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ANALYSIS OF THE PERIODIC MAINTENANCE COSTS OF AIRCRAFT FLEET

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Abstract:
Competition in airline management is strengthening and increasing globally. Aircraft maintenance costs have an important place in this sense. Aircraft maintenance has a direct effect on the airline's ability to keep airplanes constantly in the air. Aircraft maintenance is done in a timely and complete manner, the airline's profit-loss balance affects. The main purpose of aircraft maintenance is to produce safer and more secure maintenance service. This service turns into a sales and marketing service by the airline. The purpose of this study is to investigate the maintenance costs of commercial passenger aircraft over a period of 10 years. This study is to investigate the maintenance costs aircraft fleet-based profitability with maintenance costs and all other costs.

Keywords:
Aircraft, maintenance, costs

1. Introduction

The airline industry is one of the most unique bussines in the world. Competition in airline management is strengthening and increasing globally. Aircraft maintenance costs have an important place in this sense. Aircraft maintenance has a direct effect on the airline's ability to keep airplanes constantly in the air. Aircraft maintenance is done in a timely and complete manner, the airline's profit-loss balance affects.

The main purpose of aircraft maintenance is to produce safer and more secure maintenance service. This service turns into a sales and marketing service by the airline. If this service is not provided in a safe and secure manner, timely flight time decreases and aircraft stays on the ground. For this reason, maintenance has an important place for the airline. Diversification and frequent maintenance of aircraft also maximizes flight safety.

The aim of this study is to investigate the maintenance costs of 10 years old aircraft in Turkey. It's examined the time of entry of the aircraft into maintenance and the characteristics of the aircraft until the first flight of the aircraft manufacturers. In order to understand the development processes and who developed them, it was useful to establish and examine the past-future connection.

2. Methodology

The research has been prepared with the future value method of the costs that constitute the maintenance costs over a 10 year period. Model formulation; aircraft type, maintenance interval, maintenance type was prepared using seat capacity and other operational constraints. It is also shown by verifying the proposed methodology using fleet maintenance data from the X airline. Future value based methodology, X airline A320, A330 and B737, B777 aircraft types were evaluated using case studies.

3. Importance of Maintenance in Airline Operating

Maintenance is an important application to keep the equipment in working order and extend its service life. The primary stage of maintenance process, determining which machine, part or device to be serviced, planning and scheduling which worker/operator will be assigned for maintenance, shortening maintenance times and reducing maintence costs. The airplane is a engine-driven aircraft that keeps the airflow in the air to the pressure difference at the lower and upper sides of the wings. Airplanes with high-speed aircraft, carrying people and cargo, are used extensively in civilian and military operations because they save a lot of time. The most important difference that distinguishes airplanes from other means of transportation is that they can carry a person or a cargo from one place to another in a very short time. The world's two largest aircraft manufacturers produce the most preferred civilian passenger and cargo aircraft. Companies with a global flight network supply aircraft from these two aircraft manufacturers. These manufacturers are the Boeing and Airbus brand aircraft manufacturers. Boeing and Airbus offer narrow-body and wide-bodied airplanes, and offer different types of models to companies engaged in passenger and cargo transportation. Again, there is a serious competition between these two aircraft manufacturers in all models. They offer different types of aircraft to their customers in many areas such as passenger capacity, less fuel consumption, fewer breakdowns, longer range. Both manufacturers are preferred by air transport companies. Planes are called wide-bodied and narrow-body according to their size. The wide-body airplanes are single-aisle with double aisles and narrow-body planes. Large body airplanes can also have 4 engines. (Airbus A340, Boeing 747).

4. Aircraft Manufacturers

4.1. Airbus

Airbus Industrie, a European aircraft-manufacturing consortium, was established in 1970 to fill a market niche for short to medium-range high-capacity jet lines. It is now one of the world's two largest commercial aircraft manufacturers and competes directly with the American Boeing Company. The jetliner market is often dominated by orders, deliveries or annual revenues. Among the full members, the European Aviation Defense and Space Company (EADS) with German-French-Spanish capital with a share of 80 percent and the UK's UAE Systems with 20 percent. Its headquarters are located in Toulouse, France.

Airbus Industrie employs more than 50,000 people. Employees work directly on Airbus aircraft in France, Germany, Spain, the United Kingdom and China, and others are employed in engineering, sales, training and other professions worldwide. The consortium has more than 1,500 suppliers and has cooperative agreements with many companies in many countries. American companies are responsible for about a third of the components of Airbus. Common companies perform most of their sub-factories in their own factories; For example, wings for all Airbus aircraft are made in the UK and tail subgroups are made in Spain. Sub-assemblies are transported to the final assembly lines in France, Germany and China by road, rail, barge, ships and airplanes (private jet fleet, Airbus Super Carrier Beluga). Airbus A320, A330 / A340, A380 and A350 planes are completed in a complex near Toulouse, while A318, A319 and A321 planes are assembled in Hamburg.

4.2 Boeing

Boeing Company, American aerospace company—the world's largest—that is the foremost manufacturer of commercial jet transports.It is also a leading producer of military aircraft, helicopters, space vehicles, and missiles, a standing significantly enhanced with the company's acquisition of the aerospace and defense units of Rockwell International Corporation in 1996 and its merger with McDonnell Douglas Corporation in 1997. Formerly Boeing Airplane Company, the firm assumed its current name in 1961 to reflect its expansion into fields beyond aircraft manufacture. Headquarters were in Seattle until 2001, when Boeing relocated to Chicago.

The Company's founding business units are organized around three main products and service groups, namely commercial airplanes, military aircraft and missiles, and space and communications. Boeing manufactures seven separate family of commercial airplanes brought together in two facilities (Renton and Everett), a facility in Washington and California. The Renton factory produced the narrow-bodied Boeing 737 and made 757 aircraft before. Wide-bodied Boeing 767 and 777 aircraft, and a limited number of 747 (largely unexpressed) were assembled at Everett's facilities. The 787 aircraft was assembled at the Everett plant and at a plant in North Carolina, South Carolina. Boeing and General Electric's joint venture, Boeing Business Jets, produces 747, 777 and 787 aircraft in addition to VIP versions, as well as 737-700 aircraft based on the production and marketing of business jets.

Boeing's history began in 1916, when American timber merchant William E. Boeing began building the Aero Products Company shortly after US Navy official Conrad Westervelt developed a single-engine seaplane, B & W. . In 1917, the company was renamed Boaming Airplane Company, built araç flying boats tor for the Navy during World War I, and successfully sold its instructors, track planes, observation vehicles, torpedo planes and patrol bombers in the 1920s and 30s.

5. MRO Companies Performing Aircraft Maintenance in Turkey

5.1. myTECHNIC

MyTECHNIC is the world's first lean maintenance center built from the ground up. Its advantageous position between Europe and Asia makes myTECHNIC the ideal partner for airlines in Europe, as well as for European, Russian, Middle Eastern and African airlines. myTECHNIC was established in 2008 and in November 2010, Hainan Group Co. Limited (HNA). HNA Group is one of the leading companies in China with its operations in the modern service industry and has great investments in air transportation, logistics and modern financial services. HNA, headquartered in Haikou, China, has total assets exceeding $ 30 billion by the end of 2010. Designed according to the principles of simple management, myTECHNIC offers a wide range of services ranging from large and narrow-bodied aircraft to engine revisions and airplanes. Since its establishment in 2008, myTECHNIC incorporates the principles of Lean Management and productivity and safety. eliminates space, movement and time losses. It strives to expand the areas of corporate responsibility for the environment, increase the satisfaction of its partners and reduce the time of completion of the works. myTECHNIC hangar is located on an area of 60,000 square meters, with a 3-storey building with 15,400 square meters of hangar space. The facility includes 24,800 square meters workshop, office and warehouse area. In addition, there are 6,000 square meters of engine workshop. myTECHNIC received EASA (Part 145) authorization in August 2008. SHY / JAR 145 / EASA certificates were issued by the General Directorate of Civil Aviation (SHGM) simultaneously. In addition to these authorizations, myTECHNIC has ISO 9001, ISO 14001 and OHSAS 18001 certificates. Finally, it was authorized by SHGM as SHY / JAR-147 maintenance training organization.

5.2 Onur Air Technical

Onur Air, which has its own maintenance hangar in Istanbul Atatürk Airport since 2011, is the only private airline with this technical capacity. Onur Air, an EASA and Bermuda Part-145 organization, will be happy to assist its, Customer Atatürk planes during its Base and Line Maintenance services with its unique, limited slots available at Istanbul Ataturk Airport and Antalya International Airport and at competitive prices. In addition to base and line maintenance services, Onur Air is also authorized to issue III Level Non Destructive Testing Service for all A320 Family aircraft parts under D1 authorization and / or EASA Approved Composite Repairs. Onur Airlines Transportation Inc. was established on April 14, 1992 and the first flight was carried out on 14 May 1992 by the A-320 type aircraft to the Turkish Republic of Northern Cyprus Ercan Airport. In the following period, in July 1992, he included his second aircraft, his third aircraft in December 1992 and his fourth aircraft in April 1993 in his fleet. Onur Air, which continues to grow steadily, increased the number of aircraft in its fleet to 14 in 2002 and in the following years respectively; 20, 24 and 28. In 2006, the number of aircraft in the fleet of Onur Air, which reached to 7,012 seats with 31 aircraft, was 29 in 2007 and 25 in 2008. Today, Onur Air serves with its fleet of 26 aircraft.

5.3 THY Technical Inc.

5.3.1 Aircraft Maintenance

Turkish Airlines Technical Inc. Since its inception, it has been providing its customers with fast and reliable aircraft maintenance services. 9 hangars in two continents, 576.000 m2 closed area, modern facilities, international maintenance certificates (EASA, FAA), state-of-the-art equipment and more than 7.500, all of the capable aircrafts A, B , C and D maintenance in house. In addition to the main maintenance services provided to its customers, it provides quality and reliable services in many fields such as cabin renovation, airplane paint, line maintenance and business jet maintenance. Careful work carried out by expert engineers and technical staff in the field, taking care of the wishes and needs of its customers. Turkish Airlines, especially; It provides maintenance, repair and technical support to more than 100 domestic and foreign airlines. Was established on 23 May 2006 with 100% Turkish

Airlines capital. With more than 7,500 employees and affiliates, activities in order to provide all kinds of technical and infrastructure support related to maintenance, repair and airline industry.

6. Aircraft Types and Maintenance Intervals

In aviation industry, aircraft are aged by daily utilization with respct to 4 different usage parameters, calender day (DY), flight hours (FH) and flight cycles (FC). FH refers to the elapsed time between wheel lift off and touch down and a FC is defined by a complete take-off and landing sequence. For example, the maintenance planning document of the AIRBUS A320 family defines that an A check interval corresponds to 750 FH or 120 DY, C check interval 7500 FH or 730 DY, S check interval 2190 DY (table1)

Table 1

Aircraft Types	A	B	C	S
A320	750 FH 120 DY*	-	7500 FH 24 MO*	6 YE
A330 (Wide Body)	800 FH	42 MO	10000 FH 24 MO*	6 YE
B737	1000 FH	-	7500 FH 730 DY*	-
B777 (Wide Body)	1500 FH 120 DY	730 DY	1125 DY	-

6.1. Aircraft interval and Maintenance Costs

The below table shows the maintenance intervals for aircraft types. There are different maintenance and intervals for each type of aircraft. which maintenance interval of the aircraft comes first, maintenance is done accordingly. C and S treatments are also called heavy care. heavy maintenance costs are much more expensive and take longer than others.

Table 2

Aircraft Types	Maintenance Type	Interval	Cost ($)
A320	A	700 FH 120 DAY*	28000
A320	S	6 YE	700000
A320	C	7500 FH	450000
A330	B	42 MO	500000
A330	C	10000 FH 24 MO*	700000
A330	S	6 YE	1,500000
A330	A	800	64000
B737	A	1000 FH	30000
B737	C	7500 FH 730 DAY	600000
B777	A	1500 FH 120 DAY	120000
B777	B	730	500000
B777	C	1125 DY	750000

6.2. The average of the A, B, C and S maintenance of A320, B737, A330, B777
In this table, the average maintenance of aircraft types in one year is given.

Table 3

	A	B	C	S	Aircraft Count
A320	11,68	-	1,1	0,16	88
B737	8,76	-	1,1	-	66
A330	10,95	0,28	0,87	0,16	104
B777	5,84	0,5	0,32	-	38

An aircraft is maintained as per the manufacture's guidelines approved by the aviatoin regulators. The new modern airplane are more complex in systems which require not just mechanical skills, but also sound knowledge in systems, functionality and maintenance procedures.
A check: During an A check all technical systems that are needed for aircraft operation are checked.
B check: Inspecting sysetems check, cracks, inspection for corrosion, structural defects. Happens for A330 aircraft 42 month, and for B777 730 day.
C, S check: C check is a major aircraft check, the aircraft structure is inspected and all systems are tested.
Periodic maintenance actions are organized in four different classes of checks. Each check is performed at a different interval and gets more complex with the size of the interval. The given intervals can vary depending on the aircraft type and aircraft operation.
The main purpose of maintenence;

- Protect safety and reliability of the equipments.
- In case of corruption of safety and reliability restore to factory settings.
- When the reliability level of corruption provide the necessary information for the development.
- To ensure all this with minimum total cost.
- Keep aircraft in service.

7. The calculating of maintenance and operation costs

The factors that create costs in aircraft maintenance are multiple. maintenance consists of various costs. we will examine the maintenance costs over a period of 10 years. changing costs each year will also increase maintenance costs.

Table 4

AC Type	Sum of Total Hours	Capacity	Passenger Flight Time	Adding Value Rate*	Operating Income
A320	4229046253				Ticket Sales Revenue$
2008	28786711	190	5469475090	14%	677.438.457
2009	64771907	190	12306662330	23%	1.068.609.000

2010	112592604	190	21392594760	30%	1.697.210.616
2011	160891427	190	30569371130	33%	2.315.310.776
2012	223412645	190	42448402550	34%	2.783.586.415
2013	332497086	190	63174446340	36%	3.590.374.921
2014	463890783	190	88139248770	36%	4.022.031.807
2015	560843117	190	106560192230	32%	3.334.791.338,
2016	661040602	190	125597714380	31%	3.063.597.362
2017	753126080	190	143093955200	31%	3.366.422.603
2018	867193291	190	164766725290	29%	3.730.351.639
A330	2003243706	-	-	-	-
2008	18233508	290	5287717320	14%	654.926.297
2009	26748316	290	7757011640	15%	673.554.878
2010	33706555	290	9774900950	14%	775.505.068
2011	48574995	290	14086748550	15%	1.066.924.163
2012	72317976	290	20972213040	17%	1.375.268.886
2013	105288171	290	30533569590	18%	1.735.305.473
2014	182158237	290	52825888730	22%	2.410.587.878
2015	275183114	290	79803103060	24%	2.497.430.713
2016	343336365	290	99567545850	25%	2.428.665.779
2017	374849966	290	108706490140	23%	2.557.424.490
2018	522846503	290	151625485870	26%	3.432.831.348
AC Type	**Sum of Total Hours**	**Capacity**	**Passenger Flight Time**	**Adding Value Rate***	**Operating Income**
B737	5768926753				Ticket Sales Revenue$
2008	183199379	150	27479906850	72%	3.403.607.369
2009	215414912	150	32312236800	62%	2.805.727.998
2010	263842167	150	39576325050	56%	3.139.841.604
2011	306086135	150	45912920250	49%	3.477.424.464
2012	343636893	150	51545533950	41%	3.380.137.755
2013	406543392	150	60981508800	35%	3.465.744.340
2014	491509975	150	73726496250	30%	3.364.339.010
2015	751834040	150	112775106000	33%	3.529.286.489
2016	817669097	150	122650364550	31%	2.991.705.185
2017	909992149	150	136498822350	29%	3.211.265.775
2018	1079198614	150	161879792100	28%	3.664.990.894
B777	876490394		-	-	-
2010	42964	370	15896680	0%	2.333.887
2011	7687982	370	2844553340	5%	384.251.313
2012	28705388	370	10620993560	15%	1.236.139.812

2013	51563879	370	19078635230	20%	2.016.999.480
2014	73731536	370	27280668320	22%	2.398.565.799
2015	104413562	370	38633017940	22%	2.350.092.744
2016	140677398	370	52050637260	22%	2.098.094.805
2017	203359160	370	75242889200	22%	2.429.288.801
2018	266308525	370	98534154250	25%	3.217.971.402

*Adding Value Rate: Total hours the aircraft flies. (passenger flight time / grand total hour of seat)
*Capacity: The seat capacity of aircraft.
* Sum of Total Hours: Total hours the aircraft flies during that year.
*Passenger Flight Time: total hours the seat flies during that year.

In the below Table 5, non-maintenance sales expenses and maintenance costs are calculated. The fluctuations in exchange rates are also taken into consideration in 2018. Net flow is the difference between ticket sales revenue and non maintenance sales expenses. The value of the future value was also calculated by multiplying the yearly value of the exchange rate (Table 6) with the present value of netflow. Passenger flight time was calculated by multiplying seat capacity by flight time. From 2008 to 2018, all maintenance of aircraft was determined and cost calculation was made according to the type of maintenance. When calculating the cost, the seat capacity of the aircraft types was found and the seat flight time of the seats of each aircraft type was calculated. In the table 5, non-maintenance sales expenses and maintenance costs are calculated. The fluctuations in exchange rates are also taken into consideration in 2018.

Table 5

Years	**Non-Maintenance Sales Expenses**$	**Maintenance Costs**$	**Total** $	**Net Flow**$	**Future Value (2018)** $
2008	488.651.553	2.606.837	486.044.716	188.786.904	244.084.017
2009	722.059.120	3.388.093	718.671.026	346.549.879	536.135.079
2010	1.232.946.584	3.285.069	1.229.661.514	64.264.032	696.565.040
2011	1.842.488.807	3.383.473	1.839.105.334	472.821.968	789.612.686
2012	2.169.063.429	6.404.498	2.162.658.930	614.522.986	1.101.530.752
2013	3.265.551.576	9.881.614	3.255.669.962	324.823.344	617.589.483
2014	3.808.198.637	9.560.034	3.798.638.602	213.833.169	467.836.646
2015	2.919.334.237	4.910.264	2.914.423.972	415.457.101	1.130.050.048
2016	2.523.090.959	6.329.840	2.516.761.118	540.506.403	1.633.002.278
2017	2.933.041.921	7.407.438	2.925.634.482	433.380.682	1.580.836.033
2018	2.691.007.170	4.875.129	2.686.132.040	1.039.344.468	5.002.364.929

Table 6 shows the average exchange rates on a year-by-year basis based on central bank data and is reflected in the table as future value. thus, costs will appear to be equivalent to the present value over a period of 10 years.

Table 6

Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**12015**	**2016**	**2017**	**2018**
Exchange rate $	1,29	1,55	1,5	1,67	1,79	1,9	2,19	2,72	3,02	3,65	4,81

In this below table 7, after calculating the total flight time of the fleet types over the capacity of the seats, it shows how much a seat of an aircraft type flies in the air.

Table 7

Seat Capacity	190	290	150	370		
Year	**A320FAM**	**A330**	**B737**	**B777**	**Grand Total AC Hour**	**Grand Total Seat Hour**
2008	28786711	18233508	183199379	-	230219598	38237099260
2009	64771907	26748316	215414912	-	306935135	52375910770
2010	112592604	33706555	263842167	42964	410184290	70759717440
2011	160891427	48574995	306086135	7687982	523240539	93413593270
2012	223412645	72317976	343636893	28705388	668072902	125587143100
2013	332497086	105288171	406543392	51563879	895892528	173768159960
2014	463890783	182158237	491509975	73731536	1211290531	241972302070
2015	560843117	275183114	751834040	104413562	1692273833	337771419230
2016	661040602	343336365	817669097	140677398	1962723462	399866262040
2017	753126080	374849966	909992149	203359160	2241327355	463542156890
2018	867193291	522846503	1079198614	266308525	2735546933	576806157510

8. Conclusion

In this paper presents a practical future value methodology of the maintence cost of aircraft fleet. The model formulation takes aircraft type, status, maintenance, seat capacity, and other operational constraints into consideration. We also validate and demonstrate the proposed methodogy using fleet maintenance data from an airline. The proposed future value based methodology is evaluated using the case-study of an A320, A330 and B737, 777 family fleet from an airline. In this study, maintenance costs, operational expenses and all other expenses were calculated for 4 different aircraft types. In addition, the study shows which aircraft type would be more profitable for the airline, taking all criteria into consideration. Also, narrow body and wide body will allow the airline to choose the type of aircraft that is profitable. We calculated below table 8, the cost per flight hour (FH) of a 10 year fleet based on the values, we also found the cost of a fleet seat. According to this table the operator can find out which fleet is profitable.

Table 8

Ac Type	AC Purchasing Cost	Maint Cost	AC's total FH	Grand Total AC Hour	TC1	TC2
A320	$101.000.000	$827.559.933	4229046253,00	803518788070	$0,220	0,00116
B737	$106.000.000	$561.363.015	5768926753	580940674740	$0,116	0,00115
A330 (wide body)	$265.000.000	$976.758.198	2003243706	865339012950	$0,620	0,00143
B777 (wide body)	$375.000.000	$331.947.962	876490394	324301445780	$0,807	0,00218

TC1: aircraft purchasing cost + maintenance cost / total FH's of aircraft
TC2: aircraft purchasing cost + maintenance cost / total FH's of aircraft

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