods of providing the Parts (Repair-New Buy-Loan-Exchange)
- 3- Components & Aircraft Reliability
- 4- Type of part Agreement or contracts

This indicates that the first two factors are both very important strategy for reducing the AOG cost, while the latter two have a much lower degree of importance.

5. Conclusion

The AOG occurrences for X Airline B777 fleet were studied for last year. A total of 146 AOG occurrences were recorded over last year. This set included the parts that occurred several times. A second set was identified after removing the repeated parts consisted of total 115 parts.

- The total replenishment cost for AOG situations is \$1,282,661.94 , the average replenishment cost for AOG situations is \$8,785.36 , the maximum replenishment cost for AOG situations is \$250,740.00 and the minimum replenishment cost for is \$0.50
- ABC analysis was applied on this set that consisted of 115 parts to identify the critical set of parts. The results revealed that 25 parts were causing 91% of AOG cost. This set represented only 21.74% of the total parts. ABC analysis was applied again on the last set that consisted of 25 parts to identify the critical set of parts. The results revealed that 7 parts were causing 54% of AOG Occurrences.
- The total number of Aircrafts that experienced AOGs where 28 Aircrafts out of the 34 Aircrafts. The full set of AOG was sorted by Aircraft and this analysis showed that 7 aircrafts out of 28 which represented 25% of the number of Aircrafts that experienced AOG events had 45% of total AOG occurrences. Those 7 aircrafts that experienced the heights AOG occurrences were the older aircrafts in the fleet.
- The full set of AOG was sorted by ATA chapters and this analysis showed that 7 chapters out of 26 which represented 27% of the chapters had 50% of total AOG occurrences. Those 7 chapters that experienced the heights AOG occurrences.
- The number of Delays, Substitution, Cancellation and maintenance situation for B777 at X Airline include 66 AOG occurrences in the Maintenance for check, 61 AOG occurrences caused flights delay, 15 AOG occurrences caused flight delays& Substitutions and Only 4 AOG occurrences caused flights Cancellation.
- The Analysis of delay time per minute that were caused by delay and substitution situations (76 flights) revealed the following statistics:

1. Total delay time is 32867 Min
 2. Maximum delay time is 1870 Min
 3. The average delay time is 432:27 Min
 4. The minimum delay time is 15 Min
- The delay cost due to delay and substitution situations (76 flights) revealed the following statistics:
 1. The total delay cost of all flights is \$ 1,729,268
 2. The average delay cost of all flights is \$ 22,753.53
 3. The maximum delay cost of all flights is \$ 74,756
 4. The minimum delay cost of all flights is \$ 412
 - The main costs that are incurred on Airlines when flights delay occur include Passengers cost , Crew cost, Ground services cost and Catering cost
 - As a result of Questionnaire for Aircraft on ground (AOG) situations in Middle East Country Airlines, the Comparison between X Airline and Other Airlines showed the following:
 1. Y Airlines has the largest number of B777 fleets with 120 Aircraft. On other hand the K Airline has the smallest B777 fleets with 14 Aircraft only.
 2. X Airline has the highest number of AOG situation with 146 occurrences. On other hand Z Airline is has lowest AOG situation with 25 occurrences.
 3. X Airlines has the highest average flight delay time with 7 hours. On other hand Y Airlines has the lowest average flight delay time with 2.5 hours.
 4. X Airlines has the highest average flight delay cost estimated at \$22754. On other hand Y Airlines has the lowest average flight delay cost at about \$14000.
 5. X Airlines has the highest average component cost at \$8785. On other hand Y Airlines has the lowest average component cost at \$5000.
 - Part Forecasting is the main factor can be useful for managers of airlines when defining priority actions to reduce AOG costs

6. Recommendations

- X Airline must focus on the critical 7 ATA chapters that had the highest AOG occurrences in order to reduce AOG occurrences caused by those chapters.
- In order to reduce the AOG situations, X Airline should concentrate on parts forecasting, methods of providing the Parts (Repair-New Buy-Loan-Exchange) and components & Aircraft Reliability factors that have effect on AOG cost and update the factors over time to discover the new factors that may improve X Airline and reduce the AOG cost.
- X Airline should focus on the 25 parts and reduce repair cycle time because these most critical parts would reduce the AOG cost& occurrences of the B777.

- X Airline should concentrate on the parts that make long delay time and big delay cost.
- X Airline should make repair program for some parts in order to reduce AOG situations.
- X Airline should improve the mechanic and supervisor technical skills by giving them training and learning in order to discover the parts failure in proper time and reduce AOG time.
- X Airline should make good plan for alternative Aircraft when the AOG occur in order to avoid any flight delay that may occur and reduce AOG cost.
- X Airline should study the AOG cost every year in order to know the improvements that occur for the following year.

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