İSTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

DEVELOPMENT OF METHODS FOR REDUCING SCHEDULED MAINTENANCE DOWNTIME OF AIRCRAFT

Ph.D. Thesis by
Caner ŞENTÜRK

Aeronautics and Astronautics Engineering Department

Aeronautics and Astronautics Engineering Programme

Thesis Advisor: Prof. Dr. İbrahim ÖZKOL

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

UÇAKLARIN PLANLI BAKIM İÇİN YERDE KALIŞ SÜRELERİNİN AZALTILMASINA YÖNELİK YÖNTEM VE ANALİZ METODLARININ GELİŞTİRİLMESİ

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FOREWORD

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February 2018 Caner Şentürk

(Aeronautical Engineer, M.Sc.)

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ABBREVIATIONS

A/C	: Aircraft
ACARS	: Aircraft Communication Addressing and Reporting System
AD	: Airworthiness Directive
AH	: APU Hours
AHM	: Airplane Health Management
AHP	:Analytic Hierarchy Process
AI	: Airbus Industrie
ALI	: Airworthiness Limitation Item
AOT	: All Operator Telex
App	: Appendix
APU	: Auxilary Power Unit
ATA	: Air Transport Association of America
CMR	: Certification Maintenance Requirements
CN	: Consigne de Navigabilite
CY	: Engine cycles
DY	: Day
EASA	: European Aviation Safety Agency
EC	: Engine Change
FAA	: Federal Aviation Administration
FC	: Flight cycle
FH	: Flight hours
HR	: Hour
IT	: Information Technology
LD	: Landing
MO	: Month
MPD	: Maintenance Planning Document
MRB	: Maintenance Review Board
MRBR	: Maintenance Review Board Report
MRO	: Maintenance Repair and Overhaul Company
MSG	: Maintenance Steering Group
NR	: National Requirement
NT	: NOTE
PMA	: Portable Maintenance Aid
SB	: Service Bulletin
VR	: Vendor Recommendation
W	: Weight vector
YE	: Year
Σ	: Standard deviation

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DEVELOPMENT OF METHODS FOR REDUCING SCHEDULED MAINTENANCE DOWNTIME OF AIRCRAFT

SUMMARY

Maximization of aircraft utilization is one of the most important issues for airline companies. By accumulating more flight hours in a certain period of time, direct operating costs per flight hour can be reduced. Achieving more flight hours depends on aircraft availability for flight. One of the methods for increasing aircraft availability for flight is to reduce scheduled maintenance downtime of the aircraft. Methods of reducing maintenance downtime of an aircraft were examined in the scope of this thesis. By means of these methods, scheduled maintenance downtime of the aircraft is reduced, aircraft availability for flight is increased and a cost based structure has been established for the airline companies.

Today many airline companies perform maintenance checks in predetermined intervals. Maintenance tasks given in maintenance programs are performed during these maintenance checks. However, this method used by many airline companies remains currently insufficient to prevent earlier accomplishment of maintenance tasks. Due to the rigid structure of this maintenance concept and fixed intervals, such airlines are subjected to enormous loss of material, man hour etc… This cause the aircraft to be kept much more time on gorund for maintenance purposes, consequently the aircraft availability for flight decreases. In the method proposed in this thesis, a more flexible structure has been developed to perform the maintenance not only during periodic checks but also whenever the aircraft is on the ground for any reason. In this method, a single task-oriented maintenance concept has been proposed. The method proposed in this thesis has been supported with some case studies performed in an airline company.

In the scope of this thesis, a software which will help to increase the aircraft availability for flight has been developed to calculate more accurate and appropriate letter check alternatives according to real-time utilization values accumulated by each aircraft. This software allows us to use real-time utilization values for all aircraft and therefore it may suggest different appropriate letter check alternatives for each aircraft. Maintenance tasks which are planned in maintenance checks without taking into account the real-time utilization of the aircraft cause losses because of potential earlier accomplishment of these tasks and therefore decrease the aircraft availibility eventually. For these purposes, the accomplishment of maintenance tasks in the most appropriate letter check alternatives according to real-time utilization values and the suggestion of different appropriate letter check alternatives for each aircraft are studied in the software developed in this thesis.

Single task-oriented maintenance concept, the accomplishment of maintenance tasks in the most appropriate letter check alternatives according to the real-time utilization values and the calculation of different appropriate letter check alternatives for each aircraft are subject of this thesis.

With this method and maintenance concept, it is intended to decrease maintenance scheduled downtime of the aircraft, to accomplish maintenance tasks on time and to prevent losses and earlier accomplishment, to reduce maintenance cost of airline companies, to increase aircraft availability for flight and to maximize aircraft utilization, therefore to increase the flight hour in a certain period of time.

UÇAKLARIN PLANLI BAKIM İÇİN YERDE KALIŞ SÜRELERİNİN AZALTILMASINA YÖNELİK YÖNTEM VE ANALİZ METODLARININ GELİŞTİRİLMESİ

ÖZET

Havayolu şirketleri için uçak kullanımının maksimizasyonu önemli konulardan biridir. Belli bir zaman aralığında daha fazla uçuş saati gerçekleştirmek, uçuş saati başına düşen direkt işletme maliyetlerinin azaltılmasını sağlar. Uçakların, uçuş operasyonunda havada olduğu sürelerin mümkün olabildiği ölçüde fazla olması arzu edilmektedir. Uçuş operasyonları dışında yerde kaldığı sürelerin en aza indirgenmesi önem arz etmektedir. Uçağın uçuş operasyonu için planlandığı kullanım süresini artırabilmek, uçağın çeşitli sebeplerden dolayı yerde kaldığı sürelerin azaltılmasıyla mümkündür.

Uçak, uçuş operasyonu dışında çeşitli sebeplerle yerde tutulabilmektedir. Uçağın uçuş operasyonu dışında yerde kaldığı sürelerden biri de “bakım amaçlı” yerde kalmasını gerektiren süredir. Uçağın bakım için yerde kaldığı süreden kazanılacak her saat, uçağın uçuş operasyonuna katkı sağlayacak uçuş saati olarak bir kazanımdır. Daha fazla uçuş saati gerçekleştirebilmek doğrudan uçağın uçuş için kullanılabilir olmasına bağlıdır.

Uçağın uçuş için kullanılabilirliğinin arttırılmasının yöntemlerinden biri de planlı bakım yerde kalış süresinin azaltılmasıdır. Bu tez kapsamında bir uçağın planlı bakım yerde kalış süresinin azaltılmasıyla ilgili yöntemler incelenmiştir. Bu yöntemler sayesinde uçağın planlı bakım gereksinimleri için yerde tutulması gereken süreler azaltılmış, uçağın uçuş için kullanılabilirliği arttırılmış, sonuç olarak sağlanan ilave uçuş saatiyle havayolu şirketine kazanç sağlayabilecek bir yapı oluşturulmuştur.

Tez kapsamında uçakların planlı bakım için yerde kalış sürelerinin azaltılması amacına yönelik ihtiyaç duyulan yöntem ve analiz metodlarının geliştirilmesi çalışmalarıyla elde edilen sonuçlar, havayolu şirketleri için uçak kullanımının maksimizasyonuna katkı sağlaması, direkt işletme maliyetlerinin azaltılmasına etki etmeleri açılarından önemlidir.

Tezin kapsamı sivil havacılık sektöründe ticari havayolu taşımacılığında kullanılan uçakları içermektedir. Askeri havacılık ve genel havacılık kapsamındaki uçaklar bu tez çalışması kapsamı dışında tutulmuştur.

Sivil havacılık sektöründe “uçuşa elverişlilik - airworthiness” kavramı çok önemlidir. En genel anlamda bir hava taşıtı için uçuşa elverişlilik, hava taşıtının onaylı tasarım özelliklerine uygunluğunu muhafaza etmesi ve emniyetli uçuş için fiziksel şartlarını koruması olarak özetlenebilir. Sivil havacılık sektöründe, uçuşa elverişli şartları haiz olmayan bir uçağın uçmasına asla izin verilmez. Havayolu şirketleri işletmekte oldukları uçakların sürekli uçuşa elverişliliğinden sorumludur. Uçakları sürekli uçuşa elverişli durumda tutabilmenin vazgeçilmez unsuru ise bakımdır. Dolayısıyla bakım,

uçağın sürekli uçuşa elverişli şartlarını koruyabilmesi için yapılması gereken gerekliliklerden biridir ve bu gereklilikten kurallar gereği asla imtina edilemez.

Günümüzde bir çok havayolu şirketinde, bakım kontrolleri önceden belirlenmiş intervallerde gerçekleştirilmektedir. Havayolu şirketlerinin planlama bölümleri, işletmekte oldukları uçak tipleri için bu bakım intervallerini belirlerler ve her uçak tipi için bakım programları hazırlayarak, bakım işlemlerinin o uçak tipinde belirlenen intervallerde uygulanmasını takip ederler. Bakım programında verilen bakım işlemleri, belirlenen bu kontroller sırasında yapılmaktadır. Bununla birlikte günümüzde bir çok havayolu şirketi tarafından kullanılan bu yöntem yetersiz kalmakta, kalan süresi itibarıyla bir sonraki bakım kontrolüne yetişemeyecek bakım işlemleri, zorunlu olarak bir önceki bakımda uygulanmaktadır. Bakım kontrollerinin bu katı yapısından ve sabit intervallerden dolayı, havayolu şirketleri fazla malzeme ve adam-saat kaybına maruz kalmakta; uçaklar bakım için daha fazla yerde tutulmakta dolayısıyla uçuş için kullanılabilirlikleri azalmaktadır. Birçok bakım işlemi esnek olmayan rijit yapı dolayısıyla erken uygulanmakta, bu da bakım işlemlerinin gereğinden fazla uygulanmasına neden olmaktadır. Belirli bir zaman aralığında bakım işlemlerinin kümülatif uygulanma sayıları artmaktadır. Bunun sonucunda fazladan yapılan bakım işlemleri için, fazladan adam saat harcanmakta ve yine belirli zaman aralığında fazladan parça, malzeme değişimi yapılmaktadır.

Bu tezde önerilen yöntemde, bakımı sadece uçağın periyodik kontrolleri sırasında değil de, uçağın herhangi bir nedenden dolayı yerde olduğu tüm zamanlarda yapmak için daha esnek bir yapı geliştirilmiştir. Bu yöntemde tek bir bakım işlemi güdümlü bakım kavramı önerilmiştir.

Uçağın yerde olduğu her anı bir bakım fırsatı olarak değerlendirerek, kurallar gereği yapılması gereken ve bakım programlarında da tariflenen bakım gerekliliklerini, bu yerde kaldığı süreler esnasında planlayarak gerçekleştirmek ve bunun metodolji ve yöntemini oluşturmak, bunun sonucunda elde edilebilecek mali, kazançları analiz etmek bu tez kapsamındaki çalışmalardandır. Benzer şekilde esnek yapıyı kurabilmek için lojik diyagramının oluşturulması ve bu yapıyı destekleyecek bütün kriterlerin analiz edilme çalışmaları da tez kapsamında gerçekleştirilmiştir. Önerilen bu yöntem, bir havayolu şirketinde gerçekleştirilen bazı örnek durum çalışmalarıyla desteklenmiştir. Örnek durum çalışmasında oluşturulan model, geliştirilen yöntem uygulanarak, esnek yapıyla ilgili sonuçlar elde edilmiş ve elde edilen bütün sonuçlar mevcut yapıyla karşılaştırılarak, geliştirilen yöntemin sağladığı faydalar analiz edilmiştir.

Tez kapsamında yine ayrıca uçakların kullanılabilirliğinin arttırılmasına hizmet eden, uçakların gerçek zamanlı kullanımlarının dikkate alındığı, bakım işlemlerinin en uygun bakımlarda yapılabilmesini sağlayan bir yazılım geliştirilmiştir.

Uçakların gerçek zamanlı kullanımları dikkate alınmadan, belirli kabullere göre zamanından önce planlanan bakım işlemlerinin, kayıplara neden olduğu ve neticede uçak kullanılabilirliğini azalttığı bilinmektedir. Birçok bakım işlemi uygulanması gereken intervalden önce uygulanmakta, erken uygulamaların da sonuç olarak adam saat kayıbı, fazla malzeme değiştirme, uçağın fazladan yerde tutulması gibi olumsuz sonuçları olmaktadır.

Bu nedenle tez kapsamında geliştirilen yazılımda, bakım işlemlerinin uçak kullanımlarına göre en uygun zamanda yapılabilmesi ve harf kodlu bakım kontrolleri için en uygun intervallerin hesaplanarak uçak kullanımının arttırılması konuları üzerinde çalışılmıştır. Yazılımın kuvvetli yönlerinden biri de uçak bazında çözüm arayışına gidilebilmesidir. Sadece uçak filosu bazında en uygun ve en az kayıpla bakım işlemlerini uygulamaya ilave olarak, o uçak filosunda bulunan herbir uçak için ayrı ayrı, o uçakların gerçek kullanım parametrelerine uygun olarak bakım işlemlerinin uygulanabilmesi yazılımın sağladığı bir avantaj olarak değerlendirilmektedir. Dolayısıyla herbir uçağın özelinde değerlendirme ve analiz yapılabilmekte, herbir uçak için daha hassas ve gerçekçi sonuçlar elde edilebilmektedir.

Tek bir bakım işlemi güdümlü bakım kavramı yaklaşımı, bakım işlemlerinin kayıplara neden olmadan gerçek zamanlı uçak kullanımlarına göre en uygun zamanda yapılabilmesi ve harf kodlu bakım kontrolleri için en uygun intervallerin hesaplanmasıyla ilgili çalışmalar bu tezin içeriğinde yer almaktadır.

Bu iki yöntemle, uçağın planlı bakım için yerde kalış süresinin en aza indirgenmesi, bakım işlemlerinin daha etkin ve verimli şekilde gerçekleştirilmesi, erken uygulanmasının engellenmesi, havayolu şirketinin bakım masraflarının azaltılması; bakım yapma şeklinin değiştirilerek bakım için uçağın daha az yerde tutulması dolayısıyla uçakların uçuş için daha fazla kullanılabilir durumda tutulması ve belirli bir zaman aralığında daha fazla uçuş saati yapabilmesi hedeflenmektedir.

Tez kapsamında gerçekleştirilen çalışmalar, geliştirilen yöntemler ticari havayolu taşımacılığında işletilen uçaklar için olup, bu uçakların planlı bakım için yerde tutulduğu sürelerin azaltılmasını hedeflemektedir. Uçakların planlı bakım dışında da birçok nedenden dolayı yerde tutulmasını gerektiren operasyonel nedenler, yer işletme ile ilgili gereklilikler bulunmaktadır. Diğer alanlardaki sürelerin azaltılarak, buralardan sağlanacak faydalar, farklı doktora çalışmalarına ışık tutabilir, bu konularla ilgili yapılabilecek çalışmalarda analiz edilebilir.

1. INTRODUCTION

Aviation is one of the more complex sector in the world. Consequently Airline Management includes many different sub sectors to be managed together and simultaneously. Some of them may be stated as follows: Maintenance, Flight Operation, Ground Operation, Flight Training, Catering, Cargo, Scheduling, Network Planning, Crew Planning, Fleet Planning etc… (Figure 1.1).

Figure 1.1 : Complexity of Aviation Sector.

In every field, researchers try continuously to find new solutions for the problems, to improve new technics and methods in order to establish better systems and thus to help to reduce this complexity.

Airlines always need available aircraft ready to fly for their scheduling but maintenance requirements force the aircraft to be kept on the ground. Therefore the optimum solution must be found.

The aircraft is kept on the ground not only for maintenance purposes but also for other reasons such as ground operation services etc… (Figure 1.2). But our objective in this thesis is only to reduce ground time spent for maintenance purposes and to maximize aircraft utilization.

Figure 1.2 : Ground time spent for other services or activities.

The operator (Airline company) wants to increase aircraft utilization but on the other hand he should meet the regulatory requirements and perform the maintenance in an acceptable level without making any concession in terms of regulations. Since maintenance is mandatory for safety and reliability and it is not possible to reduce the number of maintenance tasks to be accomplished, the only way to achieve this is to change the philosophy of performing maintenance. Performing maintenance in a more dynamic way by utilizing every moment when the aircraft is on the ground for any reason will present a more flexible maintenance approach. Nowadays in most airlines, maintenance checks are performed in predetermined intervals and maintenance tasks given in maintenance program are performed during these scheduled maintenance checks. This approach is very static and presents some disadvantages. In order to eliminate these disadvantages and to establish a more effective maintenance structure, new approaches are proposed in this thesis.

1.1 Purpose of the Thesis

Maximization of aircraft utilization is one the most important issue of an airline. Taking into account that an aircraft is designed to be flown for most of its economic life, every ground time may be considered as a loss for an airline.

So the first objective is to keep the A/C less time on the ground for any purposes especially for maintenance purposes and therefore to increase the duration of flight availability. The main purpose of this thesis is to propose alternative ways of performing maintenance in order to keep the A/C less time on the ground. One of the ways to increase the aircraft utilization (flight hours spent in a period of time) is to reduce ground time spent for maintenance. In this thesis two different methods to reduce ground time spent for maintenance are studied. A couple of case studies accomplished in an airline company to support the first method are given. In order to improve the first method the fuzzy AHP method may be used and this method may be helpfull to support the approach of single task-oriented maintenance concept (Angus, 2005).

The single task-oriented maintenance concept allows us to establish a more flexible structure in the accomplishment of maintenance tasks and consequently to perform the maintenance in every opportunity when the aircraft is already on the ground. By utilizing the advantages of single task-oriented maintenance concept, maintenance checks may be divided into smaller checks which need the A/C to be kept less time on the ground. Some case studies on dividing the maintenance content into smaller parts are observed in the content of this thesis. And application of this approach in an airline company is given in this thesis in the second chapter.

The second objective is to prevent earlier accomplishment of some maintenance tasks and to develop a software for this purpose (second method). In order to prevent earlier accomplishment of some maintenance tasks, the real-time utilization values of aircraft have to be taken into account and the most appropriate letter check alternatives according to real-time utilization values should be calculated by means of the software.

This software allows the users to calculate more accurate and appropriate letter check alternatives for each maintenance task given in the maintenance program according to the real-time utilization values accumulated by each aircraft. One of the advantages of the software is that it has the flexibility to make the calculations for every single aircraft and for the different fleets in the airline company. The objective of the software is to prevent earlier accomplishment of maintenance tasks and therefore to maximize aircraft utilization consequently. By this way to reduce ground downtime for the shceduled maintenance tasks and to increase aircraft availability for flight is possible by using this software. This will be explained in chapter 3 in details.

1.2 Background

Because of safety issues and in order to meet the requirements requested by civil aviation authorities (Figure 1.3), the airline companies have to adopt maintenance policies, which call the aircraft at the end of certain utilization (flight hour, flight cycle or calendar time) to a maintenance base for the routine maintenance checks. (Figure 1.4) An aircraft cannot fly once it reaches the legal flight hour limit because of the airworthiness issues. It has to undergo a maintenance check before the next flight. (Afsar, 2009).

Figure 1.3 : Civil Aviation Authorities.

Airline companies are faced with various optimization problems during the planning of maintenance tasks given in maintenance programs. Taking into account that there are too many maintenance tasks in the maintenance program with different interval values and different interval types, the difficulty of the problem may be more understandable. As an example in the maintenance program (Figure 1.5) of a wide body aircraft type such as Airbus A-340 fleet, there are more than three thousands maintenance tasks with different interval values.

Moreover the usage parameters for these maintenance tasks are different: some of them are given as operational units such as FH (Flight Hours), FC (Flight Cycle) etc., some of them are given as calendar units such as HR (hours), DY (days), MO (Months), YE (Years) etc. (Figure 1.4 and Figure 1.5). So the planning department of the airline company is faced with serious problem to schedule these maintenance tasks for the appropriate letter check and the problem becomes much more difficult if several aircraft with different utilization are taken into account.

In most airlines, maintenance checks are performed in predetermined intervals and maintenance tasks given in maintenance program (Figure 1.5) are performed during these maintenance checks. But this method remains insufficient to prevent earlier accomplishment of maintenance tasks. Due to the rigid structure of maintenance checks, such airlines are subjected to enormous loss of material, man hour etc...

FLEET MAINTENANCE CHECK TYPES AND INTERVALS

	RAMP CHECK	LINE CHECK (L)	A	B	C	D	Y	S
A310-300				500 F/H	6,000 F/H OR 24 MO *			6 YE
A319 A320 A321	400F/H		750 F/H OR 120 DAYS *		20 MO OR 6,000 F/H *			6 YE
A319CJ			120 DAYS		20 MO			6 YE
A330	7 DY		800 F/H		18 MO			6 YE
A340	7 DY		800 F/H		18 MO			6 YE
B737-400			200 F/H		4,000 F/H	24,000 F/H		
B737-800			150 F/H		7,500 F/H OR 2 YE *			
B777-300ER		250 FH OR 15 DY	1000 FH / 2 MO / 125 FC*		12000 FH / 2 YE /1500 FC*			
CESSNA 172			50 F/H	100 F/H	200 F/H	1 YE		
DIAMOND DA42			100 F/H	200 F/H OR 12 MO *	1,000 F/H	1 YE		6,000 F/H OR 12 YE *

Figure 1.4 : Maintenance check types and intervals of an airline company.

A340 MAINTENANCE PLANNING DOCUMENT

TASK NUMBER	ZONE	DESCRIPTION	THRESHOLD INTERVAL	SOURCE	REFERENCE	MEN	M/H	APPLICABILITY
321000-01-1		************** TASK DELETED **************						
321000-02-1	730 740 750	MAIN GEAR AND DOORS AF FC FUNCTIONAL CHECK OF MLG AND CLG SHOCK ABSORBER NITROGEN CHARGE PRESSURES	I: 36 HRS (ELAPSED)	MRB 8	320000-200-801 MRB REFERENCE : 32.11.00/14 32.15.00/11	1 1 1	0.66 0.66 0.66	A340-500 OR A340-600
321000-03-1	731 741	MAIN GEAR AND DOORS AF LU LUBRICATION OF MAIN GEAR AND DOORS	I: 500 FC OR 4 MO	MRB 5,8	122232-600-817 MRB REFERENCE : 32.11.00/01 32.11.00/02 32.11.00/11 32.11.00/17 32.30.00/01 32.30.00/03 32.30.00/15	1 1	1.20 1.20	ALL
321000-04-1	731 741	MAIN GEAR AND DOORS AF LU LUBRICATION OF MLG BOGIE PIVOT PIN	I: 250 FC OR 4 MO	MRB	122232-640-801 MRB REFERENCE : APX.11	1 1	0.15 0.15	A340-200 OR A340-300
321000-04-2	731 741	MAIN GEAR AND DOORS AF LU LUBRICATION OF MLG BOGIE PIVOT PIN	I: 50 FC	OIT SIL	122232-640-801 OIT 999.0042/09 SIL 32-114	1 1	0.15 0.15	A340-500 OR A340-600
321000-05-1	731 741	MAIN GEAR AND DOORS AF LU LUBRICATION OF SM8 AND SM9 PIN.	I: 250 FC OR 4 MO	MRB MRB 6,9	122232-600-820 MRB REFERENCE : 32.11.00/01 APX.11	1 1	TBD TBD	A340-200 OR A340-300
321100-01-1	731 741	MAIN GEAR AF RS REMOVE MAIN GEAR FOR RESTORATION NOTE: RESTORATION TO BE PERFORMED IN ACCORDANCE ***** CONTINUED *****	I: 17000 FC OR 10 YE	MRB MRB 5 VSB	321111-920-801 VSB A33/34-32-244 MRB REFERENCE :	4 4	48.00 48.00	A340-200 OR A340-300

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Figure 1.5 : Maintenance tasks in the maintenance program called MPD.

As an example, for an airline company which performs an "A" check in every 800 FH for its X type of A/C, maintenance tasks with an interval of 800 FH or multiple 800 FH intervals such as 1600 FH, 2400 FH etc… will be performed on time during the periodic checks (A001-check, A002-check, … , An-check etc…). There will be no losses in the application of such maintenance tasks. But on the other hand, there will be losses in the application of maintenance tasks with different intervals such as 1000 FH, 1300 FH etc… which are not exact multiples of the given letter check interval value. Preventing earlier accomplishment of these maintenance tasks should only be procured by utilizing different approch in maintenance and changing the philosophy of performing maintenance.

The operator wants to increase aircraft utilization but on the other hand he should meet the regulatory requirements and perform the maintenance in acceptable level without making any concession in terms of regulations. Since maintenance is mandatory for safety and reliability and it is not possible to reduce the number of maintenance tasks to be accomplished, the only way to be achieved is to change the philosophy of performing maintenance.

Performing maintenance in a more dynamic way by utilizing every moment when aircraft is on ground for any reason will present a more flexible maintenance approach. Nowadays in most airlines, maintenance checks are performed in predetermined intervals and maintenance tasks given in maintenance program are performed during these scheduled maintenance checks. This approach is very static and presents some disadvantages.

Taking into account that maintenance is indispensable for continuing airworthiness and the regulations related to maintenance in civil aviation give the operators (airline companies) and MRO's (Maintenance Repair and Overhaul companies) the responsibility of performing the maintenance of the aircraft in an acceptable level, the concepts about "Maintenance", "Regulations" and "Maintenance Program" should be understood well prior to mention about the method.

1.3 Maintenance, Regulations and Maintenance Program

An aeronautical product is airworthy when it conforms to the regulations under which it has been certified (Boeing, 2006). Modern transport category aircraft are designed to meet continuing airworthiness requirements for an indefinite time. But this statement is valid providing the integrity is maintained by an effective inspection and corrective maintenance program (Airbus, 1996).

The owner (air carrier – Airline Company) is responsible for the continuing airworthiness of an aircraft and shall ensure that no flight takes place unless:

1. the aircraft is maintained in an airworthy condition, and;

2. any operational and emergency equipment fitted is correctly installed and serviceable or clearly identified as unserviceable, and;

3. the airworthiness certificate remains valid, and;

4. the maintenance of the aircraft is performed in accordance with the approved maintenance program (EASA, 2003).

An air carrier is responsible for the maintenance of their aircraft. But he may arrange for a maintenance provider, such as a repair station (MRO - Maintenance Repair and Overhaul Company), to perform the maintenance for him. However, he retains responsibility for the performance and approval of that maintenance even if someone else performs the work for him (FAA, 2003)

Before to mention about this dynamic method, the maintenance concept in aviation and maintenance program philosophy should be clearly explained. Maintenance program development process has been clearly explained in regulations such as "Maintenance Review Board Procedures" (FAA, 1997).

1.3.1 Maintenance

Maintenance in aviation industry may be classified into two categories such as preventive maintenance (scheduled maintenance and routine maintenance terms are also used for preventive maintenance) and corrective maintenance (unscheduled maintenance and non-routine maintenance terms are also used for corrective maintenance). (Figure 1.6) All scheduled maintenance letter checks are subject of preventive maintenance activities.

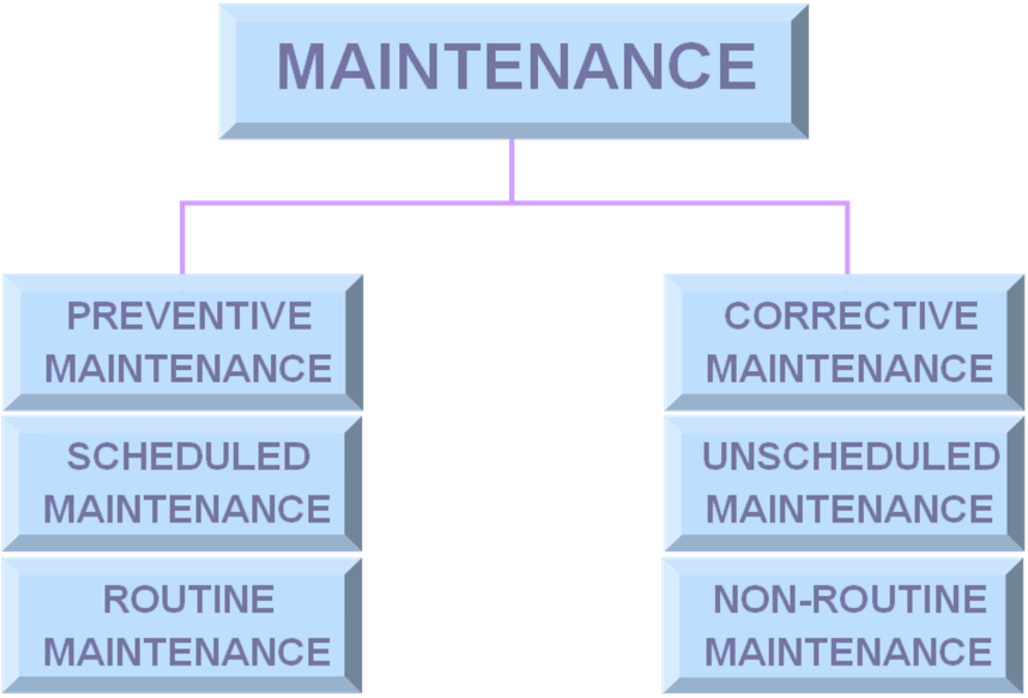


Figure 1.6 : Maintenance Categories.

1.3.1.1 Airline cost classification

Figure 1.7 illustrates a common approach to airline cost classification using functional categories. Nonoperating costs, which are directly related to the transportation of passengers or cargo, can vary so widely between airlines as a result of different corporate activities and financial structures that inter-airline comparisons are often of limited use. Operating costs arise from the production and sale of air transport output and can be "indirect" or "direct". Indirect operating costs (IOCs) are costs related to the sale and delivery of passenger or cargo services that are independent of the composition or usage of an airline's fleet. Direct operating costs (DOCs) (Figure 1.8) are largely dependent upon the types of aircraft in the fleet and how they are operated – that is, flight operations – and so would change if the fleet were changed or operated differently. DOCs can be calculated on a periodic system-wide basis, or they can be calculated per flight-hour for each aircraft type as an input into fleet and network management decisions. DOCs have both variable and fixed elements. For analytical purposes it is common for cash operating costs to be broken out of DOCs; the most significant DOC that does not qualify as a cash operating cost is depreciation (a non-cash charge).

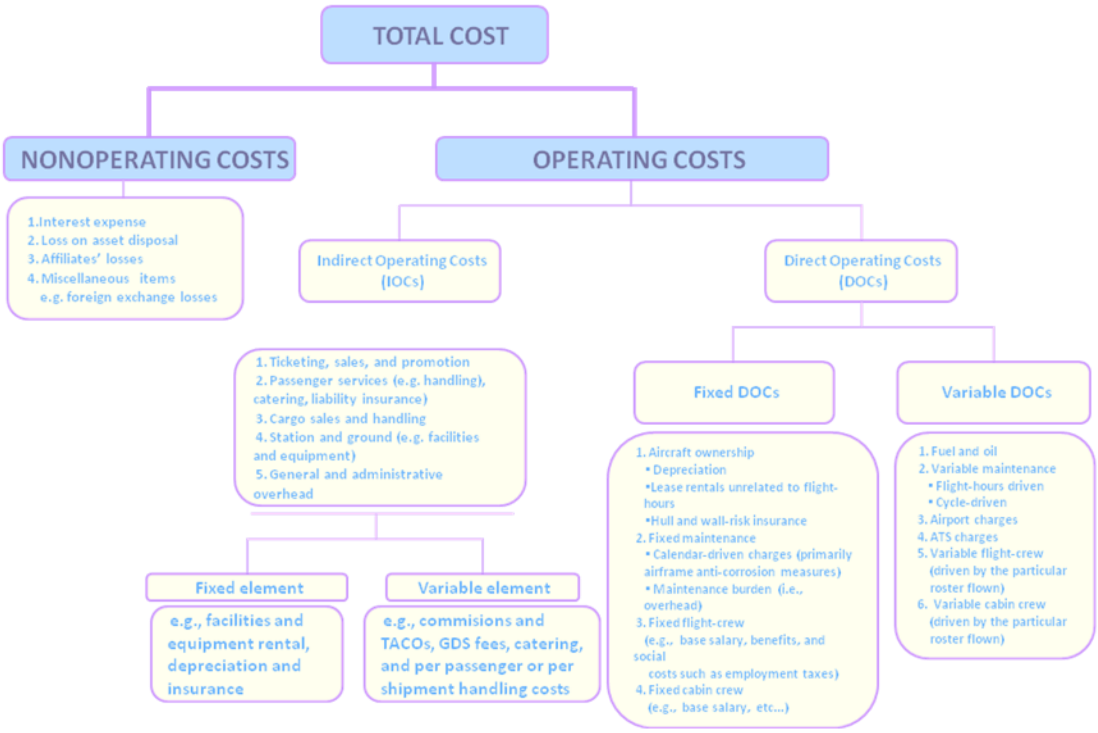


Figure 1.7 : A possible airline cost classification.

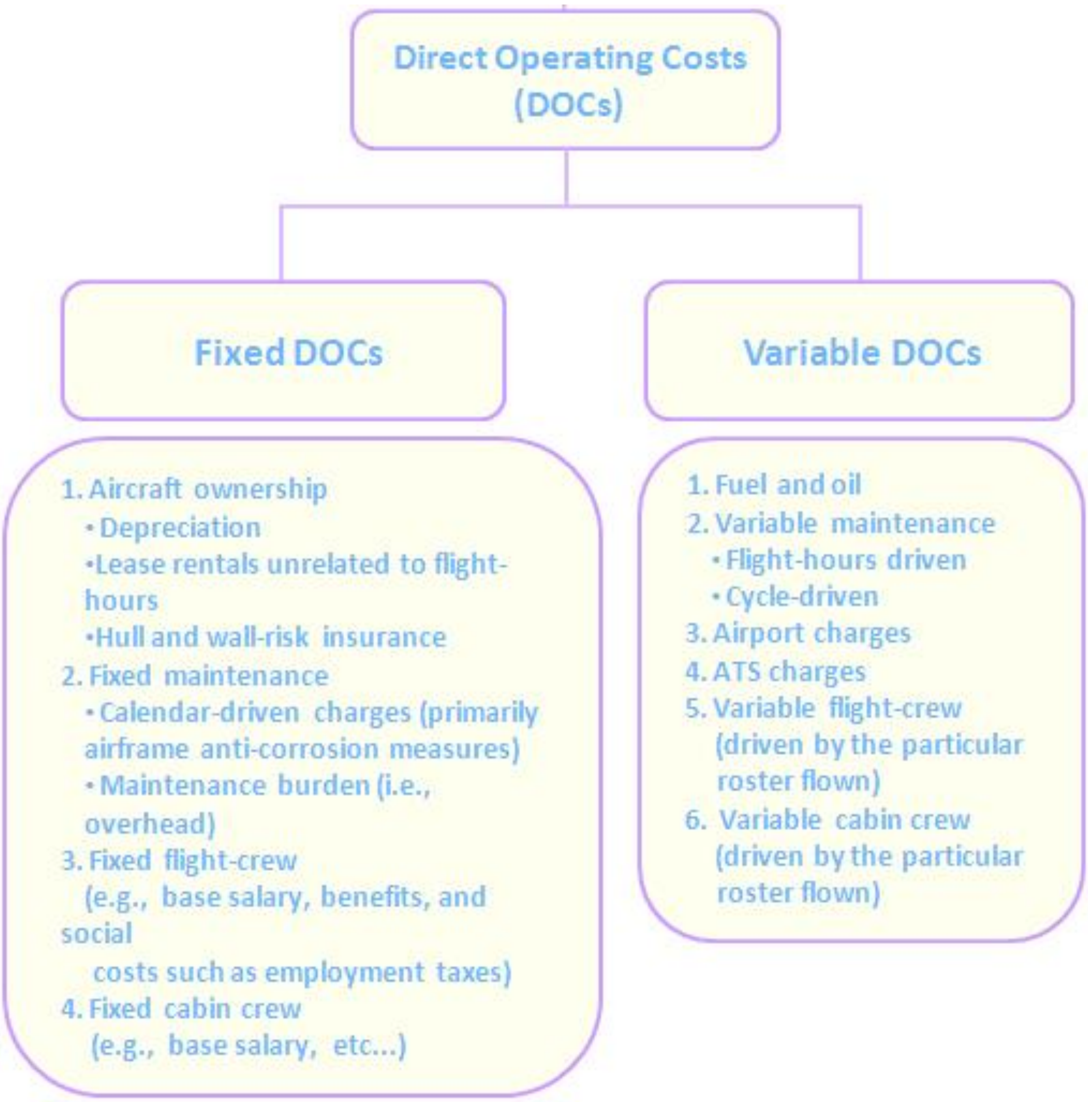


Figure 1.8 : Direct Operating Costs (DOCs).

Direct operating costs related maintenance may be classified also under two categories such as on-aircraft and off-aircraft maintenance. On-aircraft maintenance items are performed on the aircraft without carrying the component to the shops however off-aircraft maintenance is performed in the shops after the removal of the components from the aircraft.

Direct maintenance cost may be classified under two categories such as scheduled maintenance costs and unscheduled maintenance costs (Figure 1.9) Whether maintenance type is scheduled or unscheduled, its maintenance cost is composed from components & airframe and engine maintenance cost. This last cost covers all material and tool cost and man-hour cost accomplished during the maintenance.

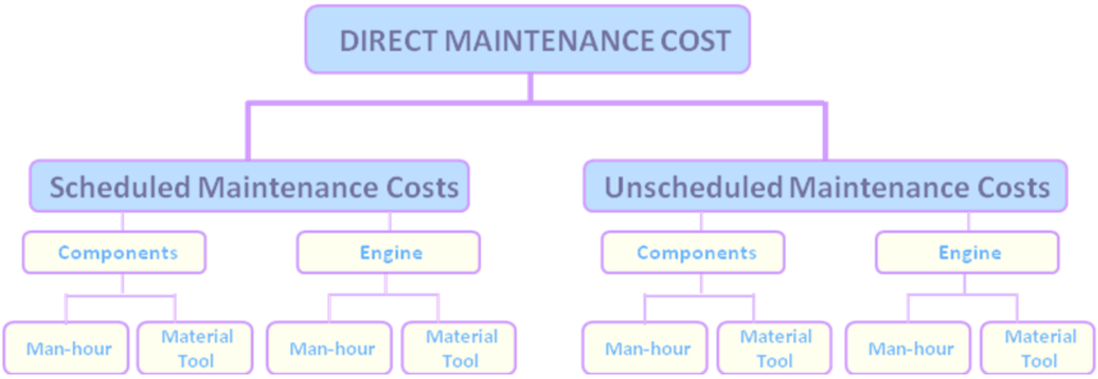


Figure 1.9 : Direct Maintenance Cost breakdown.

During the scheduled maintenance checks (preventive maintenance), all periodic maintenance tasks in maintenance program of the aircraft fleet, modifications and life limited parts changes are accomplished. Unscheduled maintenance checks are related with aircraft age. Man-hour required for a specific maintenance check is normally multiplied by a fixed coefficient which may depend on aircraft age. Airline companies may calculate this coefficient for their fleet based on their experience obtained from earlier maintenance checks. This coefficient may be assumed 1.2 for new aircraft under two years old and 2.3 for aircraft more than two years old.

1.3.2 Maintenance program history - MSG (Maintenance Steering Group)

The development of maintenance programs has a long history dating back to Aeronautical Bulletin 7E of May 15, 1930. The process of developing maintenance programs for new aircraft and powerplants has evolved from one in which each air carrier proposed its own unique program to one in which the FAA and industry work together to develop the initial minimum scheduled maintenance/inspection requirements for new aircraft and/or powerplants. Early experience in the development of initial scheduled maintenance/inspection requirements revealed that a program of effective maintenance tasks could be developed through the use of logical analysis and decision processes. In 1968, a maintenance requirements decision and analysis logic was developed by an industry team called the Maintenance Steering Group-1st Task Force (MSG-1).

1.3.2.1 MSG-1

MSG-1 procedures were used by the FAA and industry to develop the initial minimum scheduled maintenance/inspection recommendations for the B-747 aircraft and its powerplants. A later task force utilized the experience gained on the B-747 project to update the MSG-1 procedures so that a universal document could be applicable for future newly typecertificated aircraft and/or powerplants. This document was called the Maintenance Steering Group-2nd Task Force (MSG-2) document.

1.3.2.2 MSG-2

MSG-2 procedures were used to develop the initial minimum scheduled maintenance/ inspection recommendations for aircraft/powerplants of the 1970's. In 1980, the combined efforts of the FAA, the Air Transport Association of America (ATA), U.S. and European aircraft and engine manufacturers, and U.S. and foreign airlines generated new decision logic and analysis procedures contained in a new document called Maintenance Steering Group-3rd Task Force (MSG-3).

1.3.2.3 MSG-3

In 1987, after using MSG-3 analysis procedures on a number of new aircraft and powerplants in the first half of the 1980's, the airline industry decided that the benefits of the experience gained during those years should be used to improve the document for future applications. Thus, Revision 1 to MSG-3 was developed.

1.3.2.4 MSG-3R1

The FAA and industry have been using MSG-3Rl since 1988 for the development of current and future aircraft and powerplant MRBR's.

1.3.2.5 MSG-3R2

The FAA and industry have been using MSG-3R2 since 1993 for current and future aircraft and powerplant MRBR's.

1.3.3 Maintenance Review Board Report (MRBR)

An MRBR (Figure 1.10) is prepared for aircraft intended for air carrier use according to the following guidelines. An MRBR is normally not prepared for transport category aircraft having a maximum certificated takeoff weight of 12,500 pounds or less. For transport category aircraft having a maximum certificated takeoff weight of more than 12,500 pounds but not more than 33,000 pounds, a Maintenance Review Board (MRB) is sometimes convened and an MRBR generated. However, for transport category aircraft of more than 33,000 pounds maximum certificated takeoff weight, an MRB is normally convened and an MRBR generated as an expeditious means of complying in part with the maintenance instruction requirements of Appendix H to 14 CFR part 25. It is a means, in part, of developing Instructions for Continued Airworthiness, as required by regulations stated in part 25.1529 (FAA, 1997).

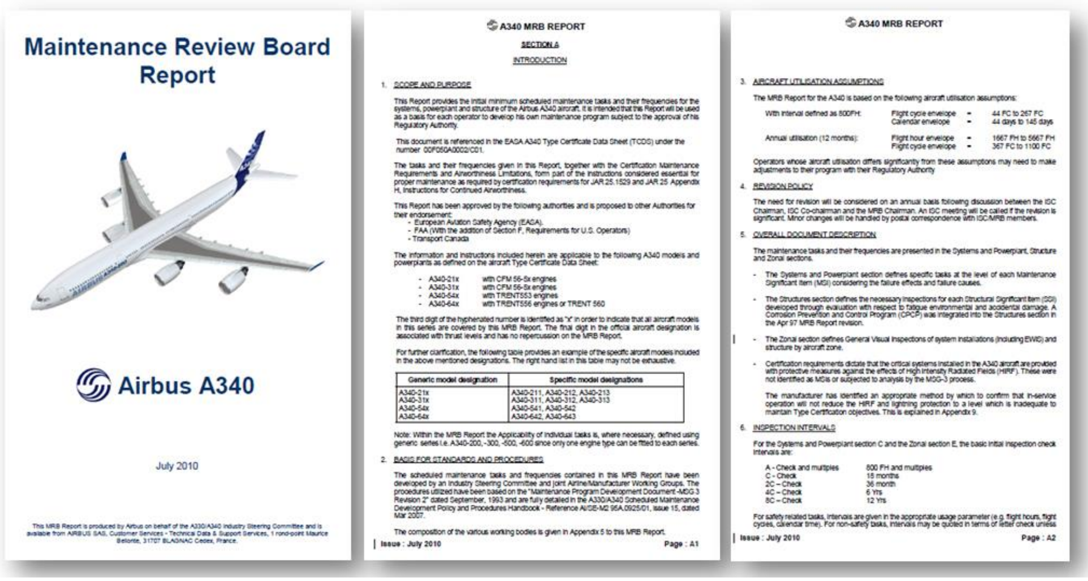


Figure 1.10 : Maintenance Review Board Report (MRBR) of an aircraft type.

An MRBR contains the initial minimum scheduled maintenance/inspection requirements for a particular transport category aircraft and on-wing engine program, but does not establish off-wing engine maintenance programs required by the Regulations. It should be developed in accordance with these guidelines and is not to be confused with, or thought of, as a maintenance program.

After approval by the FAA (or civil aviation authority of A/C manufacturer), the requirements become a base or framework around which each air carrier develops its own individual maintenance program. Although maintenance programs vary widely from one air carrier to another, the initial requirements for a particular type of aircraft will be the same for all. An air carrier's total maintenance program (methods used to implement these requirements) must be approved by the local civil aviation authority through operations specifications. As explained in the Advisory Circular published by FAA, MRBR stands for Maintenance Review Board Report and it contains the initial minimum scheduled maintenance/inspection requirements for a particular transport category aircraft and onwing engine program. Each air carrier should develop its own individual maintenance program by using MRBR as a reference and by meeting the initial minimum requirements contained in MRBR.

This Report provides the initial minimum scheduled maintenance tasks and their frequencies for the systems, powerplant and structure of the aircraft. It is intended that this Report will be used as a basis for each operator to develop his own maintenance program subject to the approval of his Regulatory Authority.

As an example in the MRBR published by Airbus for A340 A/C, some explanations about the MRBR are given as follows: The tasks and their frequencies given in this Report, together with the Certification Maintenance Requirements and Airworthiness Limitations, form part of the instructions considered essential for proper maintenance as required by certification requirements for JAR 25.1529 and JAR 25 Appendix H, Instructions for Continued Airworthiness (EASA, 2005).

This Report has been approved by the following authorities and is proposed to other Authorities for their endorsement:

- European Aviation Safety Agency (EASA).

- FAA (With the addition of Section F, Requirements for U.S. Operators)

- Transport Canada

The scheduled maintenance tasks and frequencies contained in this MRB Report have been developed by an Industry Steering Committee and joint Airline/Manufacturer Working Groups. The procedures utilized have been based on the "Maintenance Program Development Document - MSG 3 Revision 2" dated September, 1993 and are fully detailed in the A330/A340 Maintenance Program Development Policy and Procedures Handbook - Reference AI/SE-M2 95A.0925/01, issue 14, dated June 2005.

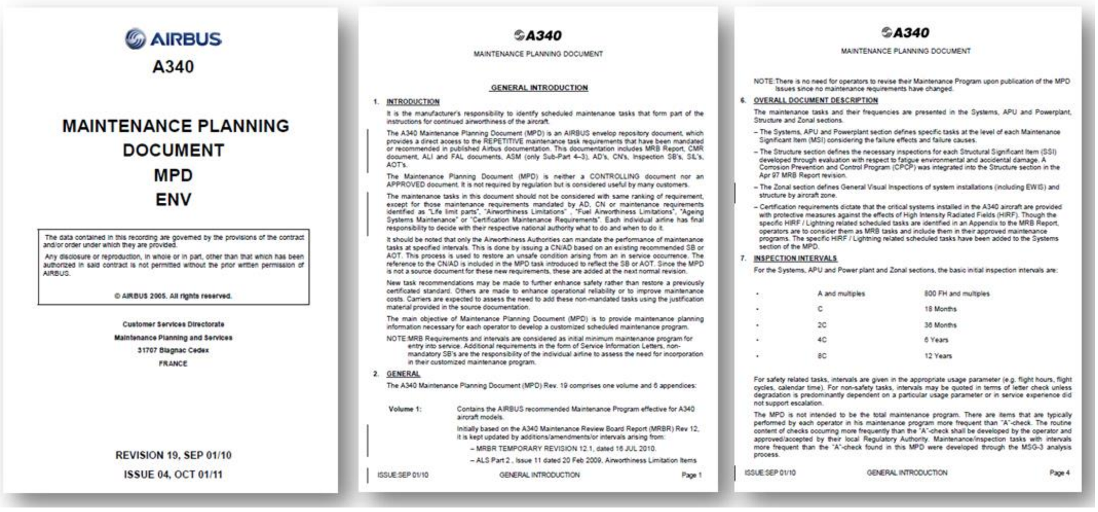
1.3.4 Maintenance Planning Document (MPD)

It is the A/C manufacturer’s responsibility to identify scheduled maintenance tasks that form part of the instructions for continued airworthiness of the aircraft. A/C manufacturer publishes also another document which is called Maintenance Planning Document (MPD) (Figure 1.11) to support operators. The Maintenance Planning Document (MPD) is neither a CONTROLLING document nor an APPROVED document (Airbus, 2007). It is not required by regulation but is considered useful by many customers. The maintenance tasks in this document should not be considered with same ranking of requirement, except for those maintenance requirements mandated by AD or CN or maintenance requirements identified as “Life limit parts”, "Airworthiness Limitations", “Fuel Airworthiness Limitations” or "Certification Maintenance Requirements”. Each individual airline has final responsibility to decide with their respective national authority what to do and when to do it. It should be noted that only the Airworthiness Authorities can mandate the performance of maintenance tasks at specified intervals. This is done by issuing a CN/AD based on an existing recommended SB or AOT. This process is used to restore an unsafe condition arising from an in service occurrence. The reference to the CN/AD is included in the MPD task introduced to reflect the SB or AOT.

The main objective of Maintenance Planning Document (MPD) is to provide maintenance planning information necessary for each operator to develop a customized scheduled maintenance program. MRB Requirements and intervals are considered as initial minimum maintenance program for entry into service.

Additional requirements in the form of Service Information Letters, non-mandatory SB's are the responsibility of the individual airline to assess the need for incorporation in their customized maintenance program.

It is the responsibility of each operator to adjust his own maintenance program in accordance with his National Requirements and to comply with existing rules with respect to reporting to his Regulatory Authority and to the manufacturer events having effects on the continued airworthiness of the aircraft (Airbus, 2007).



AIRBUS
A340

MAINTENANCE PLANNING DOCUMENT
MPD
ENV

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REVISION 19, SEP 01/10
ISSUE 04, OCT 01/11

A340
MAINTENANCE PLANNING DOCUMENT

GENERAL INTRODUCTION

1. INTRODUCTION

It is the manufacturer's responsibility to identify scheduled maintenance tasks that form part of the instructions for continued airworthiness of the aircraft.

The A340 Maintenance Planning Document (MPD) is an AIRBUS envelop repository document, which provides a direct access to the REPETITIVE maintenance task requirements that have been mandated or recommended in published Airbus documentation. This documentation includes MRB Report, CMR document, ALI and FAL documents, ASM (only Sub-Part 4-3), AD's, CN's, Inspection SB's, SIL's, AOT's.

The Maintenance Planning Document (MPD) is neither a CONTROLLING document nor an APPROVED document. It is not required by regulation but is considered useful by many customers.

The maintenance tasks in this document should not be considered with same ranking of requirement, except for those maintenance requirements mandated by AD, CN or maintenance requirements identified as "Life limit parts", "Airworthiness Limitations", "Fuel Airworthiness Limitations", "Ageing Systems Maintenance" or "Certification Maintenance Requirements". Each individual airline has final responsibility to decide with their respective national authority what to do and when to do it.

It should be noted that only the Airworthiness Authorities can mandate the performance of maintenance tasks at specified intervals. This is done by issuing a CN/AD based on an existing recommended SB or AOT. This process is used to restore an unsafe condition arising from an in service occurrence. The reference to the CN/AD is included in the MPD task introduced to reflect the SB or AOT. Since the MPD is not a source document for these new requirements, these are added at the next normal revision.

New task recommendations may be made to further enhance safety rather than restore a previously certificated standard. Others are made to enhance operational reliability or to improve maintenance costs. Carriers are expected to assess the need to add these non-mandated tasks using the justification material provided in the source documentation.

The main objective of Maintenance Planning Document (MPD) is to provide maintenance planning information necessary for each operator to develop a customized scheduled maintenance program.

NOTE: MRB Requirements and intervals are considered as initial minimum maintenance program for entry into service. Additional requirements in the form of Service Information Letters, non-mandatory SB's are the responsibility of the individual airline to assess the need for incorporation in their customized maintenance program.

2. GENERAL

The A340 Maintenance Planning Document (MPD) Rev. 19 comprises one volume and 6 appendices:

Volume 1: Contains the AIRBUS recommended Maintenance Program effective for A340 aircraft models.

Initially based on the A340 Maintenance Review Board Report (MRBR) Rev 12, it is kept updated by additions/amendments/or intervals arising from:

– MRBR TEMPORARY REVISION 12.1, dated 16 JUL 2010.

– ALS Part 2, Issue 11 dated 20 Feb 2009, Airworthiness Limitation Items

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A340
MAINTENANCE PLANNING DOCUMENT

NOTE: There is no need for operators to revise their Maintenance Program upon publication of the MPD Issues since no maintenance requirements have changed.

6. OVERALL DOCUMENT DESCRIPTION

The maintenance tasks and their frequencies are presented in the Systems, APU and Powerplant, Structure and Zonal sections.

– The Systems, APU and Powerplant section defines specific tasks at the level of each Maintenance Significant Item (MSI) considering the failure effects and failure causes.

– The Structure section defines the necessary inspections for each Structural Significant Item (SSI) developed through evaluation with respect to fatigue environmental and accidental damage. A Corrosion Prevention and Control Program (CPCP) was integrated into the Structure section in the Apr 97 MRB Report revision.

– The Zonal section defines General Visual Inspections of system installations (including EWIS) and structure by aircraft zone.

– Certification requirements dictate that the critical systems installed in the A340 aircraft are provided with protective measures against the effects of High Intensity Radiated Fields (HIRF). Though the specific HIRF / Lightning related scheduled tasks are identified in an Appendix to the MRB Report, operators are to consider them as MRB tasks and include them in their approved maintenance programs. The specific HIRF / Lightning related scheduled tasks have been added to the Systems section of the MPD.

7. INSPECTION INTERVALS

For the Systems, APU and Power plant and Zonal sections, the basic initial inspection intervals are:

•	A and multiples	600 FH and multiples
•	C	18 Months
•	2C	36 Months
•	4C	6 Years
•	8C	12 Years

For safety related tasks, intervals are given in the appropriate usage parameter (e.g. flight hours, flight cycles, calendar time). For non-safety tasks, intervals may be quoted in terms of letter check unless degradation is predominantly dependent on a particular usage parameter or in service experience did not support escalation.

The MPD is not intended to be the total maintenance program. There are items that are typically performed by each operator in his maintenance program more frequent than "A"-check. The routine content of checks occurring more frequently than the "A"-check shall be developed by the operator and approved/accepted by their local Regulatory Authority. Maintenance/inspection tasks with intervals more frequent than the "A"-check found in this MPD were developed through the MSG-3 analysis process.

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Figure 1.11 : Maintenance Planning Document (MPD) of an aircraft type

1.3.5 Aircraft utilization assumptions

When the aircraft manufacturer prepares a maintenance document such as MRBR or MPD, some aircraft utilization assumptions are taken into account. For example the Maintenance Planning Document for the A340 is based on the following aircraft utilization assumptions (Airbus, 2007):

With interval defined as 600 FH: Flight cycle envelope = 33 FC to 200 FC

Calendar envelope = 33 days to 109 days

Annual utilization (12 months): Flight hour envelope = 1667 FH to 5667 FH

Flight cycle envelope = 367 FC to 1100 FC

Operators whose aircraft utilization differs significantly from these assumptions may need to make adjustments to their program with their Regulatory Authority.

The maintenance tasks given in the maintenance program for a given type of aircraft should be accomplished in the interval given in this maintenance program. The intervals may be identified in different categories (Airbus, 2007):

Usage parameters

1.3.5.1 Operational units

- "FH" (Flight hours) : Elapsed time between wheel lift off and touchdown.

- "FC" (Flight cycle) : A complete take off and landing sequence.

- "LD" (Landing) : A complete take off and landing sequence.

- "CY" (Cycle) : Engine cycles.

- "AH" (APU Hours) : APU operating hours.

1.3.5.2 Calendar units

- "HR" (Hour) : One Calendar hour elapsed.

- "DY" (Day) : 24 Calendar hours elapsed.

- "MO" (Month) : One Calendar month.

- "YE" (Year) : One Calendar year.

1.3.5.3 Other codes

- "NR" (National Requirement)

Task known as being subject to national regulatory requirement.

- "VR" (Vendor Recommendation)

Interval value dependent on task vendor recommendation.

- "NT" or “NOTE” (Note)

Refer to the note at the end of the task description.

- “EC” (Engine Change)

Task could be accomplished at opportunity of engine change.

Task intervals may be changed in accordance with operator's Regulatory Authority practices and rules. However, tasks with Failure Effect Category 5 and 8 must not be deleted from the operator's maintenance program.

1.4 Literature Review

The purpose of this section is to review the literature on maintenance management and aircraft maintenance and to explain major studies done on these subjects. It is intented to categorize systematically the published literature on maintenance management and aircraft maintenance. Many important issues in maintenance management may have direct relations with optimization models, maintenance techniques, scheduling, and information systems etc.

For the maintenance management technics, the article submitted by (Garg, A., Deshmukh, S.G. 2006) was very helpful for the author of this thesis since literature on classification of maintenance management has so far been very limited. The author took this article as a reference and studied all the papers included in this article.

The maintenance function becomes important through the years and maintenance management has grown consequently.

Some of the articles studied in the scope of this thesis are given below:

Dekker and Scarf (1998) analyzed 112 papers on the maintenance optimization models.

Pintelon and Puyvelde (1997) and Tsang (1999) submitted articles on various performance measurement systems (PMS) and they have collected and discussed various articles on this subject. Another survey on the maintenance policies of deteriorating systems has been submitted by Wang (2002).

In the scope of this thesis 142 papers which are included in the reference review article were analyzed by the author of this thesis. These articles are classified in to six areas such as: maintenance optimization models, maintenance techniques, maintenance scheduling, maintenance performance measurement, maintenance information systems, maintenance policies.

For maintenance optimization models, they are classified according to the modeling of the deterioration as deterministic or stochastic models. Sub classification of the maintenance optimization models are: Bayesian approach, Mixed integer linear programming (MILP) formulation, Maintenance approach using fuzzy multiple criteria decision making (MCDM) and linguistic approaches, Simulation and Markovian probabilistic models, Analytic hierarchy process (AHP) and miscellaneous.

The author has studied the articles recommended by Garg, A., Deshmukh, S.G for each models stated above. Some of them are given below:

- Bayesian approach - Apeland and Scarf (2003) / Ho and Silva (2006),
- Mixed integer linear programming (MILP) formulation - Goel et al. (2003),
- Maintenance approach using fuzzy multiple criteria decision making (MCDM) and linguistic approaches - Al-Najjar and Alsyouf (2003) / Triantaphyllou et al. (1997) / Mechefske and Wang (2003, 2001) / Swanson (2003) / Pieri et al. (2002),
- Simulation and Markovian probabilistic models - Chen and Popova (2002) / Barata et al. (2002) / Sarker and Haque (2000) / Balakrishnan (1992) / Bruns (2002) / Marquez and Heguedas (2002) / Chiang and Yuan (2001) and Lam (1999).
- Analytic hierarchy process (AHP) - Bevilacqua and Braglia (2000) / Labib et al. (1998) / Rochdi et al. (1999) / Sherwin (2000) / Bevilacqua et al. (2005).
- Miscellaneous - Hsieh and Chiu (2002) / Sander and Wang (2000) / Anderson (1998) / Dhillon and Liu (2006)

For maintenance techniques, they are sub-classified as: Preventive maintenance (PM), Condition-based maintenance (CBM), Total Productive Maintenance (TPM), Computerized maintenance management systems (CMMS), Reliability Centered Maintenance (RCM), Predictive maintenance, Maintenance Outsourcing, Effectiveness Centered Maintenance (ECM), Strategic Maintenance Management (SMM), Risk-based maintenance (RBM).

The author has studied the articles recommended by Garg, A., Deshmukh, S.G for each models stated above. Some of them are given below:

- Preventive maintenance (PM) - Chelbi and Ait-Kadi (2004) / Charles et al. (2003) / Qian et al. (2005) / Chen et al. (2003) / Bloch-Mercier (2002) / Sheu et al. (2001) / Juang and Anderson (2004) / Zhao (2003) / Bris et al. (2003) / Badia et al. (2002) / Gürler and Kaya (2002) / Motta et al. (2002) / Salameh and Ghattas (2001) / Tsai et al. (2001) / Gupta et al. (2001) / Dohi et al. (2001) / Lai et al. (2000) / Ben-Daya and Alghamdi (2000) / Hsu (1999) / Gupta and Al-Turki (1998) / Gopalakrishnan et al. (1997).

- Condition-based maintenance (CBM) - Grall et al. (2002) / Chen and Trivedi (2002) / Marseguerra et al. (2002) / Jamali et al. (2005) / Saranga and Knezevic (2001) / Barbera et al. (1999) / Luce (1999).
- Total Productive Maintenance (TPM) - Wang and Lee (2001) / McKone et al. (2001) / Ireland and Dale (2001) / Das (2001) / Gupta et al. (2001) / Kodali and Chandra (2001) / Kodali (2001) / Finlow-Bates et al. (2000) / Cooke (2000) / McKone et al. (1999) / Shamsuddin et al. (2005).
- Computerized maintenance management systems (CMMS) - Fernandez et al. (2003) / Leger and Movel (2001) / Singer (1999) / Labib (1998) / Swanson (1997) / Jones and Collis (1996) / Wickers (1996).
- Reliability Centered Maintenance (RCM) - Gabbar et al. (2003) / Wessels (2003) / Eisinger and Rakowsky (2001) / Hipkin and Cock (2000) / Rausand (1998).
- Predictive maintenance - McKone and Weiss (2002) / Chu et al. (1998).
- Maintenance outsourcing - Murthy and Asgharizadeh (1999) / Martin (1997) / Buczkowski et al. (2005).
- Effectiveness centered maintenance (ECM) - Pun et al. (2002)
- Strategic maintenance management (SMM) - Murthy et al. (2002).
- Risk-based maintenance (RBM) - Khan and Haddara (2003).

For maintenance scheduling, they are sub-classified as: Techniques (such as Condition-based Maintenance (CBM), Predictive and Preventive Maintenance (PM)), wear out components, Repair rate modifying activities, Combining production and maintenance, Maintenance personel. For maintenance scheduling, some of the articles that the author studied are as follows: Dieulle et al. (2003) / Grall et al. (2002) / Gopalakrishnan et al. (2001) / Greenwood and Gupta (2000) / Tsang et al. (2006) / Artana and Ishida (2002) / Lee and Lin (2001) / Sloan and Shanthikumar (2000) / Duffuaa and Al-Sultan (1999).

For maintenance performance measurement, they are sub-classified as: Techniques (such as Various models, Vibration-based maintenance (VBM), Balanced Score Card (BSC), Quality Function Deployment (QFD), Maintenance Information Systems (MIS), Total maintenance Management (TMM), System audit approach, Maintenance Productivity Index), Overall equipment/craft efectiveness, Relation with maintenance strategy, Effect of failure on effectiveness, miscellaneous. For maintenance performance measurement, some of the articles that the author studied are as follows: Pintelon and Puyvelde (1997) / Tsang et al. (1999) / Liyanage and Kumar (2003) / Tsang (1998) / Al-Najjar and Alsyouf (2004) / Kutucuoglu et al. (2001) / Arts et al. (1998) / Raouf and Ben-Daya (1995) / Groote (1995) / Dwight (1999) / (Löfsten, 2000) / Ljungberg (1998) / Jeong and Phillips (2001) / Bamber et al. (2003) / Peters (2003) / Swanson (2001) / Pintelon et al. (2006) / Pongpech et al. (2006) / Crocker (1999) / Aronson (2002) / Bandi et al. (2003) / Lamb (1996) / Cooke and Paulsen (1997).

For maintenance information systems, some of the articles that the author studied are as follows: Pintelon et al. (1999) / Satyanarayana and Prasad (1996) / Nagarur and Kaewplang (1999) / Westerkamp (2002) / Fitzgerald et al. (1999) / Bardey et al. (2005).

For maintenance policies, some of the articles that the author studied are as follows: Wang (2002) / Pham and Wang (1996) / Iravani and Duenyas (2002) / Tu et al. (2001) / Jonsson (1999) / Ip et al. (2000) / Cua et al. (2001) / Tseng et al. (1998) / Polimac and Polimac (2001) / Andijani and Duffuaa (2002) / El Hayek et al. (2005) / Waeyenbergh and Pintelon (2002) / Nikolopoulos et al. (2003) / Oien (1998) / McIntosh et al. (2001) / Cheung et al. (2005) / Jonsson (1997) / Call (2002) / Chockie and Bjorkelo (1992).

Since the author of this thesis has been working in an airline company for about 20 years, he has huge knowledge about aircraft maintenance and all the documents about aircraft maintenance management published by aircraft manufacturers such as Airbus, Boeing etc.., aviation authorities such as EASA, FAA etc.. have been deeply analyzed in the scope of this thesis and some of them are given in the reference section of the thesis.

Other articles about aircraft maintenance have been also studied during the litterature review. Some of them are given below:

“Building flight planning for an airline company under maintenance constraints” published by H. Murat Afsar, Marie-Laure Espinouse and Bernard Penz in 2009 (Afsar, 2009). In this article, the authors explain some heuristic and meta heuristic tools in order to aid airline companies in flight planning while taking into account maintenance planning. The objective of this article is to maximize aircraft utilization before the maintenance interventions and to smooth the long-term flight load of the aircraft so that maintenance checks are regular for all the fleet. So the constraint about maintenance activities are integrated into the scope of the study.

“Airline Fleet Maintenance: Trade-off Analysis of Alternate Aircraft Maintenance Approaches” published by Michael J. Dupuy, Daniel E. Wesely, Cody S. Jenkins in 2011.). In this article, the authors explain the effectiveness of utilizing a condition-based approach, which considers the actual physical condition of the parts onboard the aircraft to dictate the time at which they are replaced. In the conclusion part, the authors emphasize the importance for airlines and aircraft manufacturers to consider the failure patterns of the parts on the airframes that they operate when deciding on a maintenance approach. For the future work, the authors suggest that the project in their article could be expanded to encompass improvements to tailor it to specific airline configurations. (Dupuy, 2011)

“Supervise on Aircraft Reliability for Improving Maintenance Program Continuously” published by Yi-Yong Cui, Qing-Gang Zhai in 2011. In this article, the authors explain that their paper keeps focus on the main problem of aircraft reliability supervision and continuous improvement of maintenance program. The authors make relationships between reliability issues and the maintenance program of the aircraft type. According to the authors, Reliability-Centered Maintenance (RCM) philosophy logic decision methods has great applied in developing aircraft maintenance program, but the dynamic management of its process has lagged behind relatively. Because of this, the maintenance program does not have a strong verification effectiveness. Reliability supervision includes the collection, identification, evaluation and disposal of the various meaningful information from signs of the failure or damage is about to take place. It can dynamically verify the validity of maintenance tasks, and improve the maintenance program continuously, which is the guarantee of reliability and operational safety of aircraft. (Cui, 2011)

“An approach to operational aircraft maintenance planning” published by N. Papakostas, P. Papachatzakis, V. Xanthakis, D. Mourtzis, G. Chryssolouris in 2010. In this article, the authors describe a short-term planning methodology of the line maintenance activities of an airline operator, at the airports, during turn-around time (TAT). The methodology that they propose supports decision making for deferring maintenance actions that affect the dispatching of the aircrafts, aiming at high fleet operability and low maintenance cost. (Papakostas, 2009)

“A performance improvement case study in aircraft maintenance and its implications for hazard identification” published by Marie Ward, Nick McDonald, Rabea Morrison, Des Gaynor and Tony Nugent in 2010. In this article, the authors describe the case that in order to improve a highly complex system such as aircraft maintenance, it is necessary to develop a comprehensive and ecologically valid model of the operational system, which represents not just what is meant to happen, but what normally happens. This model then provides the backdrop against which to change or improve the system. A performance report, the Blocker Report, specific to aircraft maintenance and related to the model was developed gathering data on anything that ‘blocks’ task or check performance. A Blocker Resolution Process was designed to resolve blockers and improve the current check system. (Ward, 2010)

“Selection of maintenance strategy for aircraft systems using multi-criteria decision making methodologies” published by Alireza Ahmadi, Suprakash Gupta, Ramin Karim and Uday Kumar in 2010. In this article, the authors propose the Multi-Criteria Decision Making (MCDM) methodology for selection of a maintenance strategy to assure the consistency and effectiveness of maintenance decisions. (Ahmadi, 2010)

“On aircraft scheduled maintenance program development” published by Alireza Ahmadi, Peter Söderholm and Uday Kumar in 2010. In this article, the authors present the issues and challenges of scheduled maintenance task development within the maintenance review board (MRB) process, and to find potential areas of improvement in the application of the MSG-3 methodology for aircraft systems. (Ahmadi, 2010)

“Periyodik Uçak Bakımlarının Planlanmasında Optimum İnterval ve Maliyet Problemleri” – “Optimum interval and maintenance cost problems for aircraft periodic maintenance check scheduling” published by Nikbay M. and Karakoç A. in 2006. The authors calculated optimum interval for aircraft maintenance periodic checks especially for “A” and “C” checks based on the minimum maintenance cost. Their purpose is to calculate an optimum maintenance check interval so as to minimize maintenance cost. A general mathematical maintenance cost function is obtained and this function is minimized. A case study for a selected Maintenance Planning Document (MPD) is performed for the maintenance tasks for “A” check and “C” check. (Nikbay, 2006)

“Expert system for aircraft maintenance services industry” published by Angus Cheung, W.H. Ip, Dawei Lu in 2005. In this article, the authors propose a method of analytical hierarchy process (AHP) which is developed for a decision support system to assist the decision-making of maintenance labor allocation. The authors developed an expert system which is a decision support used to select appropriate personnel and schedule the personnel in order to meet the demand. (Angus, 2005)

2. PROPOSED MAINTENANCE APPROACH – SINGLE TASK-ORIENTED MAINTENANCE CONCEPT

2.1 Traditional Airline Maintenance Scheduling

After explanations about maintenance program and its content, current maintenance application in traditional airlines and the maintenance approach proposed in this thesis will be discussed and comparisons between these two concepts will be explained.

In a traditional airline set-up, the maintenance department selects its preferred maintenance program and advises the operations and scheduling departments that it requires aircraft for maintenance for a given number of days for A checks, C checks and D checks (Airline Fleet, 2005). (Figure 1.4, Figure 2.1 and Figure 2.2)

Figure 2.1 : Letter checks.

Such maintenance is typically accomplished at one location usually called “main base” and the primary intention of such maintenance is to ensure that aircraft remains airworthy and onschedule. As such, line maintenance rarely becomes involved in scheduled maintenance other than performing an overnight check or something else relatively minor in nature. This is a rigid system whereby aircraft is either ‘in maintenance’ or ‘in operation’. It is also very wasteful: “The industry typically measures aircraft maintenance downtime in terms of one day or longer. Yet airlines route airplanes into six to eight hour overnight visits, or park them for eight or nine hours at the end of hub and spoke systems due to market conditions, crew rest or airport curfews.

Figure 2.2 : Traditional airline maintenance accomplishment.

Figure 2.3 : Traditional airline set-up.

2.2 Single Task-Oriented Maintenance Concept

With the introduction of advanced maintenance program management systems and supporting planning, communication and logistics systems, these visits become 'maintenance opportunities'." In other words, when an aircraft is not being operated, wherever it may be, maintenance may be performed.

In order to accomplish maintenance in the manner described above, it is necessary to operate a flexible maintenance program rather than one dominated by rigid letter checks (A, C, D etc.) (Figure 1.4, Figure 2.1 and Figure 2.3).

With the advent of MSG-3 maintenance programs, maintenance tasks are controlled individually, which makes it very much easier for airlines to tailor their maintenance to suit their operational needs.

Not only can this reduce the maintenance downtime requirement but, according to Boeing, the adoption of advanced program management techniques can reduce maintenance costs by as much as 15 per cent. In Figure 2.4 various maintenance program options have been demonstrated. In Alternative 1, a traditional block C check and five year check is shown.

Over a five-year period it is realized that 29 days of maintenance ground time are consumed. In Alternative 2 a split A and C check concept is portrayed and it too requires 29 days maintenance ground time over a five-year period. In Alternative 3 a heavy C check concept is identified and it needs 36 days maintenance downtime in a five-year period. Finally, in Alternative 4 a single task-oriented maintenance concept is portrayed; this consumes 14 days maintenance downtime over a five-year period. If one assumes that the $50,000 per day figure is applicable to the A320, this equates to a saving which can be as much as $1.1 million over a five year period. Or putting it another way, for a fleet of 30 aircraft, the savings add up to the equivalent of one new aircraft purchase every five years.

One of the possible criticisms of Alternative 4 is that it is all well and good to implement such a maintenance program when the aircraft is new, but as time goes on non-routine maintenance tends to increase and so it becomes more difficult for such a program to work in practice. But given the experience accumulated so far, it should be possible to extend such a maintenance program into a second maintenance cycle.

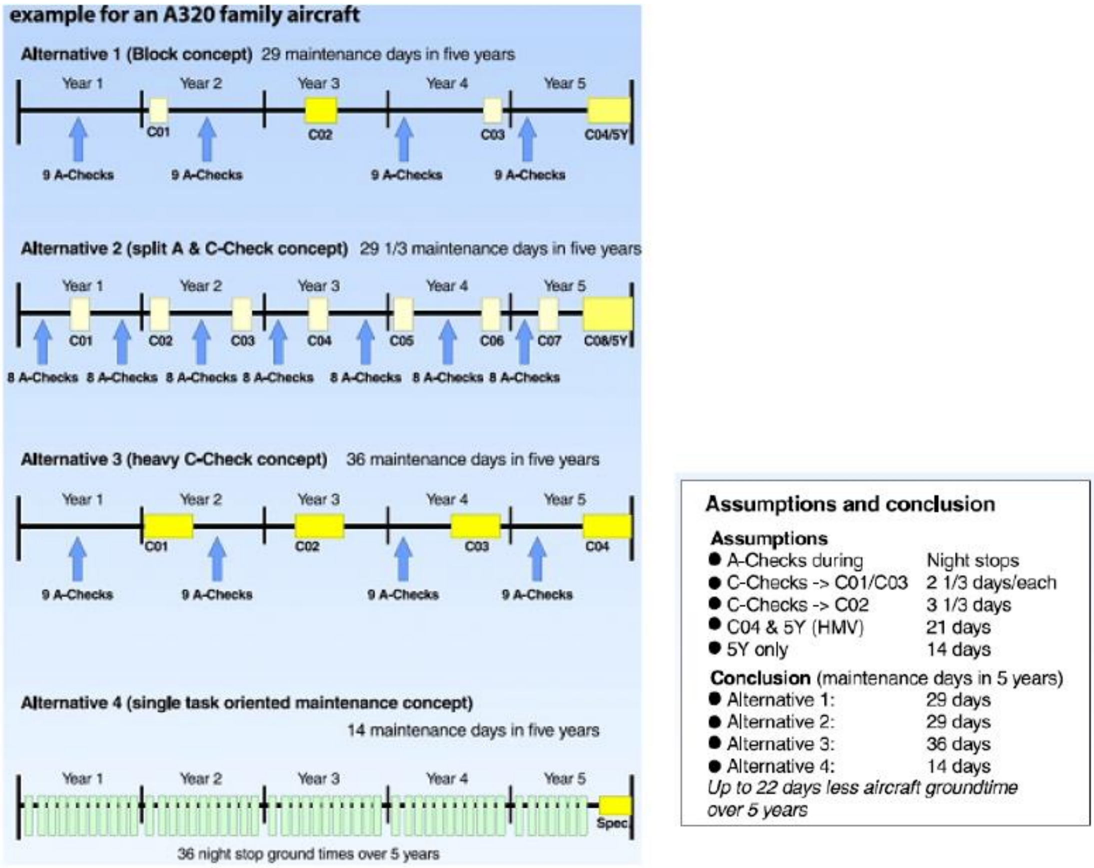


Figure 2.4 : Comparison of four alternatives (Airline Fleet, 2005).

The selection of the right maintenance program is fundamental to the reduction of maintenance downtimes: “Reducing maintenance downtime ultimately comes down to the maintenance program. If you want to come up with an incredibly phased maintenance program you will increase the maintenance downtime but reduce the amount of time that the airplane spends in heavy maintenance. If you want to go with every piece of maintenance fitted into a C check environment, you will create a situation where airplanes can run loose, less fettered by maintenance requirements, but then when they hit a C check there is all sorts of additional stuff. So there is a balancing act there, where a happy medium has to be found.” You should phase maintenance programs when the aircraft are young, during the first heavy maintenance cycle. Then in the second maintenance cycle you go back towards more of a blockoriented program.

The main goal is stretching the maintenance intervals and doing unnecessary tasks less often so eliminating non-value added work, rather than trying to put too much effort into rearranging work.

When designing a maintenance program it is essential that the nature of an airline's operation is borne in mind and that maintenance scheduling liaises closely with operations and scheduling staff. After all, there is no point in reducing maintenance downtime and increasing aircraft availability if it is not going to be used.

The airplane ought to be flying, turning or being maintained - it should not be parked on some dark corner of an airport doing nothing. Scheduling has got to recognise that it can't put an aircraft on a line for a week without visiting a place where maintenance can be accomplished.

If an airline's maintenance program is effective and unscheduled delays are minimised, airline planners will have the trust and confidence to schedule quicker transit times. Improved airline maintenance processes, maintenance troubleshooting and material supply systems can significantly reduce disruption and lower costs in the line maintenance/transit check environment.

2.2.1 Reducing other maintenance downtimes

To reduce ground time is in the process and this depends on how efficiently the maintenance organisation works, how the preparation work is done and, of course, continuity. If you maintain your aircraft to a high level continuously then you can probably reduce ground time during the heavy checks. Such efforts can probably reduce the ground time of a heavy check by between 10 and 20 per cent.

An integrated maintenance IT solution maximises improvements in schedule dependability and maintenance downtime reduction (Airline Fleet, 2005).

When considering the ability of an individual airline to reduce aircraft maintenance downtime, it is essential to consider a number of different technological aspects of the aircraft being operated and the IT and logistics infrastructures in which they function.

Modern aircraft such as the B737NG and the A320 have up-to-date diagnostics and prognostic capabilities as compared with earlier aircraft types and these permit a very much more proactive management of aircraft maintenance.

Some airlines, for example, use the Airbus Airman system whereby fault codes are transmitted through the ACARS system as the aircraft flies along. This permits airline's maintenance control centre to evaluate the codes and issue work cards at the nominated maintenance bases long before aircraft have landed. Such work could include dealing with early maintenance messages that are indicative of a potential or latent failure that are not visible to flight crews. Some airlines have a system whereby every day at a specific time all of the maintenance bases are issued their tasks by maintenance planning. Then in half an hour everyone calls in to go through their work assignments to make sure that they have staffing, the parts and the tooling to do the tasks. They have a process whereby at this specific time + half an hour every day they know the work that they are going to accomplish that evening. Their maintenance control centre also participates in the call and if any problems have been experienced on an airplane during the day they know what they are and they know what they have done to try to rectify them.

Also, they know where that plane's going to be that evening and they can add any trouble-shooting or defect rectification to the scheduled work assignment. Where Airbus has Airman, Boeing has its Airplane Health Management (AHM) system. In many ways it accomplishes a similar function to the Airman system but in addition to diagnosing a problem in flight, AHM can also predict when parts might fail so that maintenance can be scheduled to suit airline convenience. It can also instruct a search of Boeing's database to retrieve historic costs for fault rectification and assign a priority based on available data and the airline's business rules. Another technological advancement pioneered by Boeing was its Portable Maintenance Aid (PMA) which permits maintenance personnel to troubleshoot and rectify defects without having to return to fixed maintenance planning locations.

The ready availability of electronic documentation is to be one of the key factors when considering maintenance downtime management. All the documentation is online so airlines don't have any paper manuals - that's key from a number of different perspectives.

If you set up a new maintenance base getting folks datacon activity is the key thing – not printing off another umpteen stacks of books and figuring out who is going to maintain then.

It also facilitates easy access to engineering so that an engineer can be called in the middle of the night, he can fire up his laptop, research a problem, type an engineering disposition and email it out. Also, if an aircraft is damaged in the middle of the night, someone can take some pictures and email them to maintenance control, which can then assess what should be done. Being in an electronic environment is very beneficial.

Briefly an integrated maintenance IT solution is key to reducing aircraft maintenance downtimes. An integrated maintenance IT solution maximises improvements in schedule dependability and maintenance downtime reduction. New operating efficiencies, increased productivity and reduced disruption are all possible once the maintenance schedule and operational schedules are viewed as one. To fulfil this vision, airlines need maintenance IT systems that manage configuration, defect control, materials, maintenance programs, job cards, tooling, work planning, technical documentation and records in one integrated and on-line environment (Airline Fleet, 2005).

2.2.2 Methodology of single task-oriented concept

In order to apply the single task-oriented concept, each maintenance task in the maintenance program has to be studied one by one about the special characteristics of the task. Taking into account that there are too many maintenance tasks in a maintenance program, the dimension of this study may be more understandable. Nowadays a standard maintenance program includes at least more than two thousands maintenance tasks which are effective for the fleet during its whole economic life. As an example in the case study performed in this thesis, Airbus A340 fleet has been choosen and in the maintenance program of this aircraft type all 3800 maintenance tasks have been examined one by one. (Figure 2.5)

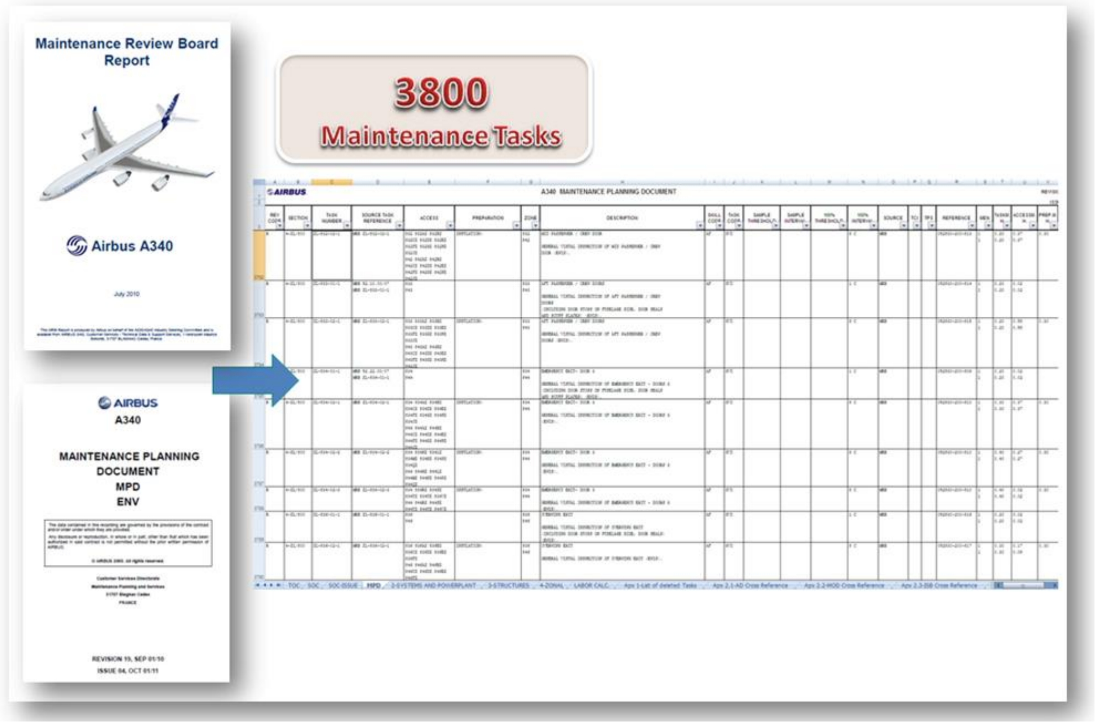


Figure 2.5 : Maintenance tasks.

Before to start the process of single task-oriented maintenance concept and to evaluate each single task according to the logic diagram of this concept, each maintenance task should be examined according to the characteristics given below:

- Maintenance task source (MRBR, MPD, SB, airline company etc...) (Figure 2.6). It is very important to know where this maintenance task is originated from especially during the decision process about the accomplishment or the postponement of the task.

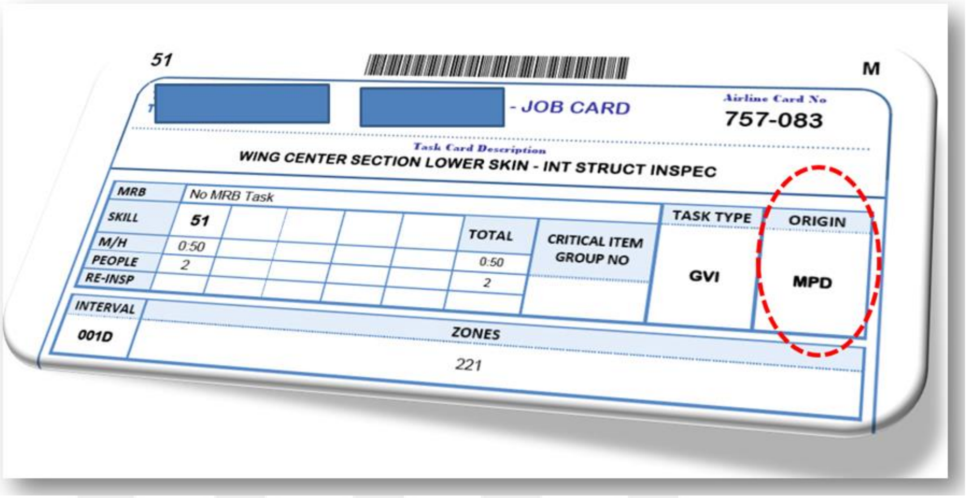


Figure 2.6 : Maintenance Task source – Job card Origin.

- Maintenance task type (GVI, DVI, NDT, OPC, FUC etc...) (Figure 2.7). Each maintenance task in the maintenance program has a special task type related to the job required in the content of the task. As an example for NDT and Borescope related tasks, specialists about this inspection have to be dedicated. Taking into account that there are many different task types, this makes more sense about the complexity of the problem.

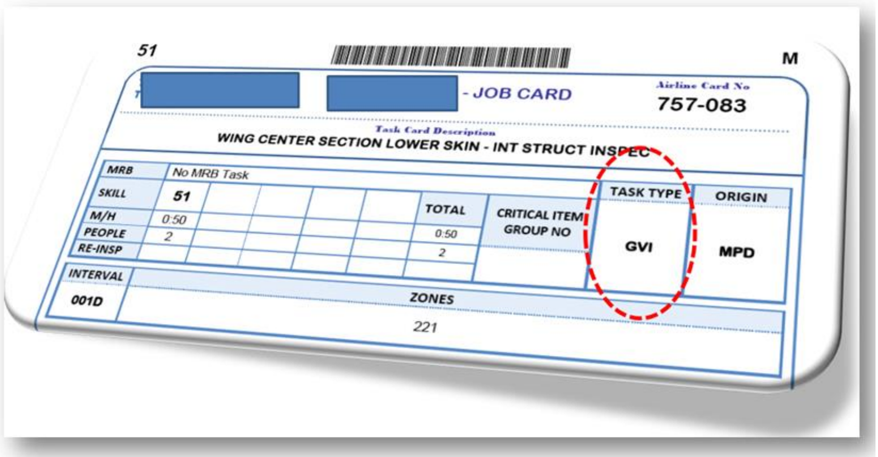


Figure 2.7 : Maintenance task type.

- Maintenance task man-hour and the number of personnel required (Figure 2.8). In the logic diagram of single task-oriented concept, the man hour of the task is one of the most important parameters which defines the possibility of the accomplishment of the task out of main base (in any station) and/or during the overnight check (night stop). According to the number of personnel to do the job and the man hour required, the decicion maker may schedule this maintenance task in or out of main base and/or during the overnight check.

Figure 2.8 : Maintenance task man hour (M/H), the number of personnel required and the skill codes for this job.

- Maintenance task skill code (mechanic, avionic etc...) and licenced personnel requirement for this fleet (Figure 2.8).

- Relationship of the maintenance task with other tasks (application before, after or together status) (Figure 2.9). For the decision maker, it is very important to know for each job card the relationship status with other job cards. Some job cards should be accomplished together, some of them should be performed before any specific job cards and some of them should be performed after some job cards etc...

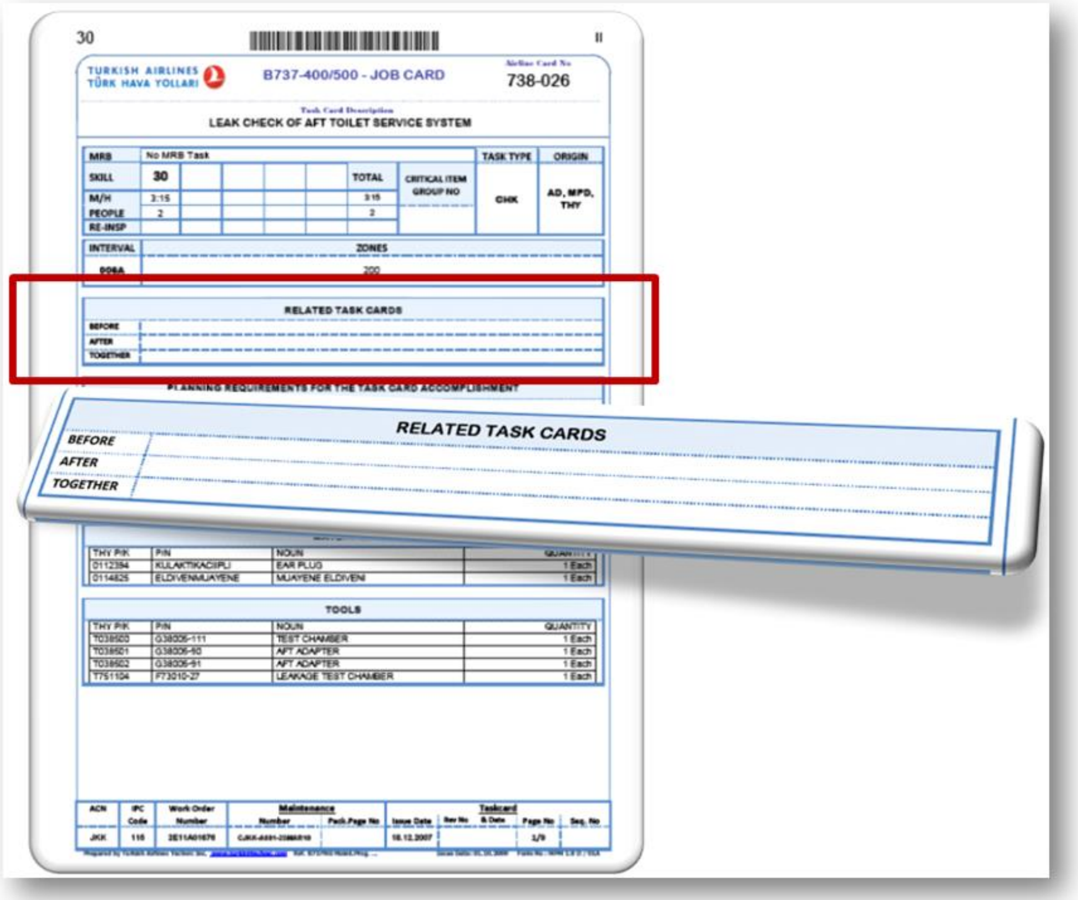


Figure 2.9 : Relationship status between job cards.

- Planning requirements of task card (Figure 2.10 and Figure 2.11). All the planning requirements for the accomplishment of the maintenance task should be taken into account.

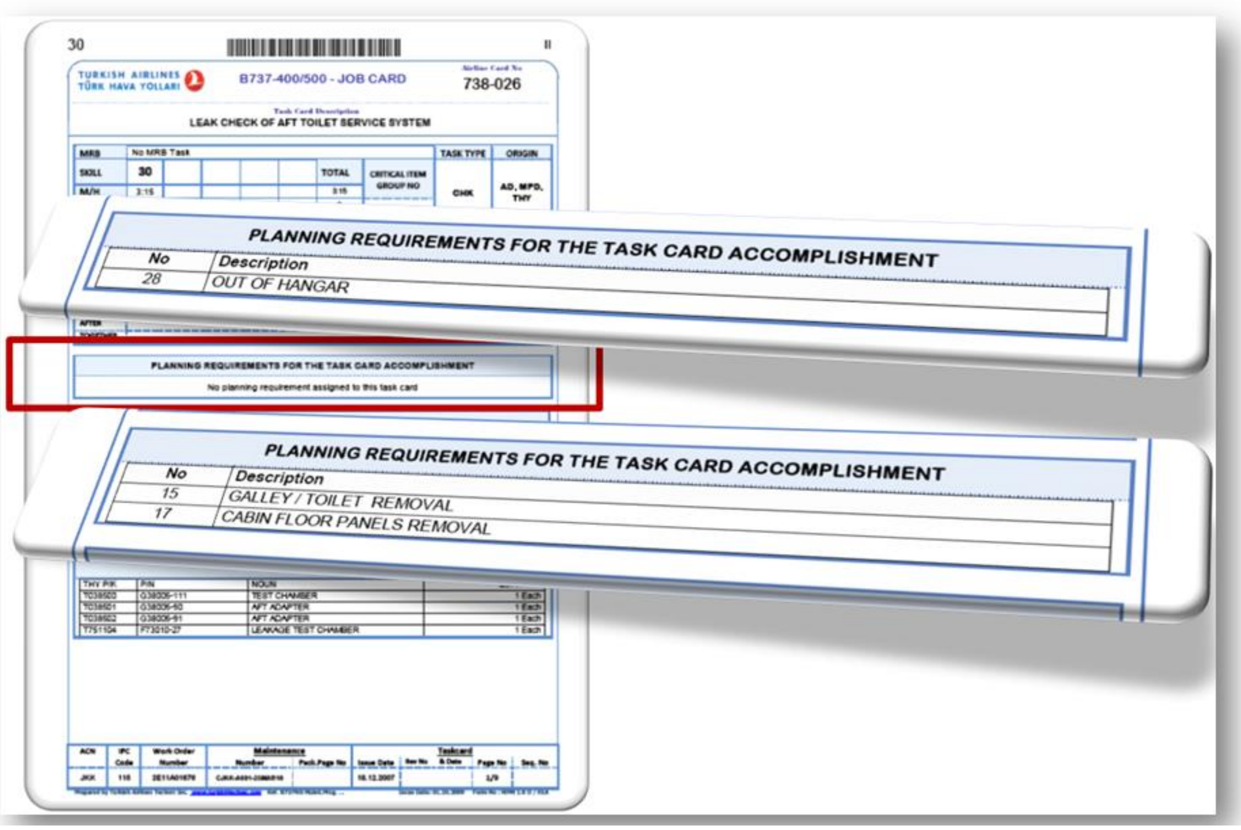
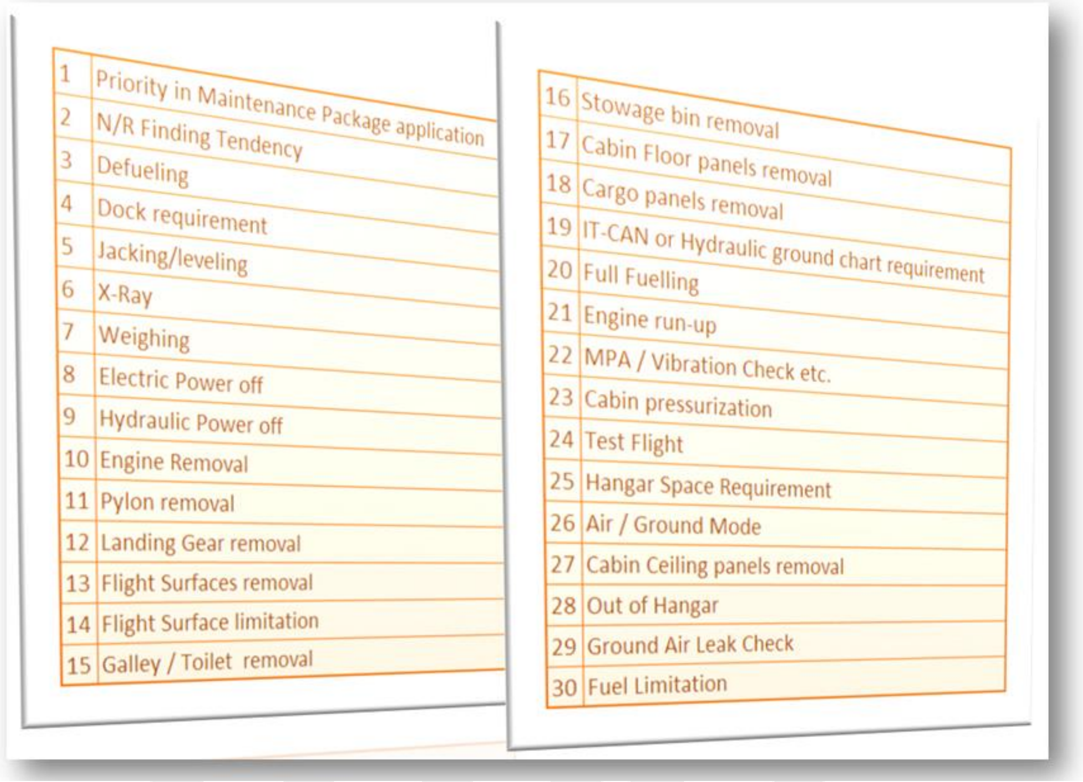


Figure 2.10 : Planning Requirements of the Job Card.



1	Priority in Maintenance Package application	16	Stowage bin removal
2	N/R Finding Tendency	17	Cabin Floor panels removal
3	Defueling	18	Cargo panels removal
4	Dock requirement	19	IT-CAN or Hydraulic ground chart requirement
5	Jacking/leveling	20	Full Fuelling
6	X-Ray	21	Engine run-up
7	Weighing	22	MPA / Vibration Check etc.
8	Electric Power off	23	Cabin pressurization
9	Hydraulic Power off	24	Test Flight
10	Engine Removal	25	Hangar Space Requirement
11	Pylon removal	26	Air / Ground Mode
12	Landing Gear removal	27	Cabin Ceiling panels removal
13	Flight Surfaces removal	28	Out of Hangar
14	Flight Surface limitation	29	Ground Air Leak Check
15	Galley / Toilet removal	30	Fuel Limitation

Figure 2.11 : Maintenance Planning Requirements.

- Reference status of the maintenance task (Figure 2.12).

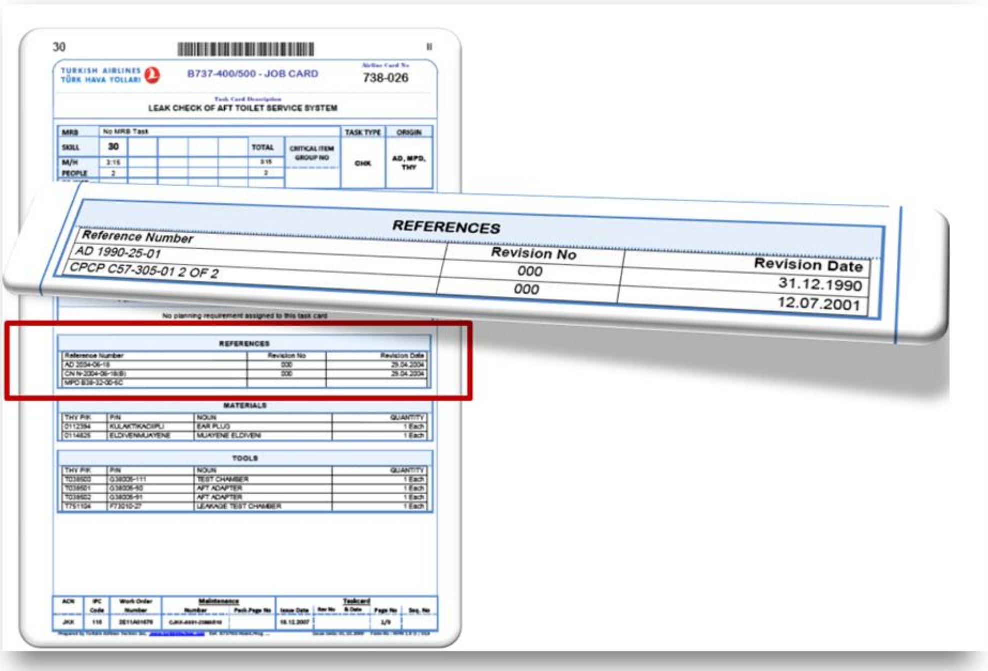


Figure 2.12 : References of Maintenance Task.

- Materials and tools required for the maintenance task (Figure 2.13). Materials and tools required for the maintenance task are very important for the decision maker during the scheduling of the maintenance task. Materials and tools should be ready and at required quantity in the location of maintenance and at any time needed.

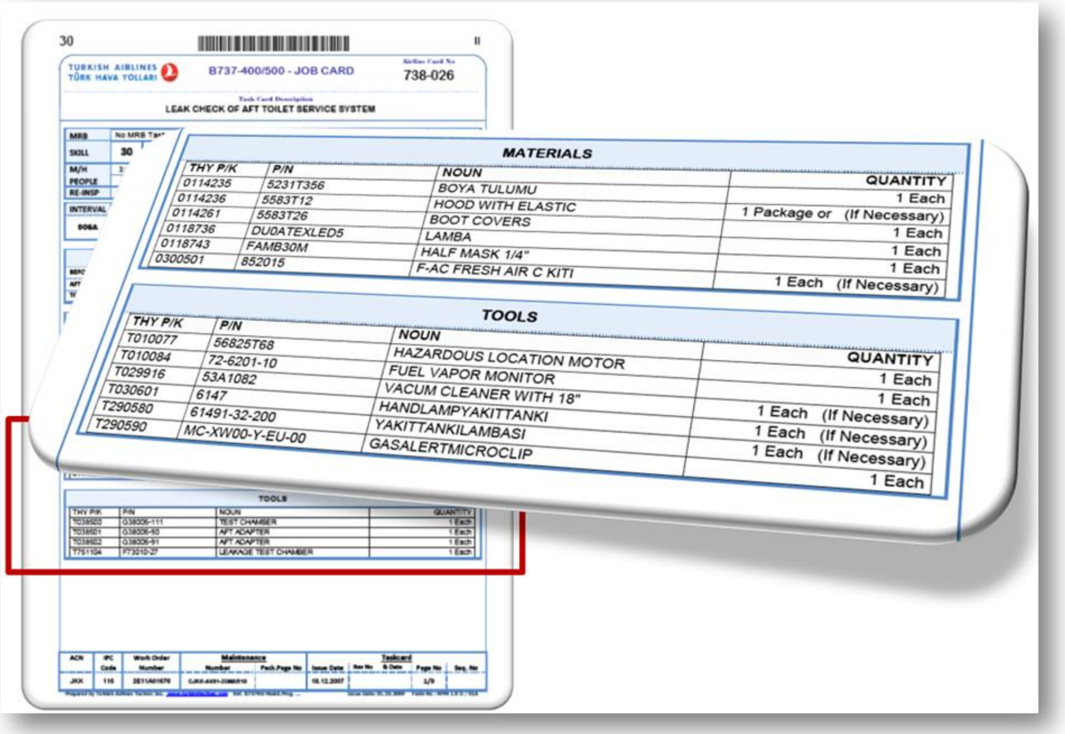
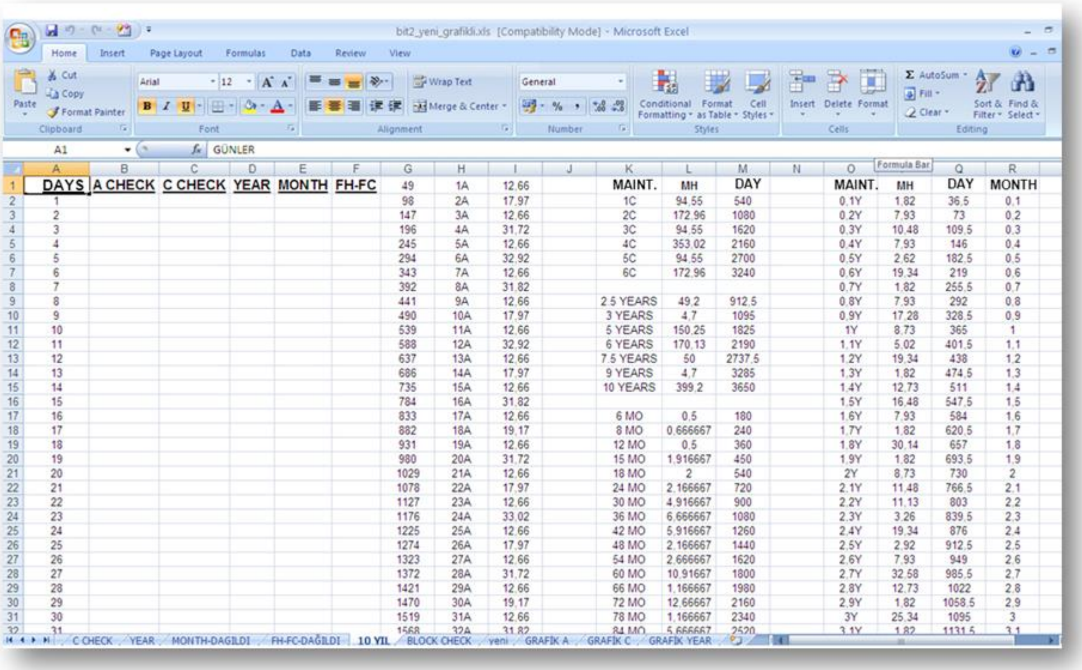


Figure 2.13 : Materials and Tools required for the Maintenance Task.

After each maintenance task has been studied one by one according to its special characteristics stated above, they are inserted in an Excel sheet one by one by calculating its accomplishment day taking into account the utilization of the aircraft and the interval of the maintenance task (Figure 2.14). Then according to the logic diagram given in Figure 2.15, the decision maker schedules each maintenance task taking into account the characteristics of the maintenance task. In this step the experience and the knowledge of the decision maker is very important in this methodology because he has to know every characteristic of the maintenance task, possibility to accomplish out of main base in terms of materials, tools, licenced technician, man hour requirement, acces panel accessibility etc...

Since there are a huge number of maintenance task and each maintenace task has its own special characteristic, it is not possible to develop an analytic structure for this problem. The study should be done by an experienced personnel in aviation who has deep knowledge about maintenance task contents.



DAYS	A CHECK	C CHECK	YEAR	MONTH	FH-FC	49	1A	12,66		MAINT.	MH	DAY		MAINT.	MH	DAY	MONTH
1						98	2A	17,97		1C	94,55	540		0,1Y	1,82	36,5	0,1
2						147	3A	12,66		2C	172,96	1080		0,2Y	7,93	73	0,2
3						196	4A	31,72		3C	94,55	1620		0,3Y	10,48	109,5	0,3
4						245	5A	12,66		4C	353,02	2160		0,4Y	7,93	146	0,4
5						294	6A	32,92		5C	94,55	2700		0,5Y	2,62	182,5	0,5
6						343	7A	12,66		6C	172,96	3240		0,6Y	19,34	219	0,6
7						392	8A	31,82						0,7Y	1,82	255,5	0,7
8						441	9A	12,66		2.5 YEARS	49,2	912,5		0,8Y	7,93	292	0,8
9						490	10A	17,97		3 YEARS	4,7	1095		0,9Y	17,28	328,5	0,9
10						539	11A	12,66		5 YEARS	150,25	1825		1Y	8,73	365	1
11						588	12A	32,92		6 YEARS	170,13	2190		1,1Y	5,02	401,5	1,1
12						637	13A	12,66		7.5 YEARS	50	2737,5		1,2Y	19,34	438	1,2
13						686	14A	17,97		9 YEARS	4,7	3285		1,3Y	1,82	474,5	1,3
14						735	15A	12,66		10 YEARS	399,2	3650		1,4Y	12,73	511	1,4
15						784	16A	31,82						1,5Y	16,48	547,5	1,5
16						833	17A	12,66		6 MO	0,5	180		1,6Y	7,93	584	1,6
17						882	18A	19,17		8 MO	0,666667	240		1,7Y	1,82	620,5	1,7
18						931	19A	12,66		12 MO	0,5	360		1,8Y	30,14	657	1,8
19						980	20A	31,72		15 MO	1,916667	450		1,9Y	1,82	693,5	1,9
20						1029	21A	12,66		18 MO	2	540		2Y	8,73	730	2
21						1078	22A	17,97		24 MO	2,166667	720		2,1Y	11,48	766,5	2,1
22						1127	23A	12,66		30 MO	4,916667	900		2,2Y	11,13	803	2,2
23						1176	24A	33,02		36 MO	6,666667	1080		2,3Y	3,26	839,5	2,3
24						1225	25A	12,66		42 MO	5,916667	1260		2,4Y	19,34	876	2,4
25						1274	26A	17,97		48 MO	2,166667	1440		2,5Y	2,92	912,5	2,5
26						1323	27A	12,66		54 MO	2,666667	1620		2,6Y	7,93	949	2,6
27						1372	28A	31,72		60 MO	10,91667	1800		2,7Y	32,58	985,5	2,7
28						1421	29A	12,66		66 MO	1,166667	1980		2,8Y	12,73	1022	2,8
29						1470	30A	19,17		72 MO	12,66667	2160		2,9Y	1,82	1058,5	2,9
30						1519	31A	12,66		78 MO	1,166667	2340		3Y	25,34	1095	3
31						1568	32A	31,82		84 MO	5,666667	2520		3,1Y	1,82	1131,5	3,1

Figure 2.14 : Calculation Sheet.

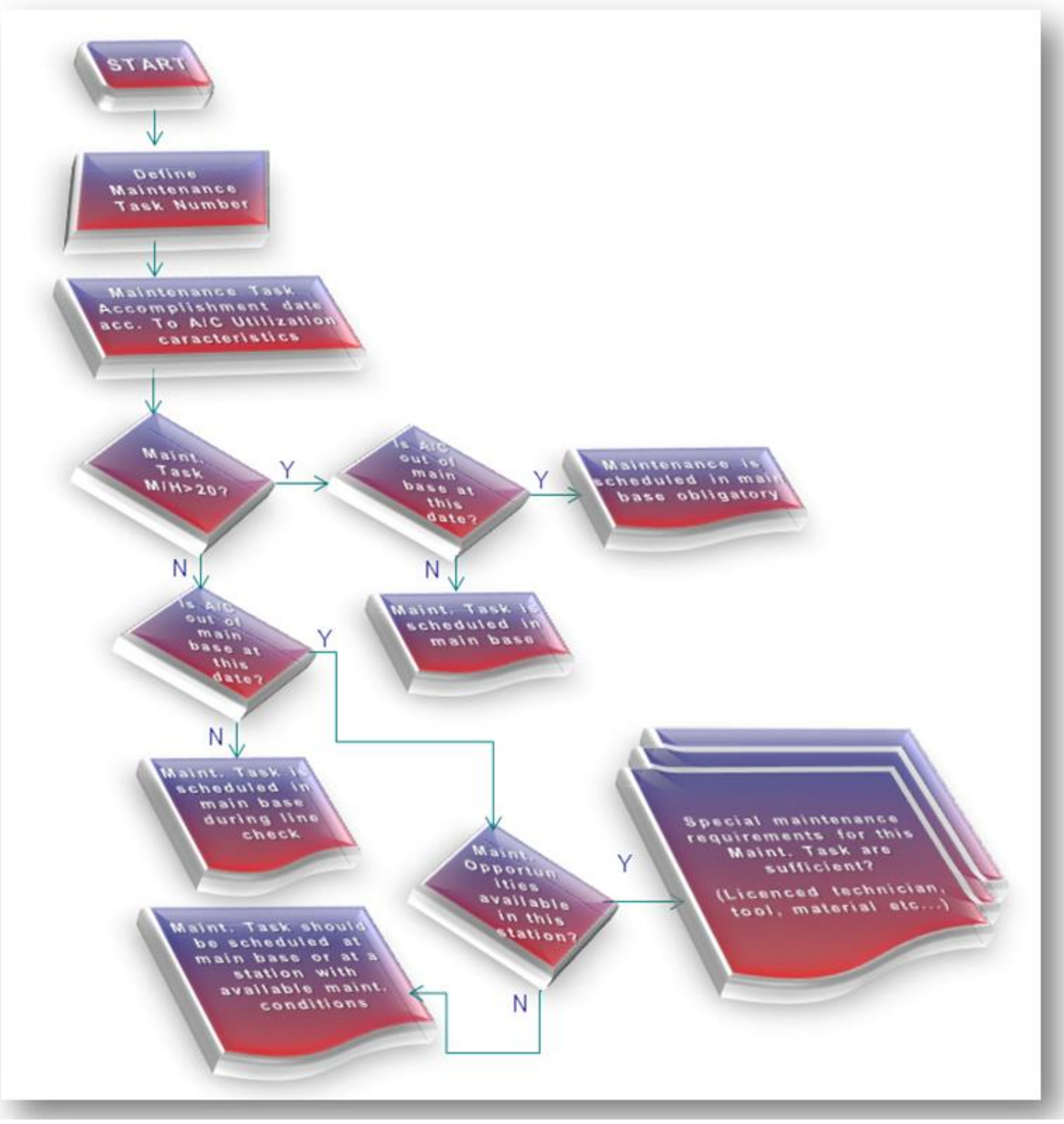


Figure 2.15 : Logic Diagram of the Single Task-Oriented Maintenance Concept.

2.3 Case study performed in an Airline Company

In a case study performed in an airline company for the fleet of Airbus A340 A/C, the results for both case have been obtained. The first case is an example of the rigid letter check system and the second case is an example of the single task oriented maintenance concept which is proposed in this thesis.

In the first case the daily distribution of maintenance tasks given in the original manufacturer maintenance program over 10 years is given in (Figure 2.16).

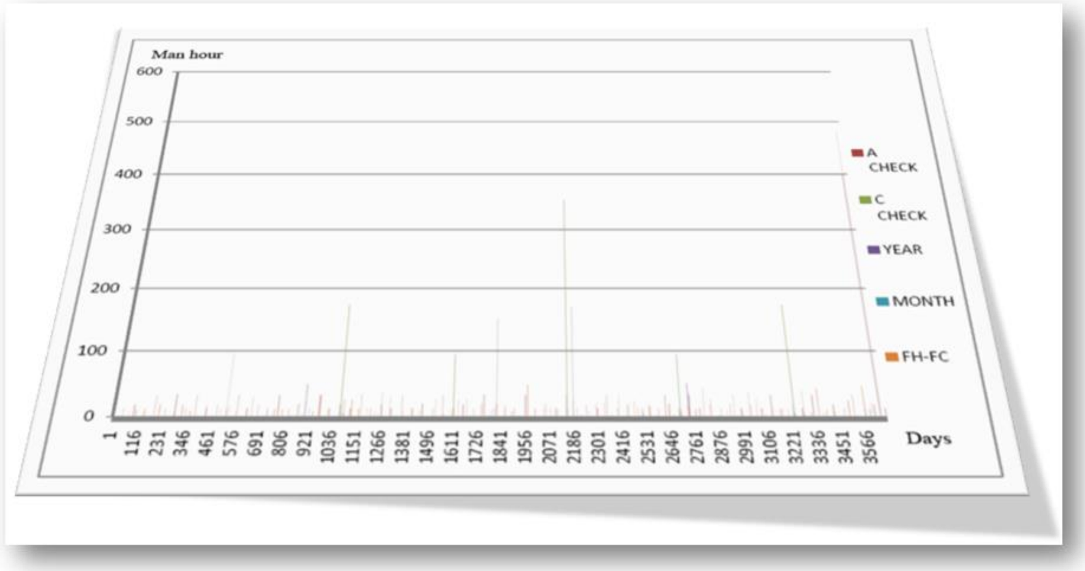


Figure 2.16 : Daily distribution of maintenance tasks given in the original maintenance program of the aircraft manufacturer over 10 years.

As shown in Figure 2.16, aircraft has to be kept in the hangar for maintenance purposes for different duration. Especially heavy maintenance work load seems to be dominant. If we observe the maintenance program of the airline company that we studied in this case study, we have similar daily distribution of maintenance tasks over a duration of 10 years. (Figure 2.17) In this step, we have to explain that this figure shows a traditional airline which performs maintenance during the predetermined letter checks (rigid letter check system).

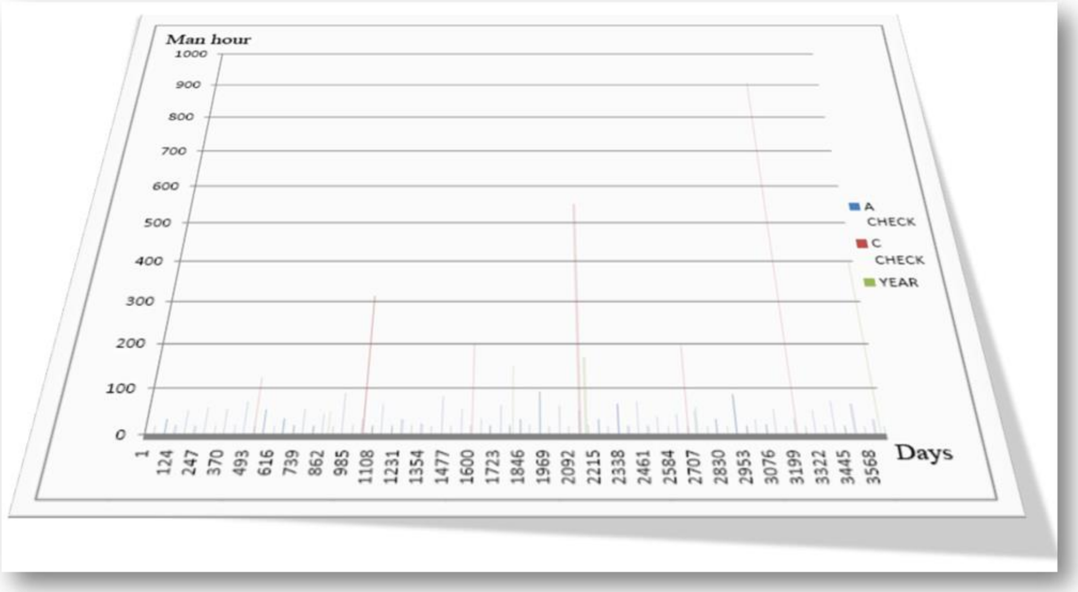


Figure 2.17 : Daily distribution of maintenance tasks given in the maintenance program of the airline company (in case study) over 10 years.

If we compare these two figures, we can see that in the second figure, the airline company that we study in this case study has letter checks such as “A” check, “C” check and “S” check and the workload of maintenance becomes higher only during these checks. In other days since there is no letter check, there is no maintenance action and the aircraft is scheduled for operation. However the duration of maintenance letter checks is high since the maintenance content is gathered only during the letter checks and not distributed in other days. This is an example of a traditional airline maintenance structure (rigid letter check system). The maintenance tasks subject to flight hour, flight cycle and multiple month intervals in Figure 2.16 are converted to appropriate letter checks in the airline company maintenance program in Figure 2.17. For this reason the distribution in Figure 2.16 is rather different than the distribution in Figure 2.17 since it contains original maintenance task intervals not the converted letter checks.

2.3.1 “A” check study

For the case study performed in an airline company for the fleet of Airbus A340 aircraft, the following assumptions are made for “A” check:

Interval for “A” check : 600 FH

Daily utilization of the fleet : 12 FH/day

49.5 days/A check 74 A checks / 10 years

If the A/C is on on ground for a complete day, 85 man hours workload is scheduled,

During the overnight or line check, 20 man hours workload is scheduled.

Leasing cost: 10.000 US$ per day, commercial loss due to not operate the aircraft: 70.000 US$ per day. Daily total loss: 60.000 US$.

2.3.1.1 Real case in the airline company for "A" check

According to the assumptions above, the aircraft should be kept on the ground for 45 days and additionally 32 overnight checks are also needed to accomplish all maintenance tasks related "A" check content (Figure 2.18). This system is a rigid letter check system used by traditional airline companies and the distribution obtained for "A" check over 10 years is given in (Figure 2.19).

Maintenance Type	Ground downtime (**days**) for maintenance	Night stops (Number of checks performed during overnight maintenance)
"**A**" Check	45	32

Figure 2.18 : "A" check requirements over 10 years for the rigid letter check system.

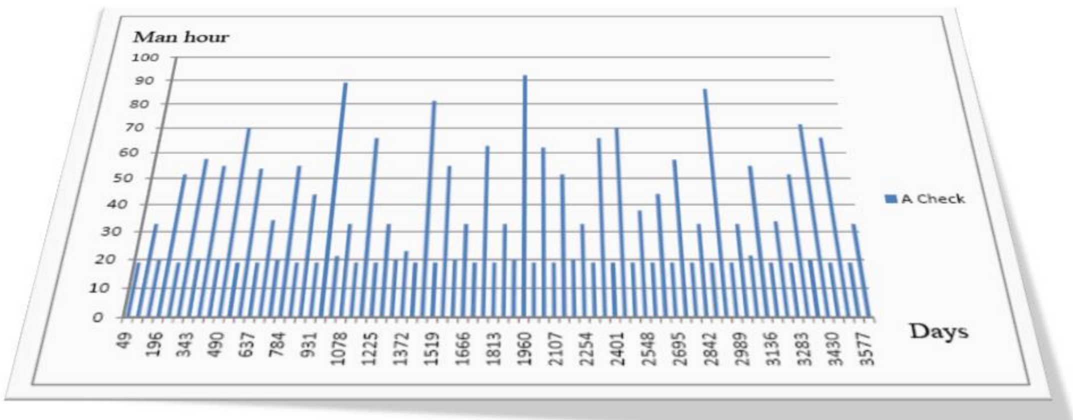


Figure 2.19 : "A" check distribution over 10 years for the airline company.

2.3.1.2 Results obtained by using “Single Task-Oriented Maintenance Concept for” for “A” check

By making the necessary calculations such as given in Figure 2.14 and taking into account all special characteristics of all maintenance tasks in this scope and by using the logic diagram given in Figure 2.15, the following results are obtained. (Figure 2.20) In this approach the single task-oriented maintenance concept has been used. Each maintenance task has been evaluated one by one according to its special characteristics and put in an appropriate overnight check and the distribution in Figure 2.21 is obtained. Note that there isn’t any maintenance task more that 20 man hours in this scope. All overnight checks have been aranged not to exceed 20 man hours. As a result 149 night stop over 10 years are sufficient in this concept without doing any extra maintenance letter check.

Maintenance Type	Ground downtime (**days**) for maintenance	Night stops (Number of checks performed during overnight maintenance)
"**A**" Check	0	149

Figure 2.20 : “A” check requirements over 10 years in “Single Task-Oriented Maintenance Concept”.

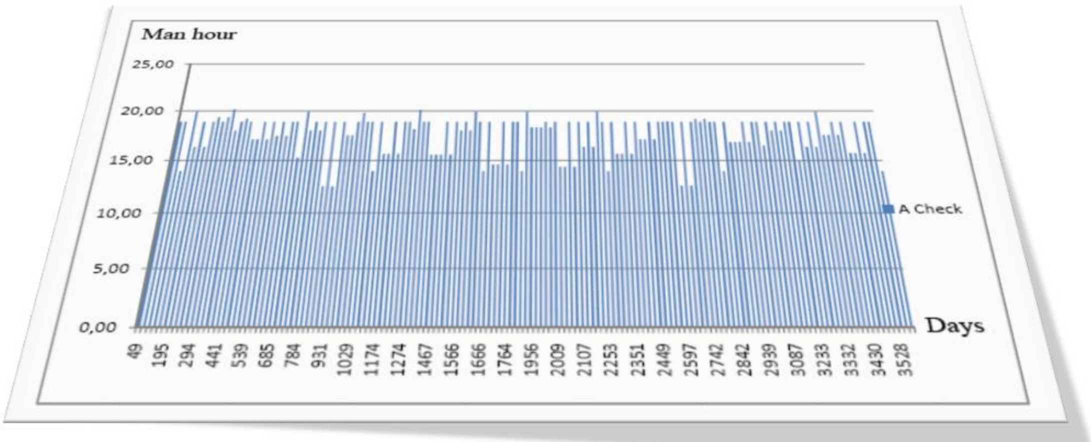


Figure 2.21 : “A” check distribution over 10 years according to the Single Task-Oriented Maintenance Concept.

If we compare the results obtained for "A" check in both methods (Rigid letter check system of a traditional airline company and Single Task-oriented maintenance concept), we have 45 days saving and 2.700.000 US$ cost saving for 45 days (Figure 2.22).

"**A**" Check	Ground downtime (**days**) for maintenance	Night stops (Number of checks performed during overnight maintenance)
Rigid system	45	32
Single Task-Oriented Maint. Concept	0	149
Cost Saving (US$)	2.700.000	

Figure 2.22 : Comparison of Rigid letter check system and Single Task-oriented maintenance concept for "**A**" check over 10 years.

2.3.2 "C" check study

For the case study performed, the following assumptions are made for "C" check:

Interval for "C" check : 18 Months

Daily utilization of the fleet : 12 FH/day

6C check is accomplished with 10 years maintenance tasks.

If the A/C is on on ground for a complete day, maximum 85 man hours workload is scheduled per day.

2.3.2.1 Real case in the airline company for "C" check

According to the assumptions above, the aircraft should be kept on the ground for 30 days over 10 years (Figure 2.23).

Maintenance Type	Ground downtime (**days**) for maintenance	Night stops (Number of checks performed during overnight maintenance)
"**C**" Check	30	0

Figure 2.23 : "C" check requirements over 10 years for the rigid letter check system.

The distribution obtained for “C” check over 10 years is given in (Figure 2.24) for the rigid letter check system applied in the airline company which is observed in this case study.

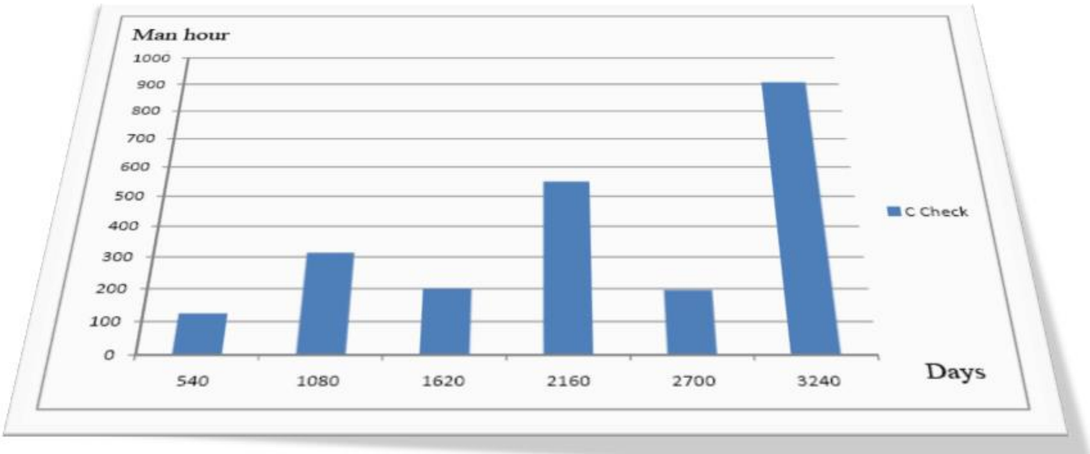


Figure 2.24 : “C” check distribution over 10 years for the airline company.

2.3.2.2 Results obtained by using “Single Task-Oriented Maintenance Concept for” for “C” check

By making the necessary calculations such as given in Figure 2.14 and taking into account all special characteristics of all maintenance tasks in the scope of “C” check and by using the logic diagram given in Figure 2.15, the distribution in Figure 2.26 is obtained. In this approach the single task-oriented maintenance concept has been used. Each maintenance task has been evaluated one by one according to its special characteristics and put in an appropriate overnight check. All overnight checks have been aranged not to exceed 20 man hours. For the maintenance task with workload more than 20 man hours per day, the aircraft is kept on the ground during the day. Maximum 85 man-hour workload can be scheduled daily.

As a result 10 days and 79 night stop over 10 years are sufficient in this concept (Figure 2.25).

Maintenance Type	Ground downtime (**days**) for maintenance	Night stops (Number of checks performed during overnight maintenance)
"**C**" Check	10	79

Figure 2.25 : “C” check requirements over 10 years in “Single Task-Oriented Maintenance Concept”.

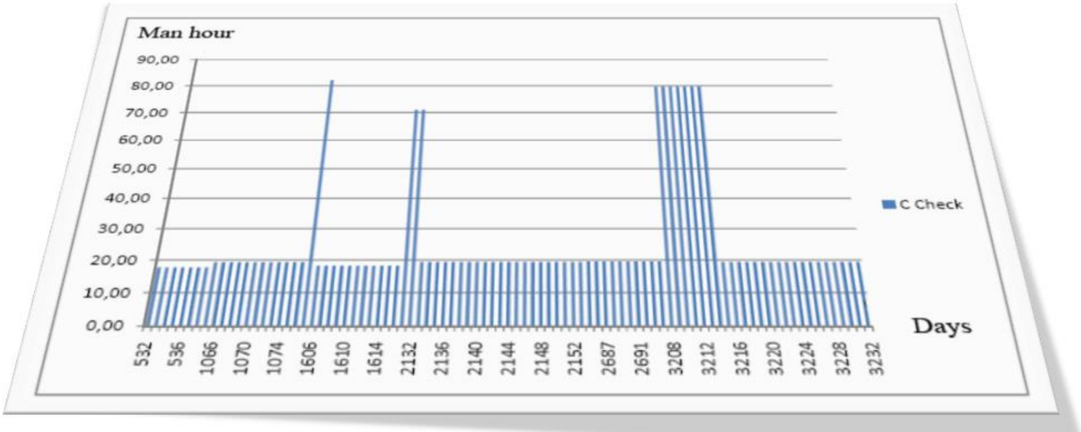


Figure 2.26 : “C” check distribution over 10 years by using the Single Task-Oriented Maintenance Concept.

If we compare the results obtained for “C” check in both methods (Rigid letter check system of a traditional airline company and Single Task-oriented maintenance concept), we have 20 days saving and 1.200.000 US$ cost saving for 20 days. (Figure 2.27)

"**C**" Check	Ground downtime (**days**) for maintenance	Night stops (Number of checks performed during overnight maintenance)
Rigid system	30	0
Single Task-Oriented Maint. Concept	10	79
Cost Saving (US$)	1.200.000	

Figure 2.27 : Comparison of Rigid letter check system and Single Task-oriented maintenance concept for “**C**” check over 10 years.

2.3.3 “S” check study

For the case study performed, the following assumptions are made for “S” check:

Interval for “S” check : 5 Years (Structural check)

Daily utilization of the fleet : 12 FH/day

2.3.3.1 Real case in the airline company for “S” check

According to the assumptions above, the aircraft should be kept on the ground for 12 days over 10 years and 2 additional night stops are needed (Figure 2.28).

Maintenance Type	Ground downtime (**days**) for maintenance	Night stops (Number of checks performed during overnight maintenance)
"**S**" Check	12	2

Figure 2.28 : “S” check requirements over 10 years for the rigid letter check system.

The distribution obtained for “S” check over 10 years is given in (Figure 2.29) for the rigid letter check system applied in the airline company which is observed in this case study.

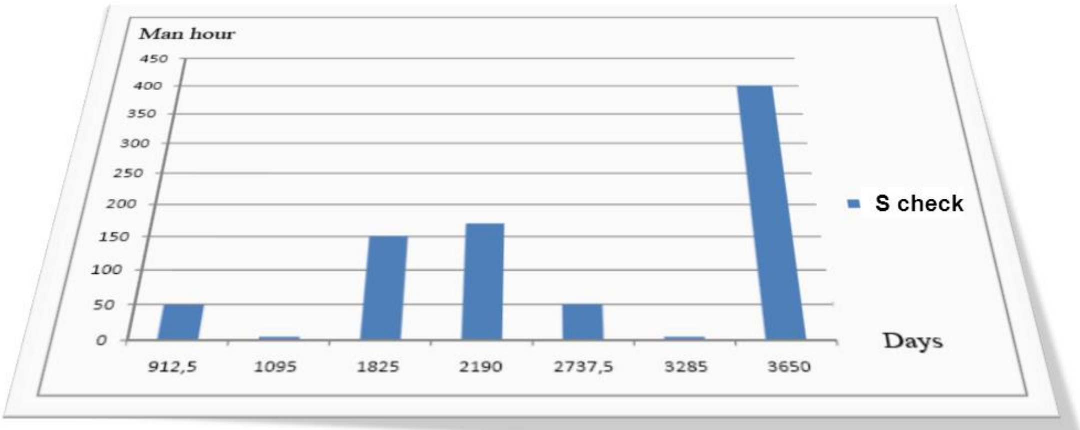


Figure 2.29 : “S” check distribution over 10 years for the airline company.

2.3.3.2 Results obtained by using “Single Task-Oriented Maintenance Concept for” for “S” check

By making the necessary calculations such as given in Figure 2.14 and taking into account all special characteristics of all maintenance tasks in the scope of “S” check and by using the logic diagram given in Figure 2.15, the distribution in Figure 2.31 is obtained. In this approach the single task-oriented maintenance concept has been used.

Each maintenance task has been evaluated one by one according to its special characteristics and put in an appropriate overnight check. All overnight checks have been aranged not to exceed 20 man hours.

For the maintenance task with workload more than 20 man hours per day, the aircraft is kept on the ground during the day. Maximum 85 man-hour workload can be scheduled daily. As a result 5 days and 35 night stop over 10 years are sufficient in this concept (Figure 2.30).

Maintenance Type	Ground downtime (**days**) for maintenance	Night stops (Number of checks performed during overnight maintenance)
"**S** " Check	5	35

Figure 2.30 : "S" check requirements over 10 years in "Single Task-Oriented Maintenance Concept".

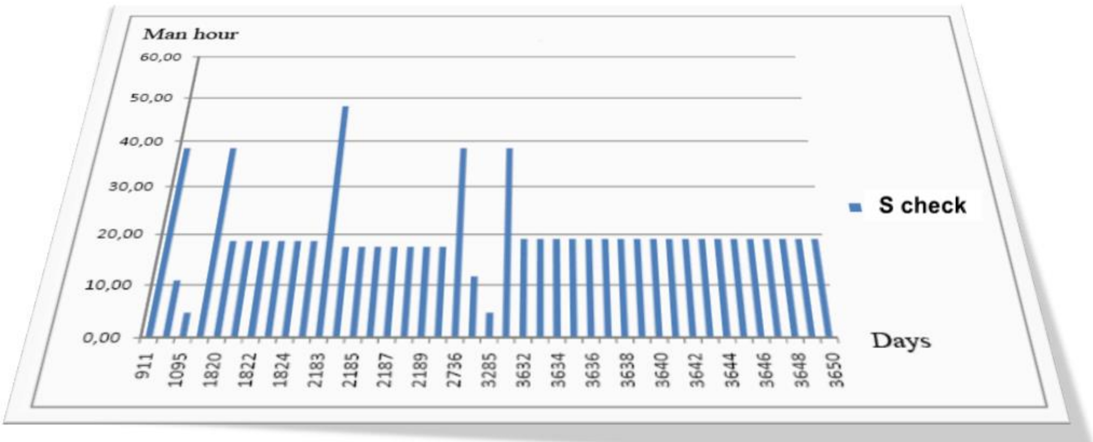


Figure 2.31 : "S" check distribution over 10 years by using the Single Task-Oriented Maintenance Concept.

If we compare the results obtained for "S" check in both methods (Rigid letter check system of a traditional airline company and Single Task-oriented maintenance concept), we have 7 days saving and 420.000 US$ cost saving for 7 days (Figure 2.32).

"**S**" Check	Ground downtime (**days**) for maintenance	Night stops (Number of checks performed during overnight maintenance)
Rigid system	12	2
Single Task-Oriented Maint. Concept	5	35
Cost Saving (US$)	420.000	

Figure 2.32 : Comparison of Rigid letter check system and Single Task-oriented maintenance concept for "**S**" check over 10 years.

2.3.4 Conclusions and advantages of the Single Task-Oriented Maintenance Concept in the case study

The results obtained from this case study performed in A340 fleet are demonstrated in Table 2.1 (Results of the case study performed in A340 A/C in an airline company by using classical maintenance approach - rigid letter check system-) and Table 2.2 (Results of the case study performed in A340 A/C in an airline company by using single task oriented maintenance concept (approach proposed in this thesis – single task oriented concept) respectively. (Şentürk, 2010-Şentürk, 2017)

Table 2.1: Results of the case study performed in A340 fleet (rigid letter check system).

Check Type	Ground Downtime for maintenance (days)	Number of checks performed during Overnight checks
A Check	45	32
C Check	30	0
Yearly Check	12	2
Total	**87**	**34**

Table 2.2: Results of the case study performed in A340 fleet (single task-oriented concept).

Check Type	Ground Downtime for maintenance (days)	Number of checks performed when the aircraft is on the ground for any reason
A Check	0	149
C Check	5	79
Yearly Check	10	35
Total	**15**	**263**

Maintenance Type	Ground downtime (days) for maintenance	Night stops (Number of checks performed during overnight maintenance)
"A" Check	45	32
"C" Check	30	0
"S" Check	12	2
TOTAL	**87**	**34**

Rigid letter check system

Maintenance Type	Ground downtime (days) for maintenance	Night stops (Number of checks performed during overnight maintenance)
"A" Check	0	149
"C" Check	10	79
"S" Check	5	35
TOTAL	**15**	**263**

Single task-oriented maintenance concept

Figure 2.33 : Comparison of two approaches: "Rigid letter check system" versus "the Single Task-Oriented Maintenance Concept".

In the case study, it is possible to see the benefits of the single task oriented maintenance concept. In a period of 10 years, an aircraft is kept on the ground for maintenance about 87 days however in the method proposed in this thesis the same aircraft is kept only for 15 days on the ground for maintenance in a period of 10 years.(Figure 2.33 and Figure 2.37) This can be achieved only by utilizing every moment as a maintenance opportunity when the aircraft is on the ground for any reason. We have 72 days savings over ten years. Commercial cost saving is 4.320.000 US$ for 72 days (Figure 2.34).

"A" + "C" + "S" Checks	Ground downtime (days) for maintenance	Night stops (Number of checks performed during overnight maintenance)
Rigid system	87	34
Single Task-Oriented Maint. Concept	15	263
Total	72 days saving	229 additionnal overnight checks
Cost Saving (US$)	4.320.000	

Figure 2.34 : Comparison of Rigid letter check system and Single Task-oriented maintenance concept over 10 years.

The global distributions for both methods are given in Figure 2.35 and Figure 2.36. This study has been performed by taking account that the maintenance tasks are performed by the most appropriate staff in a limited time. The method to select the most appropriate staff to perform the job is explained in the next section by using the method given in the article (Angus, 2005).

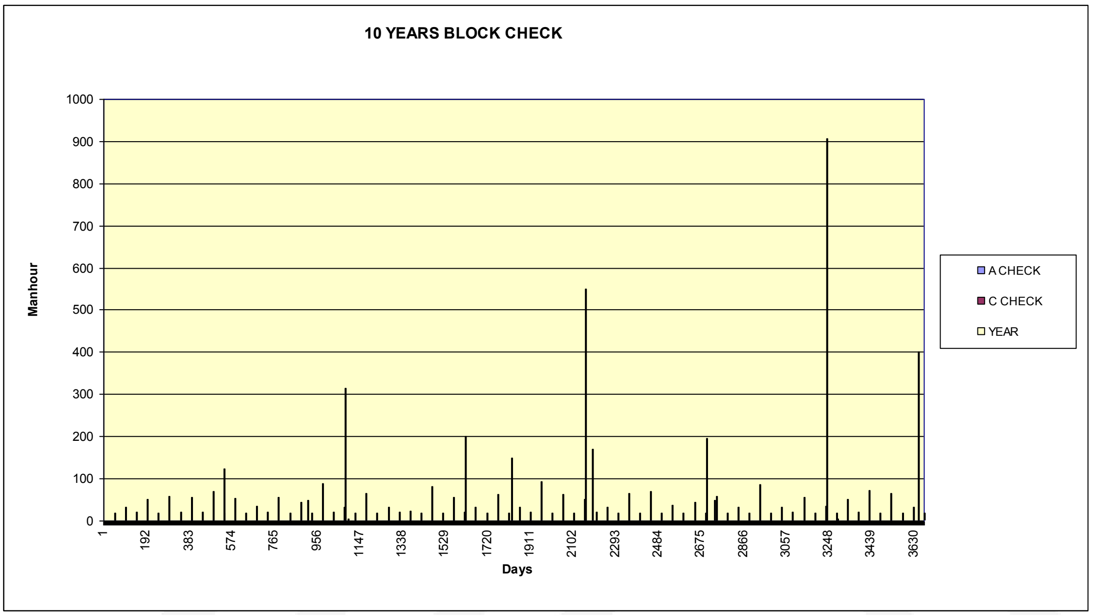


Figure 2.35 : Distribution in rigid letter check system.

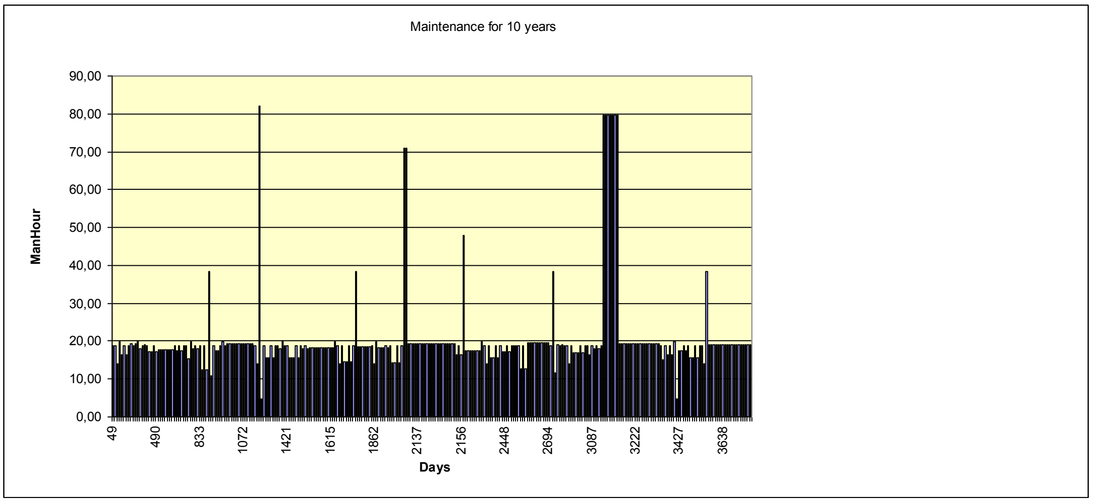


Figure 2.36 : Comparison of the rigid letter check system with the single task oriented concept for the case study performed for A340 fleet in an airline company.

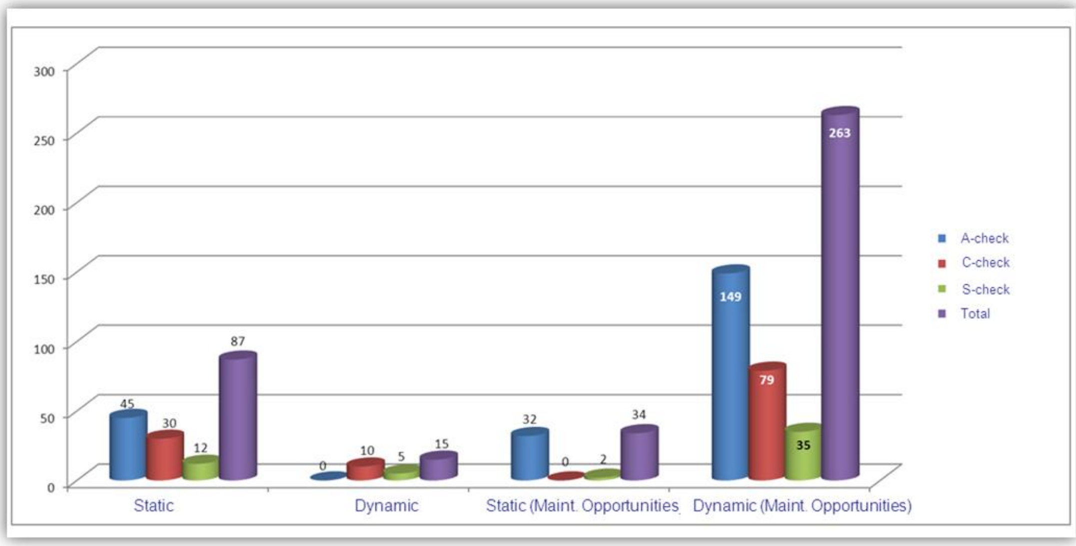


Figure 2.37 : Comparison of two methods graphically.

2.4 How to support the approach

In order to complete the tasks given in the maintenance program in a limited time when the aircraft is on the ground, we have to focus on the personnel selection process. For this purpose an expert system that has been developed for aircraft maintenance may be used (Angus, 2005). The author of this thesis think that the single task-oriented maintenance concept may be supported by the expert system methodology which is developed by Angus Cheung, W.H. Ip, Dawei Lu in 2005 and which is based on AHP.

Brief information about this expert system: According to the authors of the article, this is a decision support used to select appropriate personnel and schedule the personnel in order to meet the demand. The authors believe that in many airlines engineer selection process is mainly relied on the decision-maker's own experience without systematic approach. According to them this is not effective in obtaining an optimum decision. A better approach is required to develop systematic and comprehensive labor-selection and planning process, which can integrate relative importance among selection criteria and precise identification of alternatives' performance.

They propose the method of analytical hierarchy process (AHP) which is developed for a decision support system to assist the decision-making of maintenance labor allocation: it has the inherent capacity to handle quantitative and qualitative criteria used in labor selection (Angus, 2005).

The decision-maker can compare the alternatives' performance against certain criteria using either pair-wise comparison or a direct grade assignment.

Nevertheless, AHP cannot deal with uncertain problems precisely because it is usually hard to give discrete grades to uncertain criteria, which lies within certain ranges with different degrees. In order to overcome this problem, a **fuzzy** AHP with an extent analysis approach is proposed to obtain the solution by assigning triangular fuzzy numbers to identify the relative importance of criteria and alternatives' weighting against some criteria.

The authors suggest that the use of fuzzy AHP analysis approach may be used to improve staff allocation as well as the support of decision-making process within the maintenance industry. Through the fuzzy AHP analysis, a list of labor and skill selected according to priority can be determined to perform a particular maintenance task consistent with the real situation.

3. SECOND MAINTENANCE APPROACH ON THE REDUCING SCHEDULED MAINTENANCE DOWNTIME – USE OF THE SOFTWARE

3.1 Software based Project Development Purpose

As explained in the introduction section, the second objective of this thesis is to prevent earlier accomplishment of some maintenance tasks and to develop a software for this purpose. The objective of the software is to prevent earlier accomplishment of maintenance tasks and therefore to maximize aircraft utilization consequently. By this way to reduce ground downtime for the shceduled maintenance tasks and to increase aircraft availability for flight is possible by using this software.

Airline companies are faced with various optimization problems during the planning of maintenance tasks given in maintenance programs. Taking into account that there are too many maintenance tasks in the maintenance program with different interval values and different interval types, the difficulty of the problem may be more understandable. As an example, in the maintenance program of a wide body aircraft type such as Airbus A-340 fleet, there are more than three thousands maintenance tasks with different interval values. Moreover the usage parameters for these maintenance tasks are different: some of them are given as operational units such as FH (Flight Hours), FC (Flight Cycle) etc., some of them are given as calendar units such as HR (hours), DY (days), MO (Months), YE (Years) etc. (Figure 1.5). So the planning department of the airline company is faced with serious problem to schedule these maintenance tasks for the appropriate letter check and the problem becomes much more difficult if several aircraft with different utilization are taken into account.

Because of safety issues and in order to meet the requirements requested by civil aviation authorities, the airline companies have to adopt maintenance policies, which call the aircraft at the end of certain utilization (flight hour, flight cycle or calendar time) to a maintenance base for the routine checks. An aircraft cannot fly once it reaches the legal flight hour limit because of the airworthiness issues. It has to undergo a maintenance check before the next flight (Afsar, 2009).

In most airlines, maintenance checks are performed in predetermined intervals and maintenance tasks given in maintenance program (Figure 1.5) are performed during these maintenance checks (Figure 1.4). But this method would remain insufficient to prevent earlier accomplishment of maintenance tasks if the airline company does not take into account the real-time utilization values of each aircraft and convert the intervals of maintenance tasks with different usage parameters into letter checks just by making an average utilization assumption for the whole fleet.
The approach to consider some average value for the complete fleet causes the accomplishment of some maintenance tasks earlier for some aircraft or later for some of them. In order to prevent earlier accomplishment of some maintenance tasks, the real time utilization values of aircraft have to be taken into account and the most appropriate letter check alternatives according to real time utilization should be calculated by means of the software. In this thesis, a software development is evaluated as a project. In this project the main purpose is to calculate the most appropriate letter check alternatives according to real time utilization values.

In the current application of a traditional airline company, the real-time utilization values of aircraft are not taken into account and in order to calculate the most appropriate letter checks, some estimated utilization values are included into calculation.

As an example, daily utilization of a fleet is considered such values as FH/DAY=10.0 and FH/FC=2.0. These are the values accepted for all the fleet. This means that every aircraft in this fleet is considered to fly 10 hours a day and 2 hours per cycle (one takeoff and one landing is considered as one flight cycle) and all the aircraft are considered to accomplish same values of flight hour and flight cycle. But in real life this approach is very theoritical and these values may differ from one aircraft to another. Moreover they are highly different in narrow body aircraft fleet and wide body aircraft fleet (Figure 3.1).

In this figure, utilization values obtained for three different fleet types are very different from each other.

Flight hours accomplished by a wide body and long-range aircraft fleet, for example Airbus A340 fleet, are approximately ten times of a small training aircraft fleet (for example Cessna aircraft fleet in this figure). By this way flight cycle accomplished by a narrow body aircraft fleet, for example Airbus A320 family fleet is three times of a wide body and long-range aircraft fleet, (Airbus A340 fleet in this figure). This property of the software allows the users to compare different types of aircraft fleet and then have an idea about the utilization parameters of each type of aircraft fleet.

Utilization parameters of the selected fleet

Ratio	Minimum	Maximum	Average
FH/FC ratio	1,33	2,62	1,98
FH/DAY ratio	7,47	12,07	10,04
FC/DAY ratio	4,21	6,27	5,07

Utilization parameters of a narrow body aircraft fleet (**Airbus A320FAM)** of an airline company

Utilization parameters of the selected fleet

Ratio	Minimum	Maximum	Average
FH/FC ratio	3,94	8,01	6,39
FH/DAY ratio	9,06	12,54	11,55
FC/DAY ratio	1,47	2,44	1,81

Utilization parameters of a wide body aircraft fleet (**Airbus A340)** of an airline company

Utilization parameters of the selected fleet

Ratio	Minimum	Maximum	Average
FH/FC ratio	0,31	0,4	0,34
FH/DAY ratio	0,82	1,9	1,57
FC/DAY ratio	2,17	6,11	4,74

Utilization parameters of a training aircraft fleet (**CESSNA)** of an airline company

Figure 3.1 : Utilization values of a narrow body aircraft fleet, wide body aircraft fleet and training aircraft fleet in a company.

Therefore the approach to consider some average value for complete fleet causes the accomplishment of some maintenance tasks earlier for some aircraft or later for some of them.

To overcome this discrepancy, a project is done in this thesis to develop a software which will include the real-time utilization values of each aircraft in the fleet and thus calculate more accurate and appropriate letter check alternatives according to real-time utilization accumulated by each aircraft. This software allows the user to use real-time utilization values for each aircraft in the fleet and therefore it may suggest different appropriate letter check alternatives for each aircraft. The letter checks suggested by the software are more accurate since the real time utilization values are taken into account. Another advantage of this software is that it has the flexibility to calculate different alternatives of letter checks for a given interval with benefits or losses. Besides the software has the flexibility to make the calculations for every single aircraft and for the different fleets in the airline company.

3.2 Software

3.2.1 Software logic diagram - algorithm

The software has been developed by using Microsoft Excel and Visual Basic editor. The data should be defined in the software during the initial set-up process. Simple logic diagram for the data integration is as given in Figure 3.2.

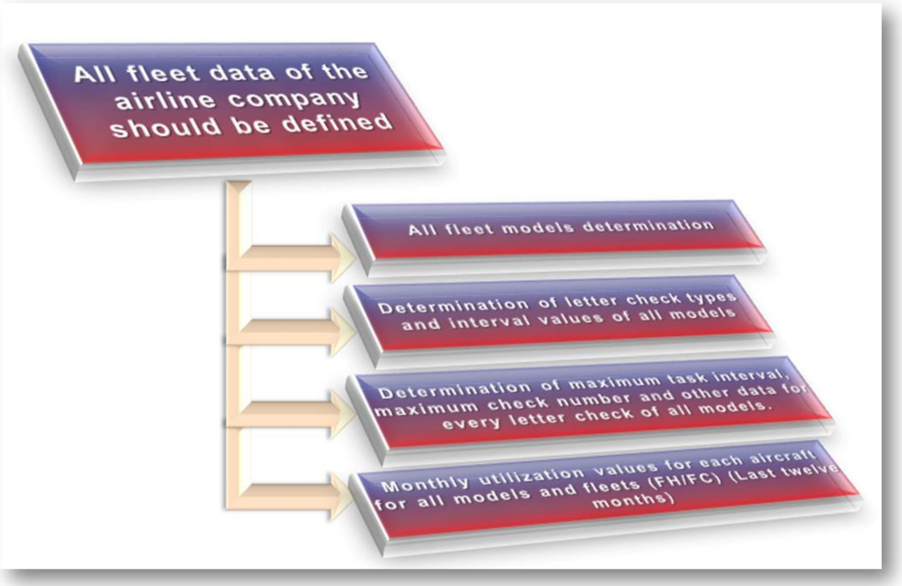


Figure 3.2 : Main data determination about airline company.

In Figure 3.2, the related data for each step should be entered in the software for the airline company:

For the first step "All fleet models determination", the similar data given in Figure 3.3 should be introduced into the software.

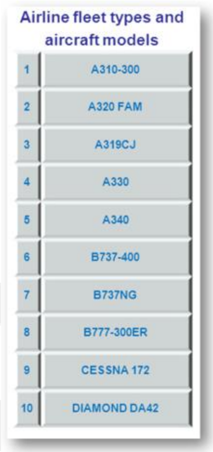


Figure 3.3 : Airline fleet types and models.

For the second step "Determination of letter check types and interval values of all models", a table created for "Maintenance check types and intervals of an airline company" such as given in Figure 1.4 may be entered in the software.

For the third step "Determination of maximum task interval, maximum check number and other data for every letter check of all models." Such data are necessary for calculations and decision process of the software and should be entered in the software. No figure is given for this step since there are many data.

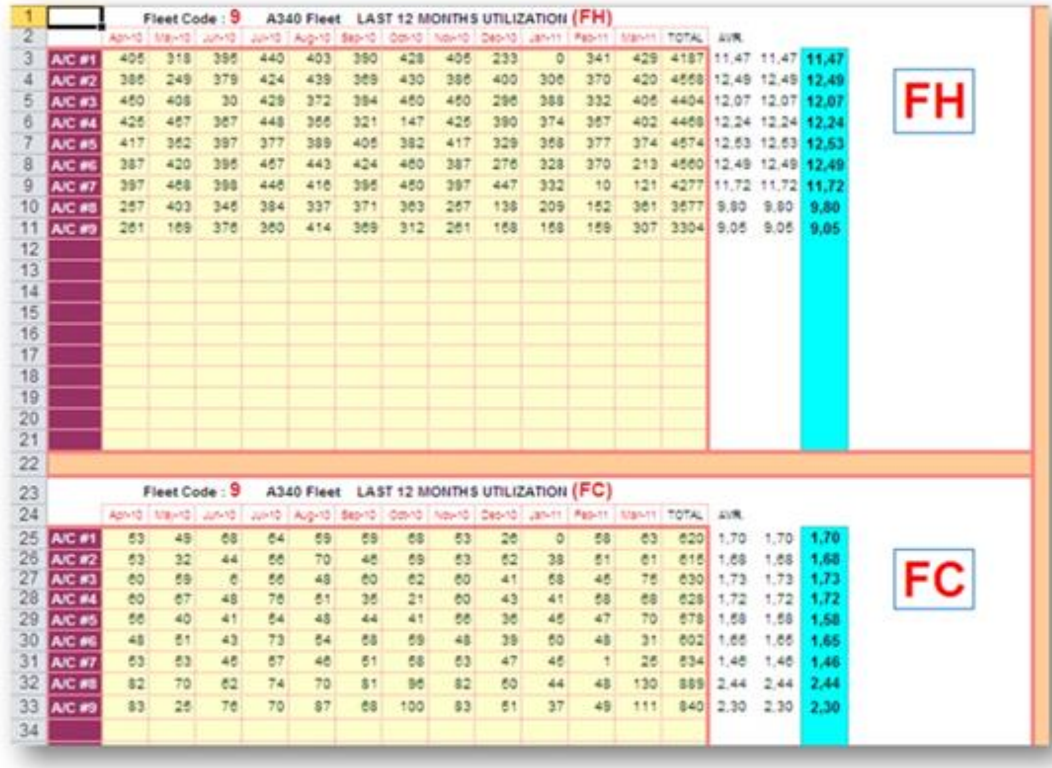
For the last step, "Monthly utilization values for each aircraft for all models and fleets (FH/FC) (Last twelve months)", FH and FC accumulated during the last 12 months for each aircraft of all models should be entered in the software such as given in Figure 3.4.

For each fleet in the airline company, similar database for utilization values such as given in Figure 3.4 should be set-up. As an example there will be 10 different database sheets for an airline company which has ten different model types. The dimension of the database matrix should be 10x25x12x2 if we consider each ten fleet has 25 aircraft and there will be data in terms of FH and FC accumulated during the last 12 months for each aircraft. The number of data that should be introduced in the software may be given as follows:

$$n = 12.2.\sum_{i=1}^{k} F_i \tag{3.1}$$

Where n is the number of the total data, 12 is the number of last twelve months, 2 is the number for FH and FC, k is the number of fleet in the airline company, F_i is the number of total aircraft in the i^{th} fleet.

The software run-up logic diagram is given in Figure 3.5 and all steps in the logic diagram will be explained in details in the software presentation section.



	Fleet Code : 9 A340 Fleet LAST 12 MONTHS UTILIZATION (FH)															
	Apr-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	Feb-11	Mar-11	TOTAL	AVR.		
A/C #1	405	318	395	440	403	390	428	405	233	0	341	429	4187	11,47	11,47	11,47
A/C #2	386	249	379	424	439	369	430	386	400	306	370	420	4558	12,49	12,49	12,49
A/C #3	450	408	30	429	372	394	450	450	296	388	332	406	4404	12,07	12,07	12,07
A/C #4	425	467	367	448	356	321	147	425	390	374	367	402	4468	12,24	12,24	12,24
A/C #5	417	362	397	377	389	405	382	417	329	368	377	374	4574	12,53	12,53	12,53
A/C #6	387	420	395	457	443	424	450	387	276	328	370	213	4550	12,49	12,49	12,49
A/C #7	397	468	398	446	416	395	450	397	447	332	10	121	4277	11,72	11,72	11,72
A/C #8	257	403	345	384	337	371	363	257	138	209	152	361	3577	9,80	9,80	9,80
A/C #9	261	169	376	360	414	369	312	261	168	168	159	307	3304	9,05	9,05	9,05

FH

	Fleet Code : 9 A340 Fleet LAST 12 MONTHS UTILIZATION (FC)															
	Apr-10	May-10	Jun-10	Jul-10	Aug-10	Sep-10	Oct-10	Nov-10	Dec-10	Jan-11	Feb-11	Mar-11	TOTAL	AVR.		
A/C #1	53	49	68	64	59	59	68	53	26	0	58	63	620	1,70	1,70	1,70
A/C #2	53	32	44	56	70	45	69	53	62	38	51	61	615	1,68	1,68	1,68
A/C #3	60	59	6	56	48	60	62	60	41	58	45	75	630	1,73	1,73	1,73
A/C #4	60	67	48	76	51	35	21	60	43	41	58	68	628	1,72	1,72	1,72
A/C #5	56	40	41	54	48	44	41	56	36	45	47	70	578	1,58	1,58	1,58
A/C #6	48	51	43	73	54	58	59	48	39	60	48	31	602	1,65	1,65	1,65
A/C #7	53	53	45	57	46	51	58	53	47	45	1	25	534	1,46	1,46	1,46
A/C #8	82	70	62	74	70	81	96	82	60	44	48	130	889	2,44	2,44	2,44
A/C #9	83	25	76	70	87	68	100	83	51	37	49	111	840	2,30	2,30	2,30

FC

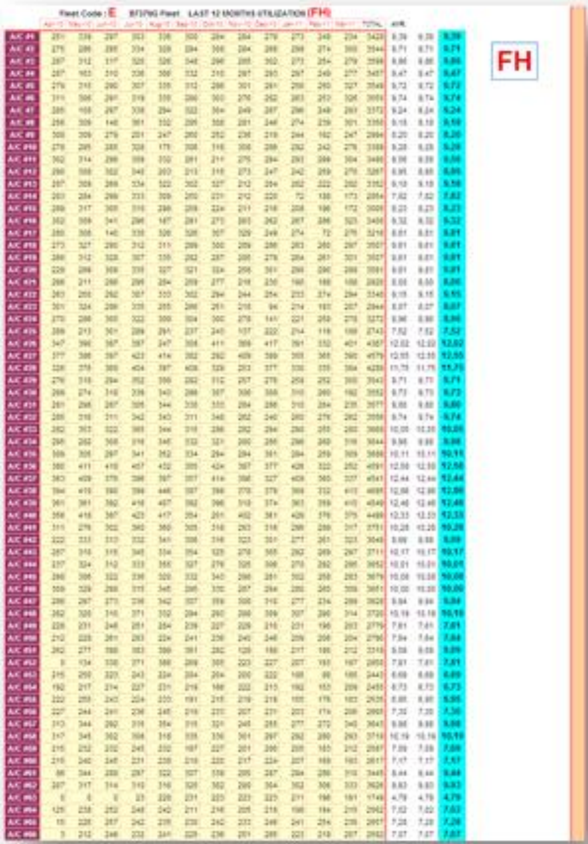


Figure 3.4 : Aircraft monthly utilization values for each aircraft.

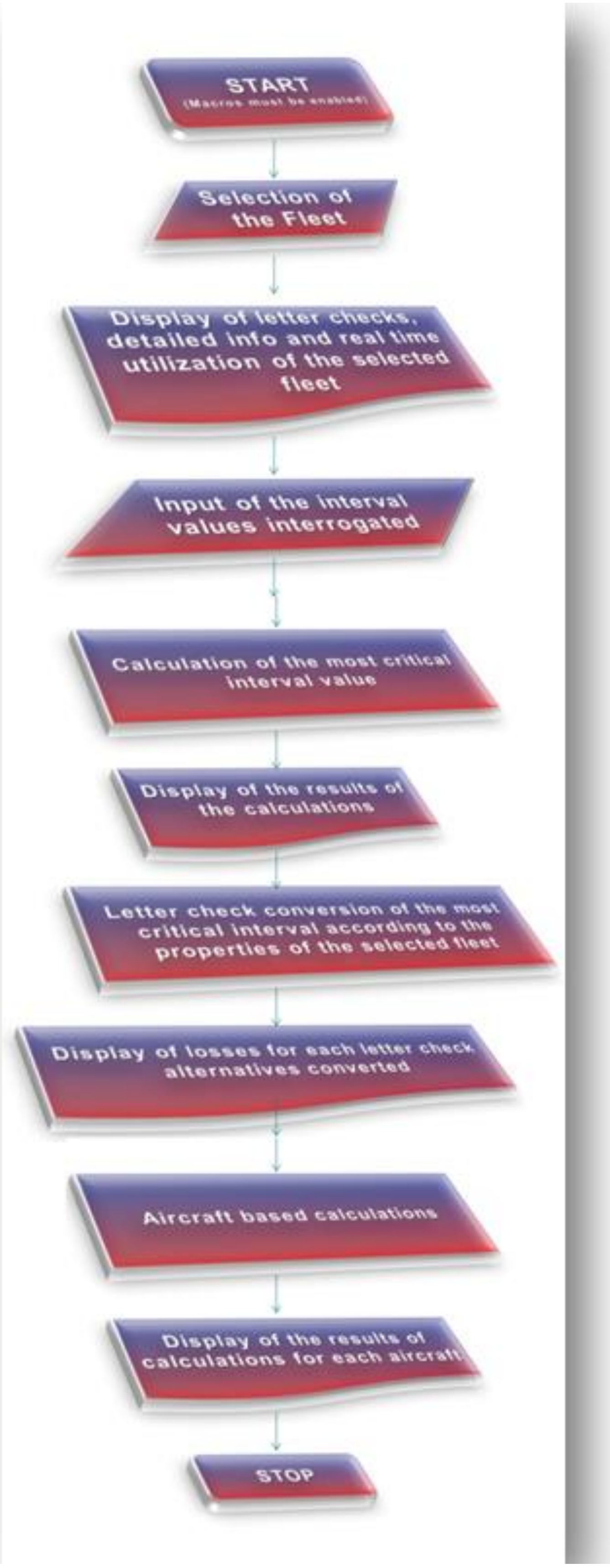


Figure 3.5 : Software algorithm.

3.2.2 Software presentation

When the software is activated, the user can select the fleet by clicking on his preferred aircraft fleet for which the calculations would be performed (Figure 3.6).

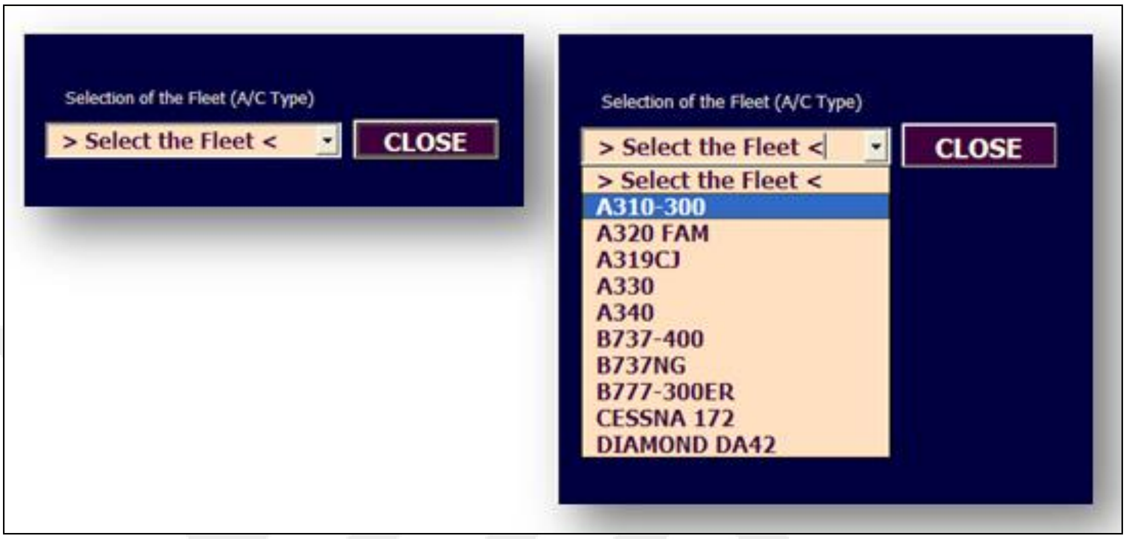


Figure 3.6 : Selection of the Fleet.

Of course, at the beginning of the set-up process of the software, all the fleets in the airline company should be set and all aircraft in each fleet and their monthly utilization values should be included in the software consequently (Figure 3.2 and Figure 3.4).

The data related with the utilization values for the selected fleet are transferred from one of the sheets embodied in the software which contains separate sheets dedicated for each fleet. According to the selected fleet type, the software recognises the related sheet and transfers the data from this related sheet. All the calculations are made on these special sheets and only the results are transferred to the software window. So the users do not need to work hard on the calculations (Figure 3.7), they only see the final results.

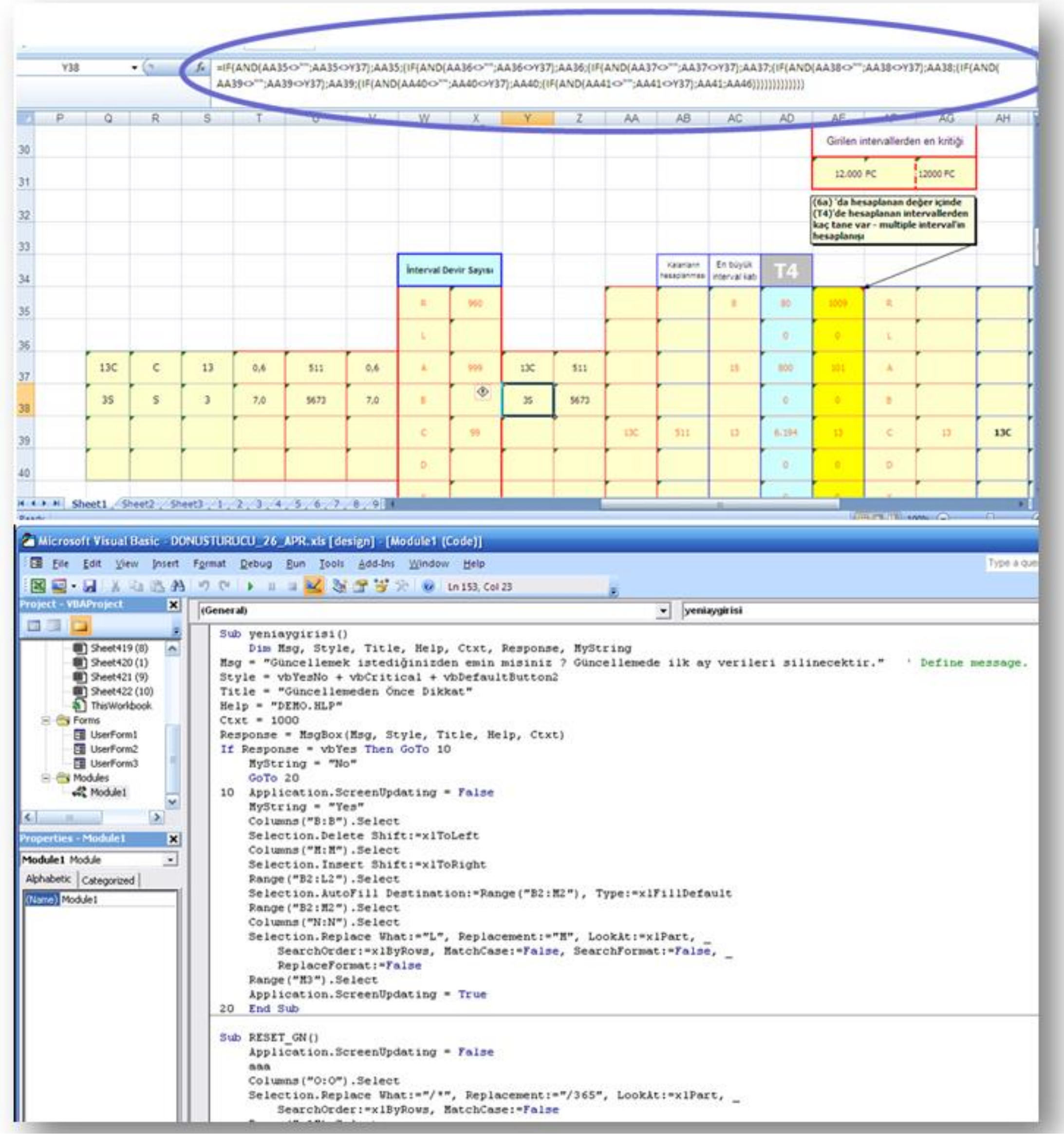


Figure 3.7 : Internal calculation process of the software.

After selected the target fleet from the selection menu, all aircraft type specifications and utilization parameters of the selected fleet appear on the screen (Figure 3.8).

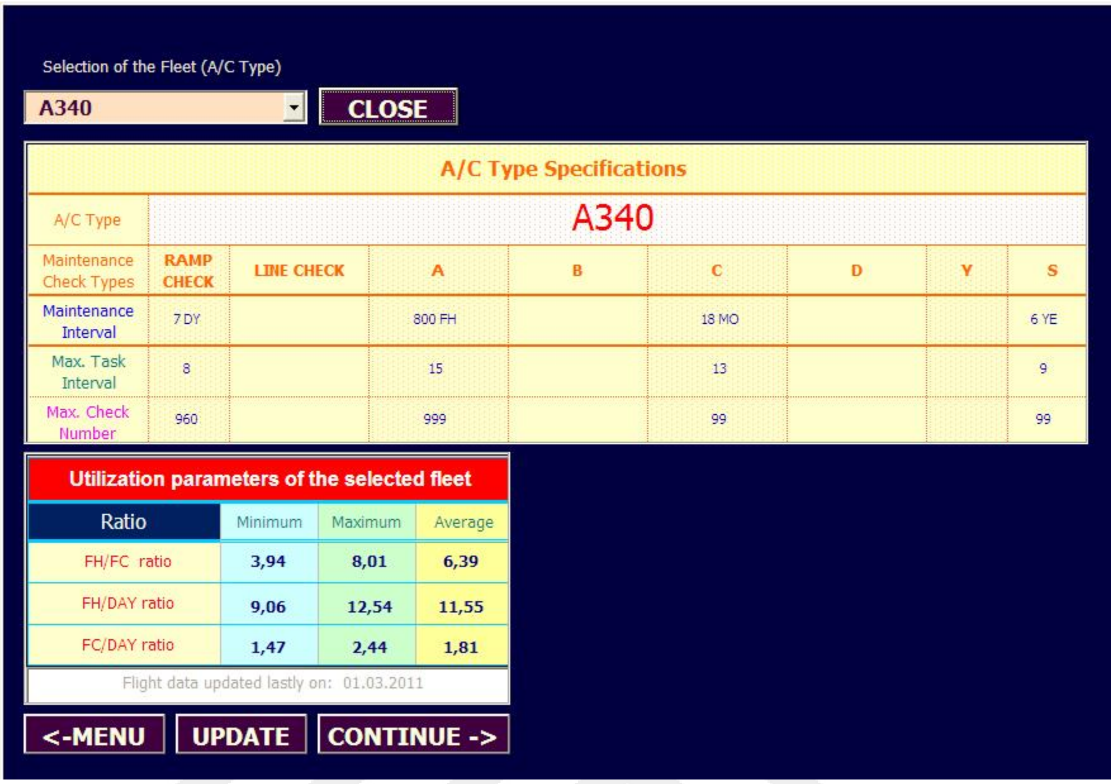


Figure 3.8 : Aircraft Type Specifications & Utilization of the selected fleet.

The utilization parameters of the selected fleet are brought automatically on the screen after the calculation (the values are for the overall fleet calculated from all aircraft in this fleet). These utilization values are the ratio given respectively: FH/FC (Flight hour accumulated per each flight cycle), FH/DAY (Flight hour accumulated per day) and finally FC/DAY (Flight cycle accumulated per day). The average values for these three parameters are calculated by the software by including all aircraft in the selected fleet and taking into consideration all flight hours and cycles values accumulated by each aircraft during last twelve months (real time utilization values). Also in order to give an idea to the user, minimum and maximum utilization values obtained from all aircraft in the selected fleet during last twelve months are given in this table. On the other hand, aircraft type specifications such as interval value of maintenance check type, maximum task interval and maximum check number for a specific check are brought automatically on the screen from the database. This kind of data is introduced in the software during the set-up process of the software. After the software gives this information, the user should input the task intervals for the maintenance task under interrogation. The software has the ability to accept 4 different interval unit types (Figure 3.9).

The software takes into account the utilization values for the selected fleet and according to these real time utilization values of this fleet, it calculates and decides which one of the intervals (input already by the user) is more critical and occurs first. After calculating the most critical interval among the ones input by the user, the software shows the results in a new table as shown in the Figure 3.10.

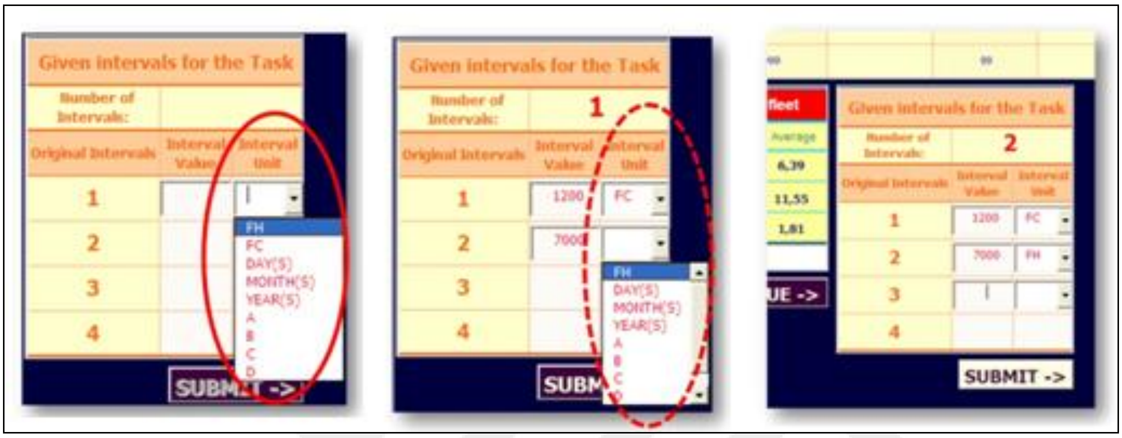


Figure 3.9 : Task Intervals.

The software does not allow the user to input the same interval unit twice and it eliminates the related interval unit automatically because the user has already selected it. For example, if the user selects the "FC" as the first interval unit, for the second interval unit "FC" could not been selected again. The software automatically eliminates the interval unit selected by the user.

Once the user inputs the interval values and units, (after submitting) the software automatically calculates the most critical interval value between the inputs taking into account the average fleet utilization (Figure 3.10).

The most critical interval value calculated by the software according to the average fleet utilization is converted to letter check alternatives by estimating losses for each letter check alternatives. The user should decide the most appropriate letter check between the ones proposed by the software taking into account the losses and the possibility of the accomplishment of this maintenance task during the checks proposed by the software.

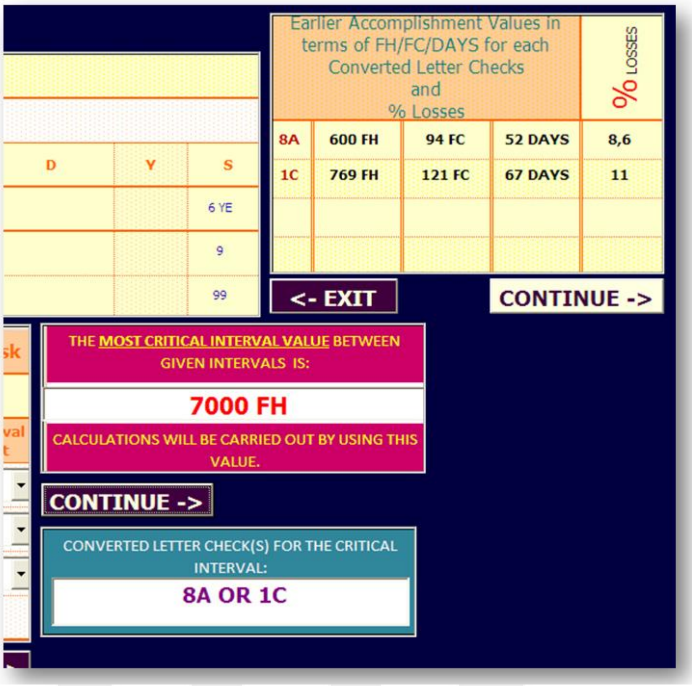


Figure 3.10 : The most critical interval & coverted letter check alternatives.

This step of the software is sufficient for a rough conversion for the complete fleet. Nevertheless, the most powerful part of the software is that it allows the users to make more accurate calculations in terms of each aircraft. If the user is not satisfied with the converted letter check alternatives calculated for all fleet, the software allows the user to continue with the more accurate step that will be performed for each aircraft (Figure 3.11).

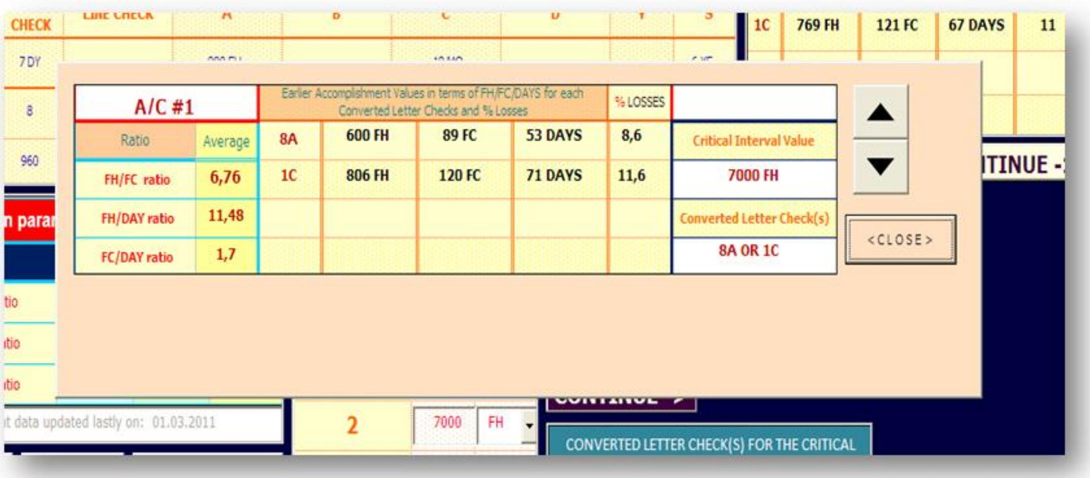


Figure 3.11 : The most critical interval & coverted letter check alternatives for each aircraft in the fleet.

The utilization values of each aircraft may differ one from each other and the converted letter check alternatives may be different for each aircraft consequently. As an example, the utilization values of the aircraft in Figure 3.11 are very close to the fleet average in Figure 3.10 so the converted letter check alternatives are the same for both the aircraft and the whole fleet. As already mentioned the software is very flexible, it makes possible for the users to observe a specific aircraft in this fleet and make calculations for only this special aircraft. The software allows the user to examine all aircraft one by one and the solutions obtained for all aircraft may be in a very large scale (Figure 3.12).

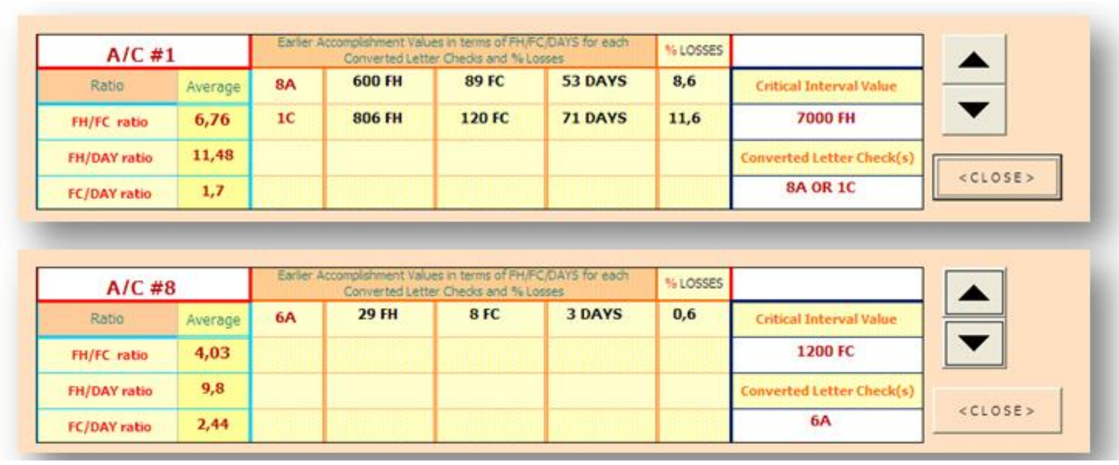


Figure 3.12 : Converted letter check alternatives for different aircraft in the fleet.

Another strong part of the software is that it allows the user to change the fleet in every step of the calculation process. As an example if the user selects a narrow body fleet such as B737 with more FC utilization per day instead of a wide body aircraft fleet in Figure 3.8, this time FC based interval becomes more critical according to utilization values of this type and converted letter check alternatives are completely different from the previous fleet (Figure 3.13).

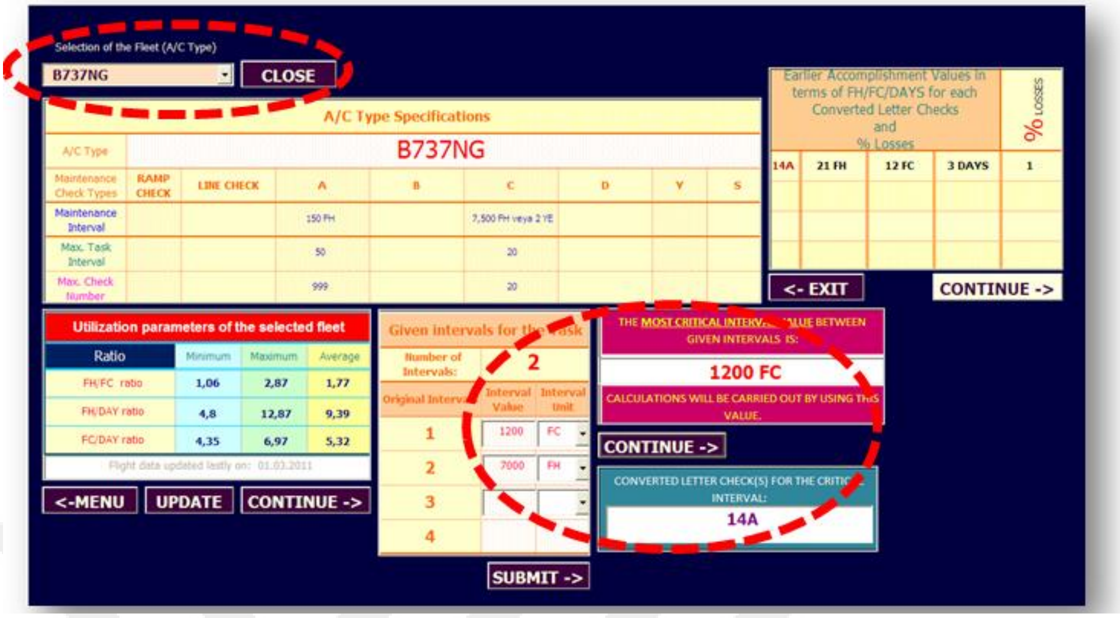


Figure 3.13 : Change of the fleet.

The results obtained in case of the fleet change for the same inputs may be completely different from the previous fleet outputs. For example, the outputs for the same inputs (task intervals) of the example given in Figure 3.10 are completely different from the ones given in Figure 3.13 (Compare Figure 3.10 and Figure 3.13).

For the whole fleet, the task interval values have been converted to “14A” check (average of 66 A/C in this example situation), however the same values have been converted to “15A” for the 1st A/C and “11A” for the 9th A/C and so on (Figure 3.14).

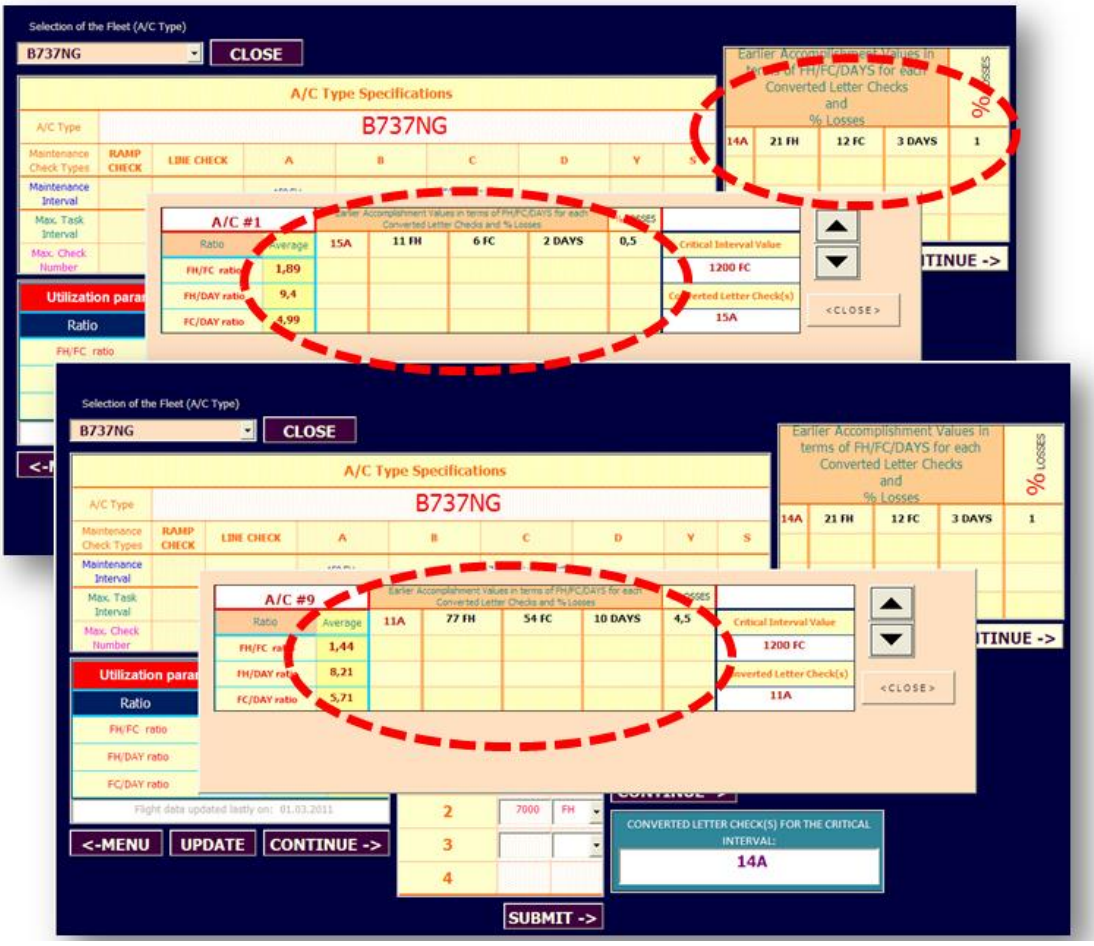


Figure 3.14 : Comparison of different A/C with different utilization.

One of the most successful properties of this software is that it may suggest more than one letter check alternative to the user and allows him to choose one of them according to the losses, hangar availability, material, tool and man-hour requirements of the maintenance task and also task accomplishment possibility during this specific check.

3.3 The advanced properties of the Software and Conclusion

This software allows the user to find the most appropriate letter check alternatives for a specific maintenance task with different interval values. It calculates the most critical interval among the intervals input by the user and during this calculation process the real time utilization values of the selected fleet are evaluated. All the calculations are based on these real time utilization values accomplished by this fleet during the last twelve months. No estimated values are used in the calculations. Therefore, results that are more accurate may be obtained by using this software. Although the software shows only the final results to the user, the software has a complex structure where lots of calculations are performed in the internal sheets of the software (Figure 3.7 and Figure 3.15) and by running many macros written in Visual basic codes.

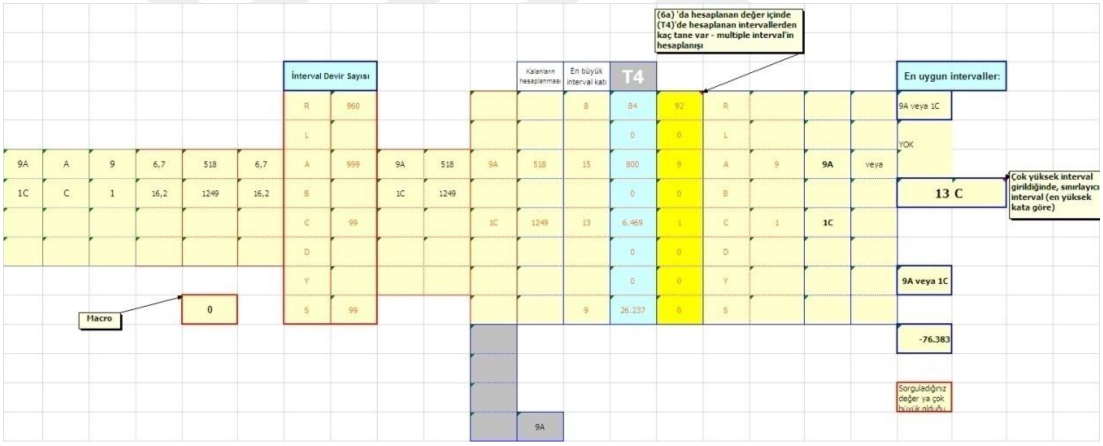


Figure 3.15 : One of the examples of calculations in sheets.

Another successful property of the software is that it gives the user the opportunity to make comparisons between different fleets. By this way this user has the opportunity to see that any maintenance task with the same interval will have different letter checks in different fleets. The software shows the different alternatives of letter checks for a specific maintenance task and for the selected fleet. However due to different utilization of aircraft in the same fleet, the conversion of given interval to letter check alternatives may differ from one aircraft to another. In other words some aircraft may have different letter check alternatives from the others since they have lower or higher utilization values from the average value of the fleet.

This software allows also the user to observe any specific aircraft in a fleet and calculates and converts the given interval values to the letter check alternatives for this specific aircraft by using the real time utilization values of this specific aircraft. By this way more accurate conversion depending on each aircraft utilization may be obtained (Figure 3.16).

A/C #1		Earlier Accomplishment Values in terms of FH/FC/DAYS for each Converted Letter Checks and % Losses				% LOSSES	
Ratio	Average	13A	122 FH	65 FC	13 DAYS	5,9	Critical Interval Value
FH/FC ratio	1,89						1100 FC
FH/DAY ratio	9,4						Converted Letter Check(s)
FC/DAY ratio	4,99						13A

A/C #4		Earlier Accomplishment Values in terms of FH/FC/DAYS for each Converted Letter Checks and % Losses				% LOSSES	
Ratio	Average	14A	8 FH	5 FC	1 DAYS	0,4	Critical Interval Value
FH/FC ratio	1,92						1100 FC
FH/DAY ratio	9,48						Converted Letter Check(s)
FC/DAY ratio	4,95						14A

A/C #9		Earlier Accomplishment Values in terms of FH/FC/DAYS for each Converted Letter Checks and % Losses				% LOSSES	
Ratio	Average	10A	83 FH	58 FC	11 DAYS	5,3	Critical Interval Value
FH/FC ratio	1,44						1100 FC
FH/DAY ratio	8,21						Converted Letter Check(s)
FC/DAY ratio	5,71						10A

A/C #15		Earlier Accomplishment Values in terms of FH/FC/DAYS for each Converted Letter Checks and % Losses				% LOSSES	
Ratio	Average	11A	1 FH	1 FC	1 DAYS	0,1	Critical Interval Value
FH/FC ratio	1,51						1100 FC
FH/DAY ratio	8,24						Converted Letter Check(s)
FC/DAY ratio	5,49						11A

Figure 3.16 : Converted letter check alternatives depending on aircraft.

Any user in an airline company may customize the software developed in this thesis and may convert the reference interval given in maintenance program for any specific maintenance task to the letter check alternatives and therefore he may assign accurate letter check values to every aircraft one by one. By using this software the earlier or later accomplishment of some maintenance tasks in some aircraft may be prevented and therefore scheduled maintenance downtime of aircraft may be reduced consequently.

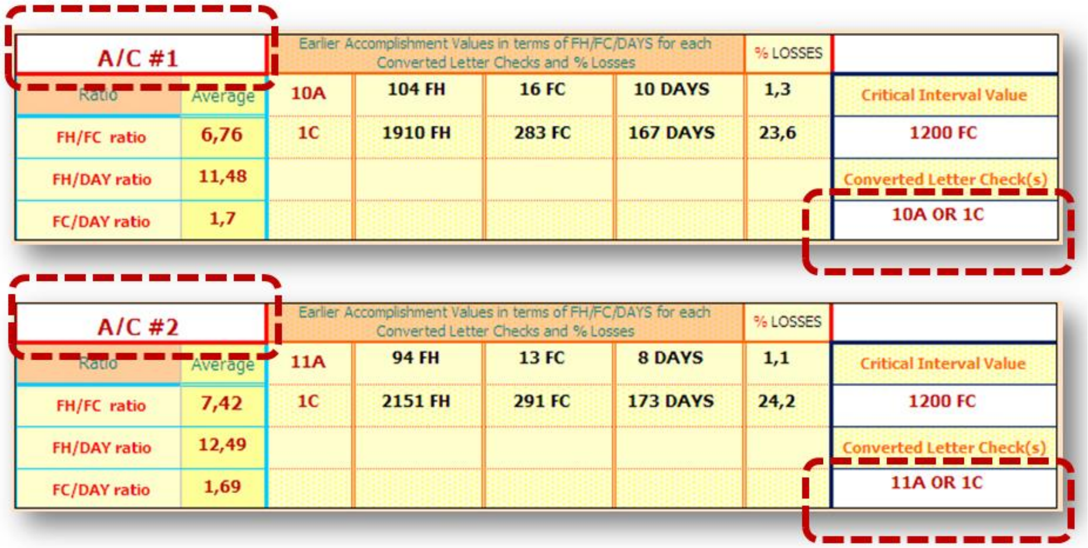
The software is very strong to calculate the most appropriate and accurate letter check alternatives for a complete fleet and also for every single A/C in the fleet. It has the flexibility to make the calculations not only for one fleet but also for different fleets in the airline company. Another strong part of the software is that it takes into account the real-time utilization values of each aircraft in the fleet. If the airline company does not take into account the real-time utilization values of each aircraft and converts the intervals of maintenance tasks with different usage parameters into letter checks just by making an average utilization assumption for the whole fleet, this will cause losses (earlier or late accomplishment of maintenance tasks for some aircraft). In other words, the approach to consider some average value for the complete fleet causes the accomplishment of some maintenance tasks earlier for some aircraft or later for some of them.

If we compare two situations below, the advantage of the software may be more understandable:

Assumptions: Daily utilization of the fleet is supposed as 12 FH/day and 2 FC/day
Maintenance task interval to be converted to letter check is 1200 FC.
“A” check for the A/C fleet is defined as 800 FH, it means that all the A/C in the fleet is taken to hangar for maintenance check after the aircraft accomplishes 800 FH.

- By using average utilization assumption for the whole fleet, the interval of the maintenance task 1200 FC is equivalent to 7200 FH or 600 days (by using 12 FH/day and 2 FC/day)

  So, this task should be performed every **9A check**. Then the converted letter check interval for this maintenance task is **9A**.
- By using the software, we obtain different cases for different aircraft in the fleet such as given in Figure 3.17.



A/C #1		Earlier Accomplishment Values in terms of FH/FC/DAYS for each Converted Letter Checks and % Losses				% LOSSES	
Ratio	Average	10A	104 FH	16 FC	10 DAYS	1,3	Critical Interval Value
FH/FC ratio	6,76	1C	1910 FH	283 FC	167 DAYS	23,6	1200 FC
FH/DAY ratio	11,48						Converted Letter Check(s)
FC/DAY ratio	1,7						10A OR 1C

A/C #2		Earlier Accomplishment Values in terms of FH/FC/DAYS for each Converted Letter Checks and % Losses				% LOSSES	
Ratio	Average	11A	94 FH	13 FC	8 DAYS	1,1	Critical Interval Value
FH/FC ratio	7,42	1C	2151 FH	291 FC	173 DAYS	24,2	1200 FC
FH/DAY ratio	12,49						Converted Letter Check(s)
FC/DAY ratio	1,69						11A OR 1C

Figure 3.17 : Converted letter check alternatives depending on aircraft (case study).

The software calculates 11A for the aircraft A/C#2 by taking into account the real-time utilization values of this aircraft.

If we take into account the average utilization assumption for the whole fleet, we lose 2A for this single maintenance task accomplishment for the aircraft A/C#2. In other words instead of performing this maintenance task in every 11A check, we have to perform it every 9A check and 2A check earlier accomplishment occurs. In long term we perform this maintenance task several times more than needed (instead of 9 applications, we perform 11 applications without the software – 2 additional unnecessary checks for the case in this example) (Figure 3.18).

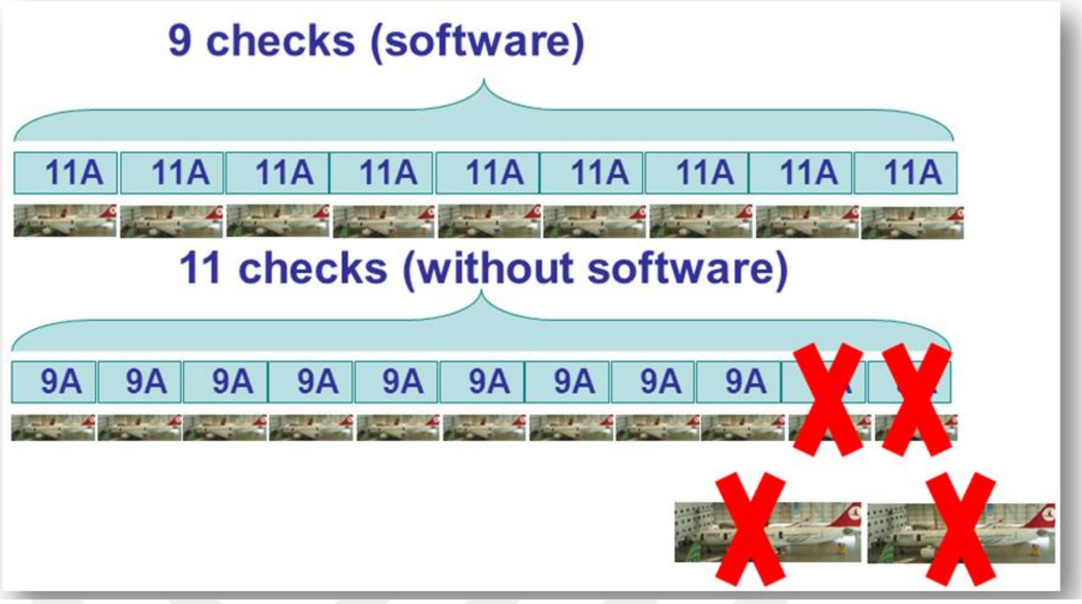


Figure 3.18 : Comparison and the advantage of the software.

If we consider the existence of several maintenance tasks (around four thousands in the maintenance program), we can easily understand the benefit of using this software for the scheduling purposes in airline companies. An airline company can prevent unnecessary accomplishments of maintenance tasks and in this way they can profit from maintenance cost, man-hour and material costs. Furthermore the availability of aircraft for flight (aircraft maximization) increases and this increases the aircraft utilization in long term consequently.

The total man hour lost during a maintenance check may be calculated with the formula given below:

$$\sum_{j=1}^{A} \sum_{i=1}^{n} \left(\frac{S_{i,j} - R_{i,j}}{S_{i,j} x\, R_{i,j}} \right) x M_i \tag{3.2}$$

Where:

n is the number of maintenance tasks given in the maintenance program.

M_i is the man hour required for the accomplishment of the i^{th} maintenance task.

$S_{i,j}$ is the interval proposed by the software for of the i^{th} maintenance task for the j^{th} aircraft.

$R_{i,j}$ is the interval applied by the airline company for of the i^{th} maintenance task for the j^{th} aircraft.

A is the number of aircraft in a specific fleet of the airline company.

$S_{i,j} - R_{i,j}$ is the earlier accomplishment of the i^{th} maintenance task for the j^{th} aircraft.

$S_{i,j} - R_{i,j}$ is the earlier accomplishment of the i^{th} maintenance task for the j^{th} aircraft.

$\frac{S_{i,j} - R_{i,j}}{S_{i,j} x R_{i,j}}$ is the unnecessary accomplishment of the i^{th} maintenance task for the j^{th} aircraft per unit interval (unit maintenance check).

$\sum_{i=1}^{n} \left(\frac{S_{i,j} - R_{i,j}}{S_{i,j} x R_{i,j}} \right) x M_i$ is the unnecessary man hour lost for the n maintenance tasks for the j^{th} aircraft during the unit maintenance check.

For the case study in Figure 3.18, if we assume that there are 600 maintenance task similar to the example given in case study related Figure 3.18, for one aircraft we lose 36 man hours per unit maintenance check. (In order to facilitate the calculations, all maintenance task man hours are assumed to be 3.)

For this case study, for one aircraft we lose approximately one day per unit maintenance check without using the software. If we use the software and assign the more accurate letter check for this aircraft taking into account its real time utilization values, we have a cost saving of 60.000 US$ for one aircraft for a number of maintenance tasks (600 in this example case study) in 18 years.

If we assume that the airline company has 200 aircraft in its fleet and there are more than 3.000 maintenance task in the maintenance program, the size of the cost saving becomes very important for the airline by using this software.

Another advantage of the software, it may help the user to prevent late accomplishment of some maintenance tasks in some aircraft. If this occurs, it is subject of severe penalties by civil aviation authorities.

n	1	2	3	4	.	.	.	600
S	11A	11A	11A	11A	11A	11A	11A	11A
R	9A	9A	9A	9A	9A	9A	9A	9A
S-R	2	2	2	2	2	2	2	2
SxR	99	99	99	99	99	99	99	99
(S-R)/SxR	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
M	3	3	3	3	3	3	3	3
((S-R)/SxR)xM	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06
Total	36,36							

Figure 3.19 : Example of man hour lost per unit maintenance check without software.

4. CONCLUSION

The major purpose of this thesis was to keep the aircraft less time on the ground for any purposes especially for maintenance purposes and thus to increase the duration of flight availability. In this thesis it was intended to propose alternative ways of performing maintenance in order to keep the aircraft less time on the ground. One of the ways to increase the aircraft utilization (flight hours spent in a period of time) is to reduce ground time spent for maintenance. In this thesis a method to reduce ground time spent for maintenance was studied. A couple of case studies accomplished in an airline company to support this method were given. The single task-oriented maintenance concept allows us to establish a more flexible structure in the accomplishment of maintenance tasks and consequently to perform the maintenance in every opportunity when the aircraft is already on the ground. By utilizing the advantages of single task-oriented maintenance concept, maintenance checks may be divided into smaller checks which require the aircraft to be kept less time on the ground. Some case studies on dividing the maintenance content into smaller parts were observed in the content of this thesis.

To reduce ground time is in the process and this depends on how efficiently the maintenance organisation works, how the preparation work is done and, of course, continuity. If you maintain your aircraft to a high level continuously then you can probably reduce ground time during the heavy checks. Such efforts can probably reduce the ground time of a heavy check by between 10 and 20 per cent.

An integrated maintenance IT solution maximises improvements in schedule dependability and maintenance downtime reduction.

When considering the ability of an individual airline to reduce aircraft maintenance downtime, it is essential to consider a number of different technological aspects of the aircraft being operated and the IT and logistics infrastructures in which they function.

Modern aircraft such as the B737NG and the A320 have up-to-date diagnostics and prognostic capabilities as compared with earlier aircraft types and these permit a very much more proactive management of aircraft maintenance. Some airlines, for example, use the Airbus Airman system whereby fault codes are transmitted through the ACARS system as the aircraft flies along. This permits airline's maintenance control centre to evaluate the codes and issue work cards at the nominated maintenance bases long before aircraft have landed. Such work could include dealing with early maintenance messages that are indicative of a potential or latent failure that are not visible to flight crews. Some airlines have a system whereby every day at a specific time all of the maintenance bases are issued their tasks by maintenance planning. Then in half an hour everyone calls in to go through their work assignments to make sure that they have staffing, the parts and the tooling to do the tasks. They have a process whereby at this specific time + half an hour every day they know the work that they are going to accomplish that evening. Their maintenance control centre also participates in the call and if any problems have been experienced on an airplane during the day they know what they are and they know what they have done to try to rectify them. Also, they know where that plane's going to be that evening and they can add any trouble-shooting or defect rectification to the scheduled work assignment. Where Airbus has Airman, Boeing has its Airplane Health Management (AHM) system. In many ways it accomplishes a similar function to the Airman system but in addition to diagnosing a problem in flight, AHM can also predict when parts might fail so that maintenance can be scheduled to suit airline convenience. It can also instruct a search of Boeing's database to retrieve historic costs for fault rectification and assign a priority based on available data and the airline's business rules. Another technological advancement pioneered by Boeing was its Portable Maintenance Aid (PMA) which permits maintenance personnel to troubleshoot and rectify defects without having to return to fixed maintenance planning locations. The ready availability of electronic documentation is to be one of the key factors when considering maintenance downtime management. All the documentation is online so airlines don't have any paper manuals - that's key from a number of different perspectives. If you set up a new maintenance base getting folks datacon activity is the key thing – not printing off another umpteen stacks of books and figuring out who is going to maintain then. It also facilitates easy access to engineering so that an engineer can be called in the middle of the night, he can fire up his laptop, research a problem, type an engineering disposition and email it out. Also, if an aircraft is damaged in the middle of the night, someone can take some pictures and email them to maintenance control, which can then assess what should be done. Being in an electronic environment is very beneficial.

Briefly an integrated maintenance IT solution is key to reducing aircraft maintenance downtimes. An integrated maintenance IT solution maximises improvements in schedule dependability and maintenance downtime reduction. New operating efficiencies, increased productivity and reduced disruption are all possible once the maintenance schedule and operational schedules are viewed as one. To fulfil this vision, airlines need maintenance IT systems that manage configuration, defect control, materials, maintenance programs, job cards, tooling, work planning, technical documentation and records in one integrated and on-line environment.

The second objective of the thesis was to prevent earlier accomplishment of some maintenance tasks and to develop a software for this purpose. In order to prevent earlier accomplishment of some maintenance tasks, the real time utilization values of aircraft have to be taken into account and the most appropriate letter check alternatives according to real time utilization values should be calculated by means of the software.

This software allows the user to find the most appropriate letter check alternatives for a specific maintenance task with different interval values. It calculates the most critical interval among the intervals input by the user and during this calculation process the real time utilization values of the selected fleet are evaluated. All the calculations are based on these real time utilization values accomplished by this fleet during the last twelve months. No estimated values are used in the calculations. Therefore, results that are more accurate are obtained by using this software.

Another successful property of the software is that it gives the user the opportunity to make comparisons between different fleets. By this way this user has the opportunity to see that any maintenance task with the same interval will have different letter checks in different fleets. The software shows the different alternatives of letter checks for a specific maintenance task and for the selected fleet. However due to different utilization of aircraft in the same fleet, the conversion of given interval to letter check alternatives may differ from one aircraft to another. In other words some aircraft may have different letter check alternatives from the others since they have lower or higher utilization values from the average value of the fleet.

This software allows also the user to observe any specific aircraft in a fleet and calculate and convert the given interval values to the letter check alternatives for this specific aircraft by using the real time utilization values of this specific aircraft. By this way more accurate conversion depending on aircraft utilization may be obtained.

Any user in an airline company may customize the software developed in this thesis and may convert the reference interval given in maintenance program for any specific maintenance task to the letter check alternatives and therefore he may assign accurate letter check values to every aircraft one by one. By using this software the earlier or later accomplishment of some maintenance tasks in some aircraft may be prevented and therefore scheduled maintenance downtime of aircraft may be reduced consequently.

4.1 Application of The Work

In a case study performed in an airline company for the fleet of Airbus A340 A/C, the results for the letter check system and the single task oriented concept have been obtained. Results of the case study performed in A340 fleet (rigid letter check system). In the case study, it is possible to see the benefits of the single task oriented maintenance concept. In a period of 10 years, an aircraft is kept on the ground for maintenance about 87 days however in the method proposed in this thesis the same aircraft is kept only for 15 days on the ground for maintenance in a period of 10 years. This can be achieved only by utilizing every moment as a maintenance opportunity when the aircraft is on the ground for any reason.

We have 72 days savings over ten years. This study has been performed by taking account that the maintenance tasks are performed by the most appropriate staff in a limited time. Commercial cost saving is 4.320.000 US$ for 72 days (Figure 2.34).

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APPENDICES

APPENDIX A.1 : Case study details
APPENDIX A.2 : Some parts of the software
APPENDIX A.3 : Article

APPENDIX A.1 : Case study details

Figure A.1 : Comparison of rigit letter check and single task oriented concept.

APPENDIX A.2 : Some parts of the software

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Private Declare Function FindWindow Lib "user32" Alias "FindWindowA" (ByVal lpClassName As String, ByVal
lpWindowName As String) As Long
Private Declare Function SetWindowLong Lib "user32" Alias "SetWindowLongA" (ByVal hwnd As Long, ByVal
nIndex As Long, ByVal dwNewLong As Long) As Long
Private Declare Function GetWindowLong Lib "user32" Alias "GetWindowLongA" (ByVal hwnd As Long, ByVal
nIndex As Long) As Long
Private Declare Function DrawMenuBar Lib "user32" (ByVal hwnd As Long) As Long
Private Const WS_BORDER = &H800000
Private Const GWL_STYLE = (-16)
Private Sub CommandButton3_MouseMove(ByVal Button As Integer, ByVal Shift As Integer, ByVal X As Single,
ByVal Y As Single)
CommandButton3.BackColor = &H80000018
CommandButton3.ForeColor = &H400040
End Sub
Private Sub CommandButton4_MouseMove(ByVal Button As Integer, ByVal Shift As Integer, ByVal X As Single,
ByVal Y As Single)
CommandButton4.BackColor = &H80000018
CommandButton4.ForeColor = &H400040
End Sub
Private Sub UserForm_Activate()
Dim lngFormHwnd As Long, lngFormStyle As Long
If Left(Application.Version, 1) = 8 Then Exit Sub
Me.BorderStyle = fmBorderStyleNone
If Application.Version < 9 Then
lngFormHwnd = FindWindow("THUNDERXFRAME", Me.Caption)
Else
lngFormHwnd = FindWindow("THUNDERDFRAME", Me.Caption)
End If
lngFormStyle = GetWindowLong(lngFormHwnd, GWL_STYLE)
lngFormStyle = lngFormStyle And Not WS_BORDER
SetWindowLong lngFormHwnd, GWL_STYLE, lngFormStyle
DrawMenuBar lngFormHwnd
End Sub
Private Sub CommandButton1_Click()
UserForm2.Show
End Sub
Private Sub CommandButton1_MouseMove(ByVal Button As Integer, ByVal Shift As Integer, ByVal X As Single,
ByVal Y As Single)
CommandButton1.BackColor = &H80000018
CommandButton1.ForeColor = &H400040
CommandButton2.BackColor = &H400040
CommandButton2.ForeColor = &H80000018
End Sub
Private Sub CommandButton2_MouseMove(ByVal Button As Integer, ByVal Shift As Integer, ByVal X As Single,
ByVal Y As Single)
CommandButton2.BackColor = &H80000018
CommandButton2.ForeColor = &H400040
CommandButton1.BackColor = &H400040
CommandButton1.ForeColor = &H80000018
End Sub
Private Sub CommandButton2_Click()
On Error Resume Next
Application.DisplayAlerts = False
Application.Quit
End Sub
Private Sub UserForm_Initialize()
UserForm1.Width = Application.Width
UserForm1.Height = Application.Height
UserForm1.Label1.Left = (UserForm1.Width - UserForm1.Label1.Width) / 2
UserForm1.Label1.TextAlign = fmTextAlignCenter
UserForm1.Label12.Left = (UserForm1.Width - UserForm1.Label12.Width) / 2
UserForm1.Label12.TextAlign = fmTextAlignCenter
UserForm1.Label10.Left = (UserForm1.Width - UserForm1.Label10.Width) / 2
UserForm1.Label10.TextAlign = fmTextAlignCenter
UserForm1.CommandButton1.Left = (UserForm1.Width - UserForm1.CommandButton1.Width) / 2
UserForm1.CommandButton2.Left = (UserForm1.Width - UserForm1.CommandButton2.Width) / 2
```

```
UserForm1.Image2.Left = (UserForm1.Width - UserForm1.Image2.Width) / 2
End Sub
Private Sub UserForm_MouseMove(ByVal Button As Integer, ByVal Shift As Integer, ByVal X As Single, ByVal
Y As Single)
CommandButton1.BackColor = &H400040
CommandButton2.BackColor = &H400040
CommandButton3.BackColor = &H400040
CommandButton1.ForeColor = &H80000018
CommandButton2.ForeColor = &H80000018
CommandButton3.ForeColor = &H80000018
End Sub
Private Declare Function FindWindow Lib "user32" Alias "FindWindowA" (ByVal lpClassName As String, ByVal
lpWindowName As String) As Long
Private Declare Function SetWindowLong Lib "user32" Alias "SetWindowLongA" (ByVal hwnd As Long, ByVal
nIndex As Long, ByVal dwNewLong As Long) As Long
Private Declare Function GetWindowLong Lib "user32" Alias "GetWindowLongA" (ByVal hwnd As Long, ByVal
nIndex As Long) As Long
Private Declare Function DrawMenuBar Lib "user32" (ByVal hwnd As Long) As Long
Private Const WS_BORDER = &H800000
Private Const GWL_STYLE = (-16)
Private Sub ComboBox1_Change()
Sheets("Sheet1").Range("R4") = UserForm2.TextBox2.Value
Sheets("Sheet1").Range("S4") = UserForm2.ComboBox1.Value
        If Application.WorksheetFunction.IsNumber(Sheets("Sheet1").Range("R4")) Then
        UserForm2.TextBox3.Visible = True
        UserForm2.ComboBox2.Visible = True
        UserForm2.Label36.Caption = Sheets("Sheet1").Range("R2")
        UserForm2.ComboBox2.RowSource = "Sheet1!Y4:Y12"
        Me.CommandButton4.Enabled = True
        UserForm2.TextBox3.SetFocus
        Else
        UserForm2.TextBox2.Value = ""
        Me.CommandButton4.Enabled = False
        UserForm2.TextBox2.SetFocus
        End If
End Sub
Private Sub ComboBox2_Change()
Sheets("Sheet1").Range("R5") = UserForm2.TextBox3.Value
Sheets("Sheet1").Range("S5") = UserForm2.ComboBox2.Value
        If Application.WorksheetFunction.IsNumber(Sheets("Sheet1").Range("R5")) Then
        UserForm2.TextBox4.Visible = True
        UserForm2.ComboBox3.Visible = True
        UserForm2.Label36.Caption = Sheets("Sheet1").Range("R2")
        UserForm2.ComboBox3.RowSource = "Sheet1!X4:X12"
        Me.CommandButton4.Enabled = True
        UserForm2.TextBox4.SetFocus
        Else
        UserForm2.TextBox3.Value = ""
        Me.CommandButton4.Enabled = False
        UserForm2.TextBox3.SetFocus
        End If
End Sub
Private Sub ComboBox3_Change()
Sheets("Sheet1").Range("R6") = UserForm2.TextBox4.Value
Sheets("Sheet1").Range("S6") = UserForm2.ComboBox3.Value
        If Application.WorksheetFunction.IsNumber(Sheets("Sheet1").Range("R6")) Then
        UserForm2.TextBox5.Visible = True
        UserForm2.ComboBox4.Visible = True
        UserForm2.Label36.Caption = Sheets("Sheet1").Range("R2")
        UserForm2.ComboBox4.RowSource = "Sheet1!W4:W12"
        Me.CommandButton4.Enabled = True
        UserForm2.TextBox5.SetFocus
        Else
        UserForm2.TextBox4.Value = ""
        Me.CommandButton4.Enabled = False
        UserForm2.TextBox4.SetFocus
        End If

End Sub
Private Sub ComboBox4_Change()
Sheets("Sheet1").Range("R7") = UserForm2.TextBox5.Value
```

```
Sheets("Sheet1").Range("S7") = UserForm2.ComboBox4.Value
        If Application.WorksheetFunction.IsNumber(Sheets("Sheet1").Range("R7")) Then
        UserForm2.Label36.Caption = Sheets("Sheet1").Range("R2")
        Me.CommandButton4.Enabled = True
        Me.CommandButton4.SetFocus
        Else
        UserForm2.TextBox5.Value = ""
        Me.CommandButton4.Enabled = False
        UserForm2.TextBox5.SetFocus
        End If
End Sub
Private Sub CommandButton1_Click()
Unload Me
UserForm1.Show
End Sub
Private Sub CommandButton3_Click()
UserForm2.TextBox3.Visible = False
UserForm2.TextBox4.Visible = False
UserForm2.TextBox5.Visible = False
UserForm2.ComboBox2.Visible = False
UserForm2.ComboBox3.Visible = False
UserForm2.ComboBox4.Visible = False

UserForm2.Frame3.Visible = True
UserForm2.CommandButton4.Visible = True
Me.CommandButton4.Enabled = False
UserForm2.ComboBox1.RowSource = "Sheet1!AE4:AE12"
UserForm2.TextBox2.SetFocus
End Sub
Private Sub CommandButton4_Click()
Sheets("Sheet1").Range("R4") = UserForm2.TextBox2.Value
Sheets("Sheet1").Range("R5") = UserForm2.TextBox3.Value
Sheets("Sheet1").Range("R6") = UserForm2.TextBox4.Value
Sheets("Sheet1").Range("R7") = UserForm2.TextBox5.Value
Sheets("Sheet1").Range("S4") = UserForm2.ComboBox1.Value
Sheets("Sheet1").Range("S5") = UserForm2.ComboBox2.Value
Sheets("Sheet1").Range("S6") = UserForm2.ComboBox3.Value
Sheets("Sheet1").Range("S7") = UserForm2.ComboBox4.Value
veriler
UserForm2.Frame4.Visible = True
UserForm2.CommandButton5.Visible = True
End Sub
Private Sub CommandButton5_Click()
Me.Frame5.Visible = True
Me.Frame6.Visible = True
UserForm2.CommandButton7.Visible = True
UserForm2.CommandButton8.Visible = True
veriler

End Sub
Private Sub CommandButton6_Click()
Dim tt As String
Unload Me
    tt = Sheets("Sheet1").Range("B1")
    Sheets(tt).Select
    Range("A1").Select
End Sub
Private Sub CommandButton7_Click()
UserForm3.Show
End Sub
Private Sub CommandButton8_Click()
Unload Me
On Error Resume Next
Application.DisplayAlerts = False
Application.Quit
End Sub
Private Sub TextBox2_Enter()
If Me.ComboBox1.Value <> "" Then
Me.CommandButton4.Enabled = True
End If
End Sub
```

```
Private Sub TextBox3_Enter()
If Me.ComboBox2.Value <> "" Then
Me.CommandButton4.Enabled = True
End If
End Sub
Private Sub TextBox4_Enter()
If Me.ComboBox3.Value <> "" Then
Me.CommandButton4.Enabled = True
End If
End Sub
Private Sub TextBox5_Enter()
If Me.ComboBox4.Value <> "" Then
Me.CommandButton4.Enabled = True
End If
End Sub
Private Sub UserForm_Activate()
Dim lngFormHwnd As Long, lngFormStyle As Long
If Left(Application.Version, 1) = 8 Then Exit Sub
Me.BorderStyle = fmBorderStyleNone
If Application.Version < 9 Then
lngFormHwnd = FindWindow("THUNDERXFRAME", Me.Caption)
Else
lngFormHwnd = FindWindow("THUNDERDFRAME", Me.Caption)
End If
lngFormStyle = GetWindowLong(lngFormHwnd, GWL_STYLE)
lngFormStyle = lngFormStyle And Not WS_BORDER
SetWindowLong lngFormHwnd, GWL_STYLE, lngFormStyle
DrawMenuBar lngFormHwnd
Me.CommandButton1.SetFocus

End Sub
Private Sub UserForm_Initialize()
DoEvents
UserForm2.Width = Application.Width
UserForm2.Height = Application.Height
Unload UserForm1
UserForm2.secenek.RowSource = "Sheet1!D1:D11"
UserForm2.Frame1.Visible = False
UserForm2.Frame2.Visible = False
UserForm2.Frame3.Visible = False
UserForm2.Frame4.Visible = False
UserForm2.Frame5.Visible = False
UserForm2.Frame6.Visible = False
UserForm2.CommandButton2.Visible = False
UserForm2.CommandButton3.Visible = False
UserForm2.CommandButton4.Visible = False
UserForm2.CommandButton5.Visible = False
UserForm2.CommandButton6.Visible = False
UserForm2.CommandButton7.Visible = False
UserForm2.CommandButton8.Visible = False
UserForm2.secenek.ListIndex = 0
Me.CommandButton1.SetFocus
End Sub
Private Sub secenek_Change()
Dim g As Integer
Sheets("Sheet1").Range("B1") = ""
g = Me.secenek.ListIndex
Select Case g
Case 0
Exit Sub
Case 1
Sheets("Sheet1").Range("B1") = 1
Case 2
Sheets("Sheet1").Range("B1") = 2
Case 3
Sheets("Sheet1").Range("B1") = 3
Case 4
Sheets("Sheet1").Range("B1") = 4
Case 5
Sheets("Sheet1").Range("B1") = 5
Case 6
```

```
Sheets("Sheet1").Range("B1") = 6
Case 7
Sheets("Sheet1").Range("B1") = 7
Case 8
Sheets("Sheet1").Range("B1") = 8
Case 9
Sheets("Sheet1").Range("B1") = 9
Case 10
Sheets("Sheet1").Range("B1") = 10
End Select
UserForm2.Frame1.Visible = True
UserForm2.Frame2.Visible = True
veriler
UserForm2.TextBox1.Text = Sheets("Sheet1").Range("N8")
UserForm2.CommandButton2.Visible = True
UserForm2.CommandButton3.Visible = True
UserForm2.CommandButton6.Visible = True
Me.CommandButton1.SetFocus
End Sub
Private Sub CommandButton1_MouseMove(ByVal Button As Integer, ByVal Shift As Integer, ByVal X As Single,
ByVal Y As Single)
CommandButton1.BackColor = &H80000018
CommandButton1.ForeColor = &H400040
End Sub
Private Sub CommandButton2_MouseMove(ByVal Button As Integer, ByVal Shift As Integer, ByVal X As Single,
ByVal Y As Single)
CommandButton2.BackColor = &H80000018
CommandButton2.ForeColor = &H400040
End Sub
Private Sub CommandButton3_MouseMove(ByVal Button As Integer, ByVal Shift As Integer, ByVal X As Single,
ByVal Y As Single)
CommandButton3.BackColor = &H80000018
CommandButton3.ForeColor = &H400040
End Sub
Private Sub CommandButton4_MouseMove(ByVal Button As Integer, ByVal Shift As Integer, ByVal X As Single,
ByVal Y As Single)
CommandButton4.BackColor = &H80000018
CommandButton4.ForeColor = &H400040
End Sub
Private Sub CommandButton5_MouseMove(ByVal Button As Integer, ByVal Shift As Integer, ByVal X As Single,
ByVal Y As Single)
CommandButton5.BackColor = &H80000018
CommandButton5.ForeColor = &H400040
End Sub
Private Sub CommandButton6_MouseMove(ByVal Button As Integer, ByVal Shift As Integer, ByVal X As Single,
ByVal Y As Single)
CommandButton6.BackColor = &H80000018
CommandButton6.ForeColor = &H400040
End Sub
Private Sub CommandButton7_MouseMove(ByVal Button As Integer, ByVal Shift As Integer, ByVal X As Single,
ByVal Y As Single)
CommandButton7.BackColor = &H80000018
CommandButton7.ForeColor = &H400040
End Sub
Private Sub CommandButton8_MouseMove(ByVal Button As Integer, ByVal Shift As Integer, ByVal X As Single,
ByVal Y As Single)
CommandButton8.BackColor = &H80000018
CommandButton8.ForeColor = &H400040
End Sub
Private Sub UserForm_MouseMove(ByVal Button As Integer, ByVal Shift As Integer, ByVal X As Single, ByVal
Y As Single)
CommandButton6.BackColor = &H400040
CommandButton6.ForeColor = &H80000018
CommandButton2.BackColor = &H400040
CommandButton2.ForeColor = &H80000018
CommandButton3.BackColor = &H400040
CommandButton3.ForeColor = &H80000018
CommandButton4.BackColor = &H400040
CommandButton4.ForeColor = &H80000018
CommandButton5.BackColor = &H400040
CommandButton5.ForeColor = &H80000018
```

```
CommandButton1.BackColor = &H400040
CommandButton1.ForeColor = &H80000018
CommandButton7.BackColor = &H400040
CommandButton7.ForeColor = &H80000018
CommandButton8.BackColor = &H400040
CommandButton8.ForeColor = &H80000018
End Sub

Option Explicit
Private Sub Workbook_BeforeClose(Cancel As Boolean)
Dim i As Integer
On Error Resume Next
Application.CommandBars("Tools").Enabled = True

ActiveWindow.DisplayWorkbookTabs = True
For i = 1 To 12
On Error Resume Next
Application.OnKey "{F" & i & "}"
Application.OnKey "+{F" & i & "}"
Application.OnKey "^{F" & i & "}"
Application.OnKey "%{F" & i & "}"
Application.OnKey "+^{F" & i & "}"
Next i

End Sub

Private Sub Workbook_Open()

Dim i As Integer

On Error Resume Next

Application.ScreenUpdating = False


    Application.CommandBars("Tools").Enabled = False
    Application.WindowState = xlMaximized



Application.ScreenUpdating = True

Application.CommandBars("Tools").Enabled = False
ActiveWindow.DisplayWorkbookTabs = False

For i = 1 To 12
On Error Resume Next
Application.OnKey "{F" & i & "}", ""
Application.OnKey "+{F" & i & "}", ""
Application.OnKey "^{F" & i & "}", ""
Application.OnKey "%{F" & i & "}", ""
Application.OnKey "+^{F" & i & "}", ""
Next i

        UserForm1.Height = Application.Height
        UserForm1.Width = Application.Width

temizleme
UserForm1.Show

End Sub
Sub Macro1()
'
' Macro1 Macro
' Macro recorded 09.03.2010 by C_SENTURK
'

'
    Range("G4:N6").Select
    Selection.Copy
End Sub
```

```
Sub geridon()
UserForm2.Show
End Sub
Sub veriler()
UserForm2.Label2.Caption = Sheets("Sheet1").Range("G4")
UserForm2.Label3.Caption = Sheets("Sheet1").Range("H4")
UserForm2.Label4.Caption = Sheets("Sheet1").Range("I4")
UserForm2.Label5.Caption = Sheets("Sheet1").Range("J4")
UserForm2.Label6.Caption = Sheets("Sheet1").Range("K4")
UserForm2.Label7.Caption = Sheets("Sheet1").Range("L4")
UserForm2.Label8.Caption = Sheets("Sheet1").Range("M4")
UserForm2.Label9.Caption = Sheets("Sheet1").Range("N4")

UserForm2.Label10.Caption = Sheets("Sheet1").Range("G5")
UserForm2.Label11.Caption = Sheets("Sheet1").Range("H5")
UserForm2.Label12.Caption = Sheets("Sheet1").Range("I5")
UserForm2.Label13.Caption = Sheets("Sheet1").Range("J5")
UserForm2.Label14.Caption = Sheets("Sheet1").Range("K5")
UserForm2.Label15.Caption = Sheets("Sheet1").Range("L5")
UserForm2.Label16.Caption = Sheets("Sheet1").Range("M5")
UserForm2.Label17.Caption = Sheets("Sheet1").Range("N5")

UserForm2.Label18.Caption = Sheets("Sheet1").Range("G6")
UserForm2.Label19.Caption = Sheets("Sheet1").Range("H6")
UserForm2.Label20.Caption = Sheets("Sheet1").Range("I6")
UserForm2.Label21.Caption = Sheets("Sheet1").Range("J6")
UserForm2.Label22.Caption = Sheets("Sheet1").Range("K6")
UserForm2.Label23.Caption = Sheets("Sheet1").Range("L6")
UserForm2.Label24.Caption = Sheets("Sheet1").Range("M6")
UserForm2.Label25.Caption = Sheets("Sheet1").Range("N6")


UserForm2.Label26.Caption = Sheets("Sheet1").Range("G2")

If Sheets("Sheet1").Range("J9") = "" Then UserForm2.Label27.Caption = "" Else UserForm2.Label27.Caption
= Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("J9"), 2)
If Sheets("Sheet1").Range("K9") = "" Then UserForm2.Label28.Caption = "" Else UserForm2.Label28.Caption
= Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("K9"), 2)
If Sheets("Sheet1").Range("L9") = "" Then UserForm2.Label29.Caption = "" Else UserForm2.Label29.Caption
= Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("L9"), 2)

If Sheets("Sheet1").Range("J10") = "" Then UserForm2.Label30.Caption = "" Else UserForm2.Label30.Caption
= Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("J10"), 2)
If Sheets("Sheet1").Range("K10") = "" Then UserForm2.Label31.Caption = "" Else UserForm2.Label31.Caption
= Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("K10"), 2)
If Sheets("Sheet1").Range("L10") = "" Then UserForm2.Label32.Caption = "" Else UserForm2.Label32.Caption
= Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("L10"), 2)

If Sheets("Sheet1").Range("J11") = "" Then UserForm2.Label33.Caption = "" Else UserForm2.Label33.Caption
= Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("J11"), 2)
If Sheets("Sheet1").Range("K11") = "" Then UserForm2.Label34.Caption = "" Else UserForm2.Label34.Caption
= Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("K11"), 2)
If Sheets("Sheet1").Range("L11") = "" Then UserForm2.Label35.Caption = "" Else UserForm2.Label35.Caption
= Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("L11"), 2)



UserForm2.Label37.Caption = ""
UserForm2.Label42.Caption = ""
UserForm2.Label47.Caption = ""
UserForm2.Label52.Caption = ""

UserForm2.Label38.Caption = ""
UserForm2.Label43.Caption = ""
UserForm2.Label48.Caption = ""
UserForm2.Label53.Caption = ""

UserForm2.Label39.Caption = ""
UserForm2.Label44.Caption = ""
UserForm2.Label49.Caption = ""
UserForm2.Label54.Caption = ""
```

```
UserForm2.Label40.Caption = ""
UserForm2.Label45.Caption = ""
UserForm2.Label50.Caption = ""
UserForm2.Label55.Caption = ""

UserForm2.Label41.Caption = ""
UserForm2.Label46.Caption = ""
UserForm2.Label51.Caption = ""
UserForm2.Label56.Caption = ""


On Error Resume Next

UserForm2.Label37.Caption = Sheets("Sheet1").Range("AH4")
UserForm2.Label42.Caption = Sheets("Sheet1").Range("AH5")
UserForm2.Label47.Caption = Sheets("Sheet1").Range("AH6")
UserForm2.Label52.Caption = Sheets("Sheet1").Range("AH7")

UserForm2.Label38.Caption = Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("AI4"), 0) & "
" & Sheets("Sheet1").Range("AJ4")
UserForm2.Label43.Caption = Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("AI5"), 0) & "
" & Sheets("Sheet1").Range("AJ5")
UserForm2.Label48.Caption = Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("AI6"), 0) & "
" & Sheets("Sheet1").Range("AJ6")
UserForm2.Label53.Caption = Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("AI7"), 0) & "
" & Sheets("Sheet1").Range("AJ7")

UserForm2.Label39.Caption = Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("AK4"), 0) & "
" & Sheets("Sheet1").Range("AL4")
UserForm2.Label44.Caption = Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("AK5"), 0) & "
" & Sheets("Sheet1").Range("AL5")
UserForm2.Label49.Caption = Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("AK6"), 0) & "
" & Sheets("Sheet1").Range("AL6")
UserForm2.Label54.Caption = Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("AK7"), 0) & "
" & Sheets("Sheet1").Range("AL7")

UserForm2.Label40.Caption = Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("AM4"), 0) & "
" & Sheets("Sheet1").Range("AN4")
UserForm2.Label45.Caption = Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("AM5"), 0) & "
" & Sheets("Sheet1").Range("AN5")
UserForm2.Label50.Caption = Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("AM6"), 0) & "
" & Sheets("Sheet1").Range("AN6")
UserForm2.Label55.Caption = Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("AM7"), 0) & "
" & Sheets("Sheet1").Range("AN7")

UserForm2.Label41.Caption = Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("AO4"), 1)
UserForm2.Label46.Caption = Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("AO5"), 1)
UserForm2.Label51.Caption = Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("AO6"), 1)
UserForm2.Label56.Caption = Application.WorksheetFunction.RoundUp(Sheets("Sheet1").Range("AO7"), 1)


UserForm2.TextBox6.Text = Sheets("Sheet1").Range("Q50")
UserForm2.TextBox7.Text = Sheets("Sheet1").Range("AJ41")


End Sub
Sub temizleme()

Range("B1,R4:S7").ClearContents

End Sub


Sub yeniaygirisi()
    Dim Msg, Style, Title, Help, Ctxt, Response, MyString
Msg = "Güncellemek istediğinizden emin misiniz ? Güncellemede ilk ay verileri silinecektir."   ' Define
message.
Style = vbYesNo + vbCritical + vbDefaultButton2
Title = "Güncellemeden Önce Dikkat"
Help = "DEMO.HLP"
```

```
Ctxt = 1000
Response = MsgBox(Msg, Style, Title, Help, Ctxt)
If Response = vbYes Then GoTo 10
    MyString = "No"
    GoTo 20
10  Application.ScreenUpdating = False
    MyString = "Yes"
    Columns("B:B").Select
    Selection.Delete Shift:=xlToLeft
    Columns("M:M").Select
    Selection.Insert Shift:=xlToRight
    Range("B2:L2").Select
    Selection.AutoFill Destination:=Range("B2:M2"), Type:=xlFillDefault
    Range("B2:M2").Select
    Columns("N:N").Select
    Selection.Replace What:="L", Replacement:="M", LookAt:=xlPart, _
        SearchOrder:=xlByRows, MatchCase:=False, SearchFormat:=False, _
        ReplaceFormat:=False
    Range("M3").Select
    Application.ScreenUpdating = True
20  End Sub

Sub RESET_GN()
    Application.ScreenUpdating = False
    aaa
    Columns("O:O").Select
    Selection.Replace What:="/*", Replacement:="/365", LookAt:=xlPart, _
        SearchOrder:=xlByRows, MatchCase:=False
    Range("a1").Select
    Application.ScreenUpdating = True
End Sub
Sub alma_hepsini()
    Application.ScreenUpdating = False
    aaa
    Columns("O:O").Select
    Selection.Replace What:="/*", Replacement:="/1000000000000", LookAt:=xlPart, _
        SearchOrder:=xlByRows, MatchCase:=False
    Range("a1").Select
    Application.ScreenUpdating = True
End Sub
Sub RESET_GN_365farklihepsi()
    UserForm2.Show
    If (Sheets("Sheet1").Range("A65531").Value = 1) Then Exit Sub
    ccgun = Sheets("Sheet1").Range("A65532").Value

    Columns("O:O").Select
    ddd = "/" & ccgun
    Selection.Replace What:="/*", Replacement:=ddd, LookAt:=xlPart, _
        SearchOrder:=xlByRows, MatchCase:=False
    Range("a1").Select
End Sub
```

APPENDIX A.3 : Article

The effects of the use of single task-oriented maintenance concept and more accurate letter check alternatives on the reduction of scheduled maintenance downtime of aircraft

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***Abstract*— This paper provides a connection between an industrial problem of the maximization of aircraft utilization and maintenance cost savings. A more flexible structure is proposed to perform the maintenance not only during scheduled periodic checks but also whenever the aircraft is on the ground for any reason. The proposed method is the use of the single task-oriented maintenance concept. The results obtained from a case study performed in an airline company by using classical maintenance approach - rigid letter check system and the single task-oriented maintenance concept are compared to emphasize the benefits of the proposed concept. To help to reduce scheduled maintenance downtime of aircraft, a software has been developed to support the single-task oriented maintenance concept by calculating more accurate and appropriate letter check alternatives for the related maintenance task.**

Keywords - Maintenance task; letter check; Maintenance program; single task-oriented maintenance concept; aircraft utilization.

Introduction

Maximization of aircraft utilization is one of the most important issues for airline companies. By accumulating more flight hours in a certain period of time, direct operating costs per flight hour can be reduced. Achieving more flight hours depends on aircraft availability for flight. One of the methods for increasing aircraft availability for flight is to reduce scheduled maintenance downtime (ground time spent for maintenance) of the aircraft. Taking into account that an aircraft is designed to be flown for most of its economic life, every ground time may be considered as a loss for an airline company.

In a traditional airline set-up, the maintenance department selects its preferred maintenance program and advises the operations and scheduling departments that it requires aircraft for maintenance for a given number of days for A checks, C checks and D checks [1]. Such maintenance is typically accomplished at one location usually called "main base" and the primary intention of such maintenance is to ensure that aircraft remains airworthy and on schedule. As such, line maintenance rarely becomes involved in scheduled maintenance other than performing an overnight check or something else relatively minor in nature. This is a rigid system whereby aircraft is either 'in maintenance' or 'in operation'. It is also very wasteful: "The industry typically measures aircraft maintenance downtime in terms of one day or longer. Yet airlines route airplanes into six to eight hour overnight visits, or park them for eight or nine hours at the end of hub and spoke systems due to market conditions, crew rest or airport curfews. Therefore in order to prevent losses and to reduce ground time spent for maintenance during the long periodic checks, a more flexible structure is needed to perform the maintenance not only during periodic checks but also whenever the aircraft is on the ground for any reason. The philosophy is based on the idea to use any ground time for maintenance purposes.

Single task-oriented maintenance concept

With the introduction of advanced maintenance program management systems and supporting planning, communication and logistics systems, all waiting time on ground becomes ‘maintenance opportunities’. In other words, when an aircraft is not being operated, wherever it may be, maintenance may be performed.

In order to accomplish maintenance in the manner described above, it is necessary to operate a flexible maintenance program rather than one dominated by rigid letter checks (A, C, D etc.).

With the advent of MSG-3 maintenance programs, maintenance tasks are controlled individually, which makes it very much easier for airlines to tailor their maintenance to suit their operational needs.

Not only can this reduce the maintenance downtime requirement but, according to Boeing, the adoption of advanced program management techniques can reduce maintenance costs by as much as 15 per cent. In Figure 1.1 various maintenance program options have been demonstrated. In Alternative 1, a traditional block C check and five year check is shown [1].

Over a five-year period it is realized that 29 days of maintenance ground time are consumed. In Alternative 2 a split A and C check concept is portrayed and it too requires 29 days maintenance ground time over a five-year period. In Alternative 3 a heavy C check concept is identified and it needs 36 days maintenance downtime in a five-year period. Finally, in Alternative 4 a single task-oriented maintenance concept is portrayed; this consumes 14 days maintenance downtime over a five-year period. If one assumes that the $50,000 per day figure is applicable to the A320, this equates to a saving which can be as much as $1.1 million over a five year period. Or putting it another way, for a fleet of 30 aircraft, the savings add up to the equivalent of one new aircraft purchase every five years.

One of the possible criticisms of Alternative 4 is that it is all well and good to implement such a maintenance program when the aircraft is new, but as time goes on non-routine maintenance tends to increase and so it becomes more difficult for such a program to work in practice. But given the experience accumulated so far, it should be possible to extend such a maintenance program into a second maintenance cycle.

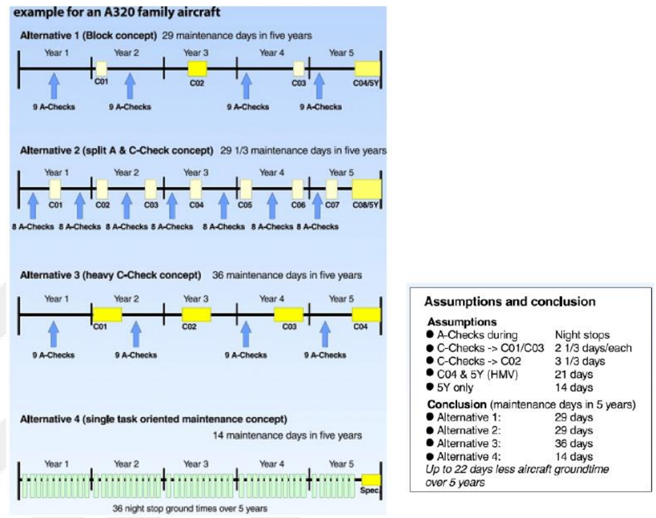


Figure 1.1 Comparison of four alternatives [1]

In order to apply the single task-oriented maintenance concept, each maintenance task in the maintenance program has to be studied one by one about the special characteristics of the task. Taking into account that there are too many maintenance tasks in a maintenance program, the dimension of this study may be more understandable. Nowadays a standard maintenance program includes at least more than two thousands maintenance tasks which are effective for the fleet during its whole economic life. As an example in the case study performed in this article, Airbus A340 fleet has been choosen and in the maintenance program of this aircraft type all 3800 maintenance tasks have been examined one by one. Before to start the process of single task-oriented maintenance concept and to evaluate each single task according to the logic diagram of this concept given in Figure 1.2, each maintenance task should be examined according to the characteristics given below:

•Maintenance task source (MRBR, MPD, SB, airline company etc...): It is very important to know where this maintenance task is originated from especially during the decision process about the accomplishment or the postponement of the task.

•Maintenance task type (GVI, DVI, NDT, OPC, FUC etc...): Each maintenance task in the maintenance program has a special task type related to the job required in the content of the task. As an example for NDT and Borescope related tasks, specialists about this inspection have to be dedicated. Taking into account that there are many different task types, this makes more sense about the complexity of the problem.

•Maintenance task man-hour and the number of personnel required: In the logic diagram of single task-oriented concept, the man hour of the task is one of the most important parameters which defines the possibility of the accomplishment of the task out of main base (in any station) and/or during the overnight check (night stop). According to the number of personnel to do the job and the man hour required, the decicion maker may schedule this maintenance task in or out of main base and/or during the overnight check.

•Maintenance task skill code (mechanic, avionic etc...) and licenced personnel requirement for this fleet.

•Relationship of the maintenance task with other tasks (application before, after or together status): For the decision maker, it is very important to know for each job card the relationship status with other job cards. Some job cards should be accomplished together, some of them should be performed before any specific job cards and some of them should be performed after some job cards etc...

•Planning requirements of task card: All the planning requirements given in Fig. 1.3 for the accomplishment of the maintenance task should be taken into account.

•Reference status of the maintenance task

•Materials and tools required for the maintenance task: Materials and tools required for the maintenance task are very important for the decision maker during the scheduling of the maintenance task. Materials and tools should be ready and at required quantity in the location of maintenance and at any time needed.

After each maintenance task has been studied one by one according to its special characteristics stated above, they are inserted in an Excel sheet one by one by calculating its accomplishment day taking into account the utilization of the aircraft and the interval of the maintenance task. In this step, more accurate and appropriate interval can be calculated by the software developped for his purpose which is explained in the second section of this article. Then according to the logic diagram given in Figure 1.2, the decision maker schedules each maintenance task taking into account the characteristics of the maintenance task. In this step the experience and the knowledge of the decision maker is very important in this methodology because he has to know every characteristic of the maintenance task, possibility to accomplish out of main base in terms of materials, tools, licenced technician, man hour requirement, acces panel accessibility etc...

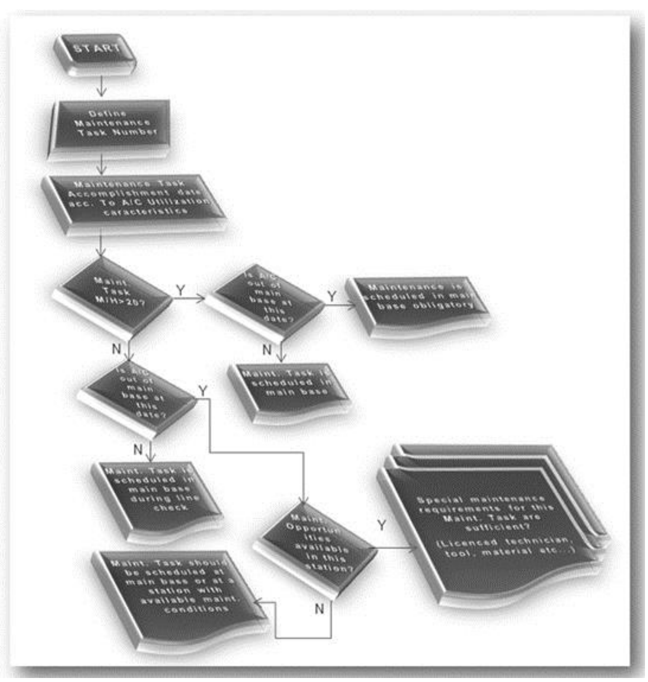
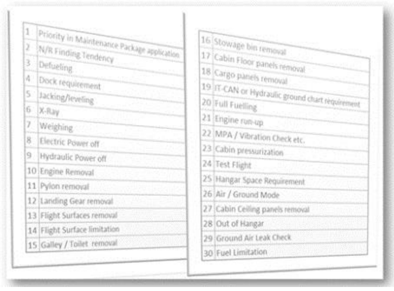


Figure 1.2 Logic Diagram of the Single Task-Oriented Maintenance Concept



1	Priority in Maintenance Package application
2	N/R Finding Tendency
3	Defueling
4	Dock requirement
5	Jacking/leveling
6	X-Ray
7	Weighing
8	Electric Power off
9	Hydraulic Power off
10	Engine Removal
11	Pylon removal
12	Landing Gear removal
13	Flight Surfaces removal
14	Flight Surface limitation
15	Galley / Toilet removal

16	Stowage bin removal
17	Cabin Floor panels removal
18	Cargo panels removal
19	IT-CAN or Hydraulic ground chart requirement
20	Full Fuelling
21	Engine run-up
22	MPA / Vibration Check etc.
23	Cabin pressurization
24	Test Flight
25	Hangar Space Requirement
26	Air / Ground Mode
27	Cabin Ceiling panels removal
28	Out of Hangar
29	Ground Air Leak Check
30	Fuel Limitation

Figure 1.3 Maintenance Planning Requirements

Case study performed in an Airline Company

In a case study performed in an airline company for the fleet of Airbus A340 A/C, the results for both cases have been obtained. The first case is an example of the rigid letter check system and the second case is an example of the single task- oriented maintenance concept which is proposed in this article.

In the first case the daily distribution of maintenance tasks given in the original manufacturer maintenance program over 10 years is given in Fig. 1.4.

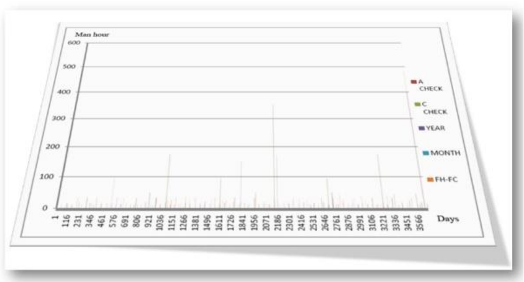


Figure 1.4 Daily distribution of maintenance tasks given in the original maintenance program of the aircraft manufacturer over 10 years

As shown in Fig. 1.4, aircraft has to be kept in the hangar for maintenance purposes for different duration. Especially heavy maintenance work load seems to be dominant. If we observe the maintenance program of the airline company that we studied in this case study, we have similar daily distribution of maintenance tasks over a duration of 10 years (Fig. 1.5). In this step, we have to explain that this figure shows a traditional airline which performs maintenance during the predetermined letter checks (rigid letter check system).

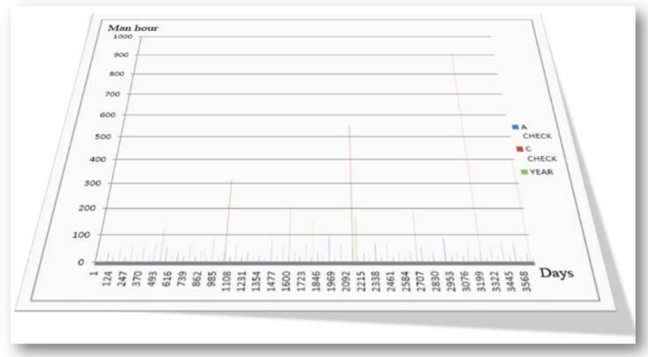


Figure 1.5 Daily distribution of maintenance tasks given in the maintenance program of the airline company (in case study) over 10 years

If we compare these two figures, we can see that in the second figure, the airline company that we study in this case study has letter checks such as “A” check, “C” check and “S” check and the workload of maintenance becomes higher only during these checks. In other days since there is no letter check, there is no maintenance action and the aircraft is scheduled for operation. However the duration of maintenance letter checks is high since the maintenance content is gathered only during the letter checks and not distributed in other days. This is an example of a traditional airline maintenance structure (rigid letter check system). The maintenance tasks subject to flight hour, flight cycle and multiple month intervals in Fig. 1.4 are converted to appropriate letter checks in the airline company maintenance program in Fig. 1.5. For this reason the distribution in Fig. 1.4 is rather different than the distribution in Fig. 1.5 since it contains original maintenance task intervals and not the converted letter checks ones.

“A” Check Study

For the case study performed in an airline company for the fleet of Airbus A340 aircraft, the following assumptions are made for “A” check:

Interval for “A” check : 600 FH
Daily utilization of the fleet : 12 FH/day
49.5 days/A check - 74 A checks / 10 years

If the A/C is on on ground for a complete day, 85 man hours workload is scheduled,
During the overnight or line check, 20 man hours workload is scheduled.
Leasing cost: 10.000 US$ per day, commercial loss due to not operate the aircraft: 70.000 US$ per day. Daily total loss: 60.000 US$.

Real case in the airline company for "A" check

According to the assumptions above, the aircraft should be kept on the ground for 45 days and additionally 32 overnight checks are also needed to accomplish all maintenance tasks related "A" check content (Fig. 1.8). This system is a rigid letter check system used by traditional airline companies and the distribution obtained for "A" check over 10 years is given in Fig. 1.6.

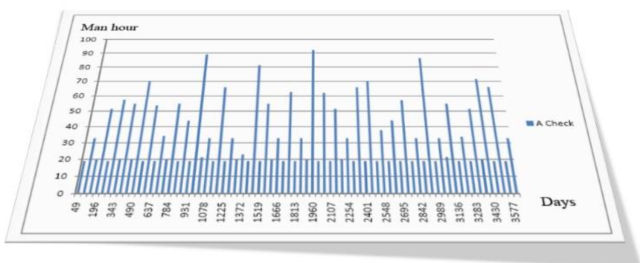


Figure 1.6 "A" check distribution over 10 years for the airline company

Results obtained by using "Single Task-Oriented Maintenance Concept" for "A" check

By making the necessary calculations and taking into account all special characteristics of all maintenance tasks in this scope and by using the logic diagram given in Fig. 1.2, the following results are obtained (Fig. 1.8). In this approach the single task-oriented maintenance concept has been used. Each maintenance task has been evaluated one by one according to its special characteristics and put in an appropriate overnight check and the distribution in Fig. 1.7 is obtained. Note that there isn't any maintenance task more than 20 man hours in this scope. All overnight checks have been arranged not to exceed 20 man hours. As a result 149 night stop over 10 years are sufficient in this concept without doing any extra maintenance letter check.

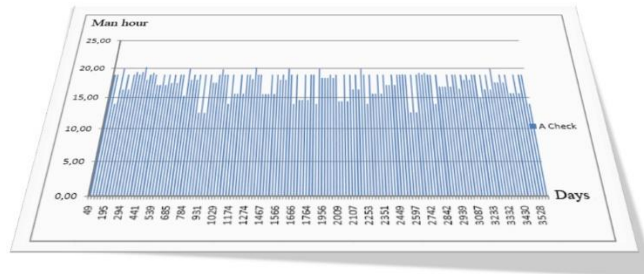


Figure 1.7 "A" check distribution over 10 years according to the Single Task-Oriented Maintenance Concept

If we compare the results obtained for "A" check in both methods (Rigid letter check system of a traditional airline company and Single Task-oriented maintenance concept), we have 45 days saving and 2.700.000 US$ cost saving for 45 days (Fig. 1.8).

"A" Check	Ground downtime (days) for maintenance	Night stops (Number of checks performed during overnight maintenance)
Rigid system	45	32
Single Task-Oriented Maint. Concept	0	149
Cost Saving (US$)	2.700.000	

Figure 1.8 Comparison of Rigid letter check system and Single Task-oriented maintenance concept for "A" check over 10 years

"C" Check Study

For the case study performed, the following assumptions are made for "C" check:

Interval for "C" check : 18 Months
Daily utilization of the fleet : 12 FH/day
6C check is accomplished with 10 years maintenance tasks.
If the A/C is on ground for a complete day, maximum 85 man hours workload is scheduled per day.

Real case in the airline company for "C" check

According to the assumptions above, the aircraft should be kept on the ground for 30 days over 10 years (Fig. 1.11).

The distribution obtained for "C" check over 10 years is given in (Fig. 1.9) for the rigid letter check system applied in the airline company which is observed in this case study.

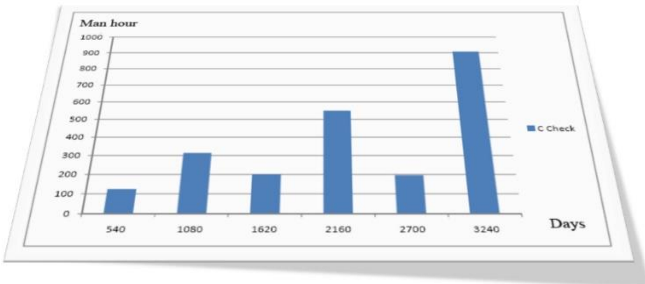


Figure 1.9 "C" check distribution over 10 years for the airline company

Results obtained by using "Single Task-Oriented Maintenance Concept" for "C" check

By making the necessary calculations and taking into account all special characteristics of all maintenance tasks in the scope of "C" check and by using the logic diagram given in Fig. 1.2, the distribution in Fig. 1.10 is obtained. In this approach the single task-oriented maintenance concept has been used. Each maintenance task has been evaluated one by one according to its special characteristics and put in an appropriate overnight check. All overnight checks have been arranged not to exceed 20 man hours. For the maintenance task with workload more than 20 man hours per day, the aircraft is kept on the ground during the day. Maximum 85 man-hour workload can be scheduled daily.

As a result 10 days and 79 night stop over 10 years are sufficient in this concept (Fig. 1.11).

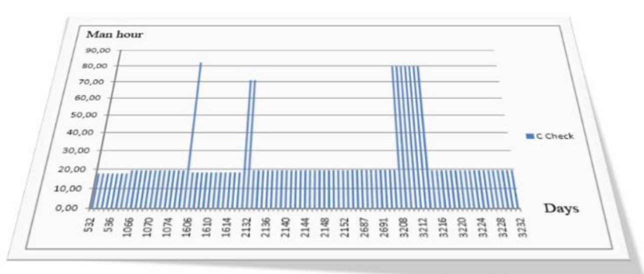


Figure 1.10 "C" check distribution over 10 years by using the Single Task-Oriented Maintenance Concept

If we compare the results obtained for "C" check in both methods (Rigid letter check system of a traditional airline company and Single Task-oriented maintenance concept), we have 20 days saving and 1.200.000 US$ cost saving for 20 days (Fig. 1.11).

"C" Check	Ground downtime (days) for maintenance	Night stops (Number of checks performed during overnight maintenance)
Rigid system	30	0
Single Task-Oriented Maint. Concept	10	79
Cost Saving (US$)	1.200.000	

Figure 1.11 Comparison of Rigid letter check system and Single Task-oriented maintenance concept for "C" check over 10 years

"S" Check Study

For the case study performed, the following assumptions are made for "S" check:

Interval for "S" check : 5 Years (Structural check)
Daily utilization of the fleet : 12 FH/day

Real case in the airline company for "S" check

According to the assumptions above, the aircraft should be kept on the ground for 12 days over 10 years and 2 additional night stops are needed (Fig. 1.14).

The distribution obtained for "S" check over 10 years is given in (Fig. 1.12) for the rigid letter check system applied in the airline company which is observed in this case study.

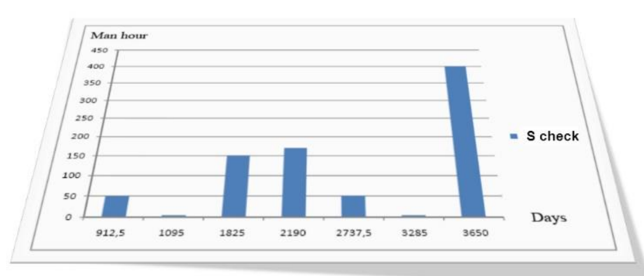


Figure 1.12 "S" check distribution over 10 years for the airline company

Results obtained by using "Single Task-Oriented Maintenance Concept" for "S" check

By making the necessary calculations and taking into account all special characteristics of all maintenance tasks in the scope of "S" check and by using the logic diagram given in Fig. 1.2, the distribution in Fig. 1.13 is obtained. In this approach the single task-oriented maintenance concept has been used.

Each maintenance task has been evaluated one by one according to its special characteristics and put in an appropriate overnight check. All overnight checks have been arranged not to exceed 20 man hours.

For the maintenance task with workload more than 20 man hours per day, the aircraft is kept on the ground during the day. Maximum 85 man-hour workload can be scheduled daily. As a result 5 days and 35 night stop over 10 years are sufficient in this concept (Fig. 1.14).

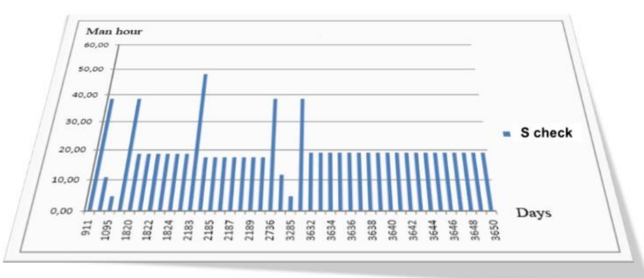


Figure 1.13 "S" check distribution over 10 years by using the Single Task-Oriented Maintenance Concept

If we compare the results obtained for "S" check in both methods (Rigid letter check system of a traditional airline company and Single Task-oriented maintenance concept), we have 7 days saving and 420.000 US$ cost saving for 7 days (Fig. 1.14).

"S" Check	Ground downtime (days) for maintenance	Night stops (Number of checks performed during overnight maintenance)
Rigid system	12	2
Single Task-Oriented Maint. Concept	5	35
Cost Saving (US$)	420.000	

Figure 1.14 Comparison of Rigid letter check system and Single Task-oriented maintenance concept for "S" check over 10 years

Conclusions and advantages of the Single Task-Oriented Maintenance Concept in the case study

The results obtained from this case study performed in A340 fleet are demonstrated in Fig. 1.15. In this figure, the results of the case study performed in A340 A/C in an airline company by using classical maintenance approach - rigid letter check system and those by using the single task-oriented maintenance concept (approach proposed in this article) are given respectively.

Maintenance Type	Ground downtime (days) for maintenance	Night stops (Number of checks performed during overnight maintenance)
"A" Check	45	32
"C" Check	30	0
"S" Check	12	2
TOTAL	**87**	**34**

Rigid letter check system

Maintenance Type	Ground downtime (days) for maintenance	Night stops (Number of checks performed during overnight maintenance)
"A" Check	0	149
"C" Check	10	79
"S" Check	5	35
TOTAL	**15**	**263**

Single task-oriented maintenance concept

Figure 1.15 Comparison of two approaches: "Rigid letter check system" versus "the Single Task-Oriented Maintenance Concept"

In the case study, it is possible to see the benefits of the single task oriented maintenance concept. In a period of 10 years, an aircraft is kept on the ground for maintenance about 87 days however in the method proposed in this thesis the same aircraft is kept only for 15 days on the ground for maintenance in a period of 10 years (Fig. 1.16 and Fig. 1.17). This can be achieved only by utilizing every moment as a maintenance opportunity when the aircraft is on the ground for any reason. We have 72 days savings over ten years. Commercial cost saving is 4.320.000 US$ for 72 days. (Fig. 1.16)

"A" + "C" + "S" Checks	Ground downtime (days) for maintenance	Night stops (Number of checks performed during overnight maintenance)
Rigid system	87	34
Single Task-Oriented Maint. Concept	15	263
Total	72 days saving	229 additionnal overnight checks
Cost Saving (US$)	4.320.000	

Figure 1.16 Comparison of Rigid letter check system and Single Task-oriented

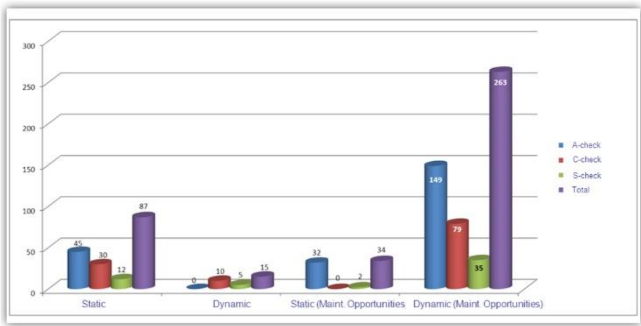


Figure 1.17 Comparison of two methods graphically

Calculation of more accurate and appropriate letter check alternatives according to real-time utilization of the aircraft fleet

To help to reduce scheduled maintenance downtime of aircraft, a software has been developed to support the single-task oriented maintenance concept by calculating more accurate and appropriate letter check alternatives for the related maintenance task. With this software solution it is intended to aid airline companies in calculating the most appropriate letter check alternatives for maintenance tasks given in maintenance programs by taking into account the real-time utilization of the aircraft fleet.

Airline companies are faced with various optimization problems during the planning of maintenance tasks given in maintenance programs. Taking into account that there are too many maintenance tasks in the maintenance program with different interval values and different interval types, the difficulty of the problem may be more understandable. As an example in the maintenance program of a wide body aircraft type such as Airbus A-340 fleet, there are more than three thousands maintenance tasks with different interval values. Moreover the usage parameters for these maintenance tasks are different: some of them are given as operational units such as FH (Flight Hours), FC (Flight Cycle) etc., some of them are given as calendar units such as HR (hours), DY (days), MO (Months), YE (Years) etc... So the planning department of the airline company is faced with serious problem to schedule these maintenance tasks for the appropriate letter check and the problem becomes much more difficult if several aircraft with different utilization are taken into account.

Because of safety issues and in order to meet the requirements requested by civil aviation authorities, the airline companies have to adopt maintenance policies, which call the aircraft at the end of certain utilization (flight hour, flight cycle or calendar time) to a maintenance base for the routine checks. An aircraft cannot fly once it reaches the legal flight hour limit because of the airworthiness issues. It has to undergo a maintenance check before the next flight. [2] [3] [4].

In most airlines, maintenance checks are performed in predetermined intervals and maintenance tasks given in maintenance program are performed during these maintenance checks. But this method would remain insufficient to prevent earlier accomplishment of maintenance tasks if the airline company does not take into account the real-time utilization values of each aircraft and convert the intervals of maintenance tasks with different usage parameters into letter checks just by making an average utilization assumption for the whole fleet.

The approach to consider some average value for the complete fleet causes the accomplishment of some maintenance tasks earlier for some aircraft or later for some of them.

In a traditional airline application, the real-time utilization values of aircraft fleet are not taken into account and in order to calculate the most appropriate letter check, some estimated utilization values are included into calculation. As an example, daily utilization of a fleet is considered such values as FH/DAY=10.0 and FH/FC=2.0. These are the values accepted for all the fleet. This means that every aircraft in this fleet is considered to fly 10 hours a day and 2 hours per cycle (one takeoff and one landing is considered as one flight cycle) and all aircraft are considered to accomplish same values of flight hour and flight cycle. But in real life this approach is very theoretical and these values may differ from one aircraft to another. Moreover they are highly different in narrow body aircraft fleet and wide body aircraft fleet. (Fig. 1.18) [5] ... [19]

Utilization parameters of the selected fleet			
Ratio	Minimum	Maximum	Average
FH/FC ratio	1,33	2,62	1,98
FH/DAY ratio	7,47	12,07	10,04
FC/DAY ratio	4,21	6,27	5,07

Utilization parameters of the selected fleet			
Ratio	Minimum	Maximum	Average
FH/FC ratio	3,94	8,01	6,39
FH/DAY ratio	9,06	12,54	11,55
FC/DAY ratio	1,47	2,44	1,81

Figure 1.18 Utilization values in narrow body aircraft fleet (left) and wide body aircraft fleet (right) in a company.

Solution

To overcome this discrepancy and to consider the real-time utilization values of each aircraft, a software has been developed. This software allows the users to calculate more accurate and appropriate letter check alternatives for each maintenance task given in the maintenance program according to real-time utilization accumulated by each aircraft. One of the advantages of the software is that it has the flexibility to make the calculations for every single aircraft and for the different fleets in the airline company.

Software

The software algorithm is given in Fig.1.19. At the beginning of the set-up process of the software, all the fleets in the airline company should be determined and inserted in the software. All aircraft in each fleet and their monthly utilization values should be included in the software consequently. (Fig. 1.20) Besides, letter check types and interval values, maximum task interval, maximum check number and other data for every letter check of all models of the airline company should be determined and introduced in the software.

For each fleet in the airline company, similar database for utilization values such as given in Fig. 1.20 should be set-up. As an example there will be 10 different database sheets for an airline company which has ten different model types. The dimension of the database matrix should be 10x25x12x2 if we consider each ten fleet has 25 aircraft and there will be data in terms of FH and FC accumulated during the last 12 months for each aircraft. The number of data that should be introduced in the software may be given as follows (1):

$$n = 12.2.\sum_{i=1}^{k} F_i \qquad (1)$$

Where n is the number of the total data, 12 is the number of last twelve months, 2 is the number for FH and FC, k is the number of fleet in the airline company, F_i is the number of total aircraft in the i^{th} fleet.

In the software, the user can select the aircraft fleet for which the calculations would be performed. After selected the target fleet from the selection menu, all aircraft type specifications and utilization parameters of the selected fleet appear on the screen. (Fig. 1.21)

The utilization parameters of the selected fleet are brought automatically on the screen after the calculation (the values are for the overall fleet calculated from all aircraft in this fleet) on the other hand aircraft type specifications such as maintenance check type interval value, maximum task interval and maximum check number for a specific check are brought automatically on the screen from the database. This kind of data is introduced in the software during the set-up process of the software.

After this information is given by the software, the user should input the task intervals for the maintenance task under interrogation. The software has the ability to accept 4 different interval unit types. (Fig. 1.22)

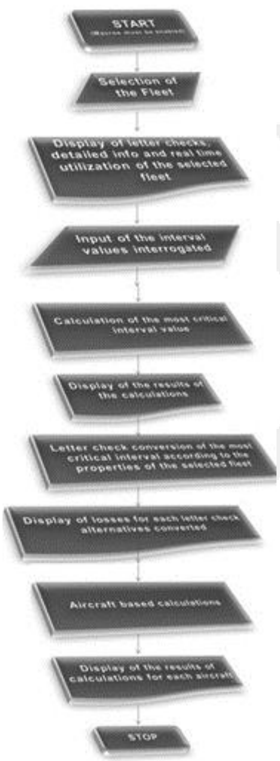


Figure 1.19 Software Algorithm

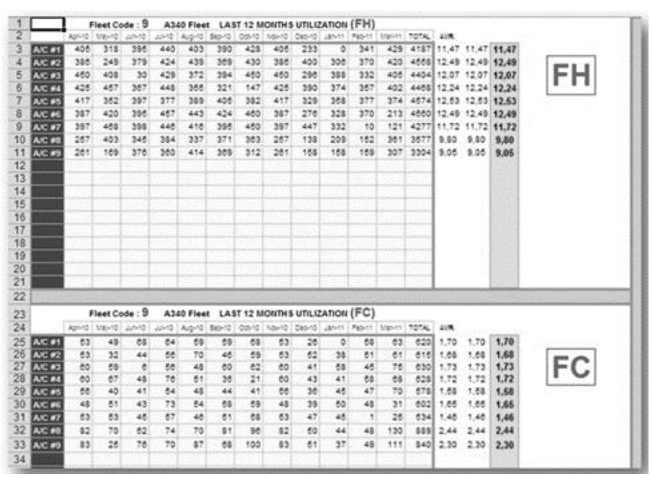


Figure 1.20 Aircraft monthly utilization values for each aircraft

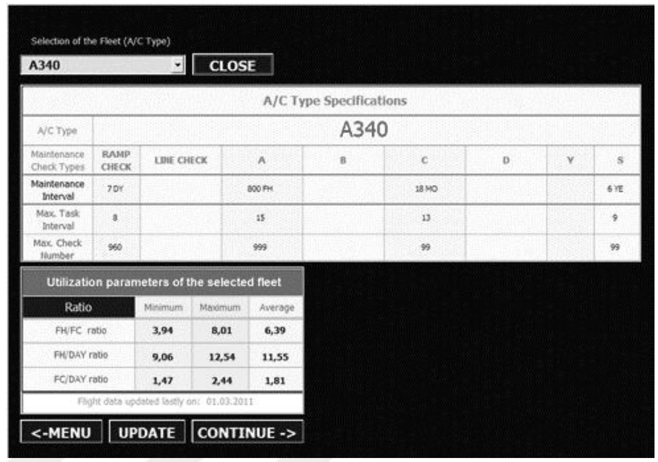


Figure 1.21 A/C Type Specifications & Utilization parameters of the selected fleet

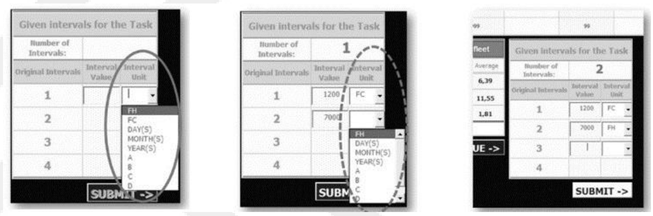


Figure 1.22 A/C Task Intervals

The software does not allow the user to input the same interval unit twice and it eliminates the related interval unit automatically once it has been selected by the user. For example, if the user selects the “FC” as the first interval unit, for the second interval unit “FC” could not been selected again. The software automatically eliminates the interval unit selected by the user. Once the user inputs the interval values and units, the software automatically calculates the most critical interval value between the inputs taking into account the average fleet utilization (Fig. 1.23).

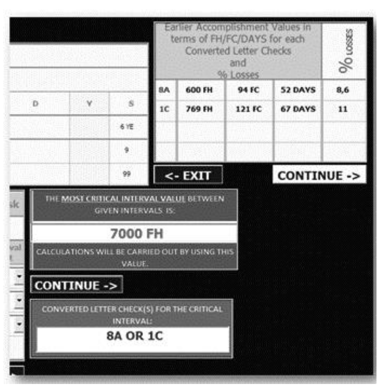


Figure 1.23 The most critical interval & coverted letter check alternatives

The most critical interval value calculated by the software according to the average fleet utilization is converted to letter check alternatives by estimating losses for each letter check alternatives. The user should decide the most appropriate letter check between the ones proposed by the software taking into account the losses and the possibility of the accomplishment of this maintenance task during the checks proposed by the software. This step of the software is sufficient for a rough conversion for the complete fleet. But the most powerful part of the software is that it allows the users to make more accurate calculations in terms of each aircraft. If the user is not satisfied with the converted letter check alternatives calculated for all fleet, the software allows the user to continue with the more accurate step performed in terms of each aircraft. (Fig.1.24)

Figure 1.24 The most critical interval & coverted letter check alternatives for each aircraft

The utilization values of each aircraft may differ one from each other and the converted letter check alternatives also may be different for each aircraft consequently. As an example the utilization values of the aircraft in Fig.1.24 are very close to the fleet average in Fig.21 so the converted letter check alternatives are the same for both the aircraft and the whole fleet. The software allows the user to examine all aircraft one by one and the solutions obtained for all aircraft may be in a very large scale. (Fig. 1.25)

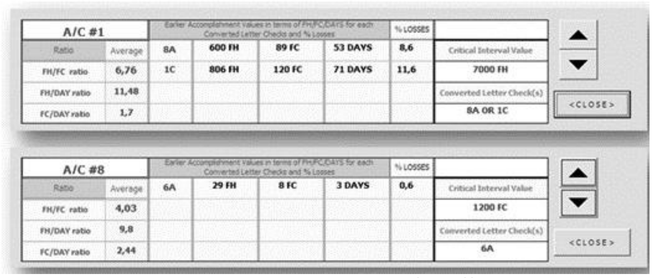


Figure 1.25 Converted letter check Alternatives for different A/C

Another strong part of the software is that it allows the user to change the fleet in every step of the calculation process. As an example if the user selects a narrow body fleet such as B737 with more FC utilization per day instead of a wide body aircraft fleet in Fig. 1.21 this time FC based interval becomes more critical according to utilization values and converted letter check alternatives are completely different from the previous fleet.

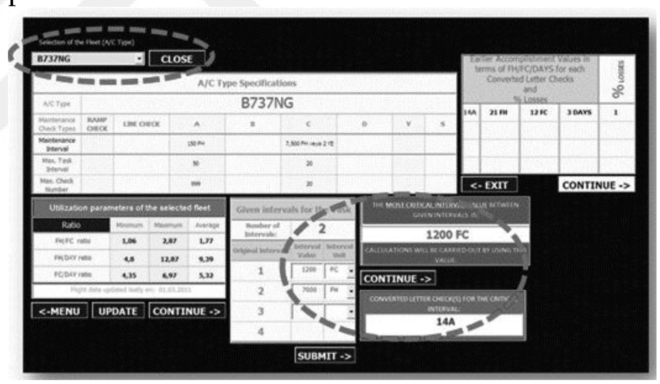


Figure 1.26 Change of the fleet

The results obtained in case of the fleet change for the same inputs may be completely different from the previous fleet outputs. (Fig. 1.26) For example the outputs for the same inputs (task intervals) are different for different fleets (compare the outputs in Fig. 1.23 and in Fig. 1.26.

For the whole fleet, the task interval values have been converted to”14A” check (average of 66 A/C in this example situation), however the same values have been converted to “15A” for the 1st A/C and “11A” for the 9th A/C and so on. (Fig. 1.27)

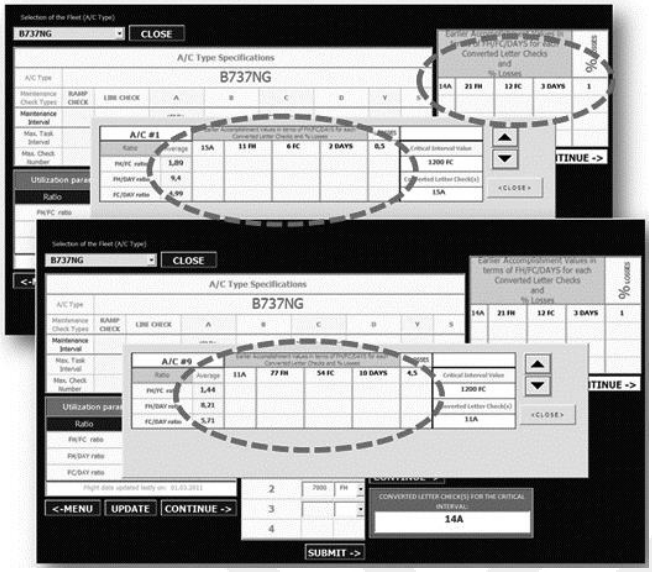


Figure 1.27 Comparison of different A/C with different utilization

Conclusion

The software is very strong to calculate the most appropriate and accurate letter check alternatives for a complete fleet and also for every single A/C in the fleet. It has the flexibility to make the calculations not only for one fleet but also for different fleets in the airline company. Another strong part of the software is that it takes into account the real-time utilization values of each aircraft in the fleet. If the airline company does not take into account the real-time utilization values of each aircraft and converts the intervals of maintenance tasks with different usage parameters into letter checks just by making an average utilization assumption for the whole fleet, this will cause losses (earlier or late accomplishment of maintenance tasks for some aircraft). In other words, the approach to consider some average value for the complete fleet causes the accomplishment of some maintenance tasks earlier for some aircraft or later for some of them.

If we compare two situations below, the advantage of the software may be more understandable:

Assumptions: Daily utilization of the fleet is supposed as 12 FH/day and 2 FC/day

Maintenance task interval to be converted to letter check is 1200 FC.
A check for the A/C fleet is 800 FH, it means that all the A/C in the fleet is taken to hangar for maintenance check after the aircraft accomplishes 800 FH.

•By using average utilization assumption for the whole fleet, the interval of the maintenance task 1200 FC is equivalent to 7200 FH or 600 days (by using 12 FH/day and 2 FC/day)
So, this task should be performed every 9A check. Then the converted letter check interval for this maintenance task is 9A.
•By using the software, we obtain different cases for different aircraft in the fleet such as given in Fig. 1.28.

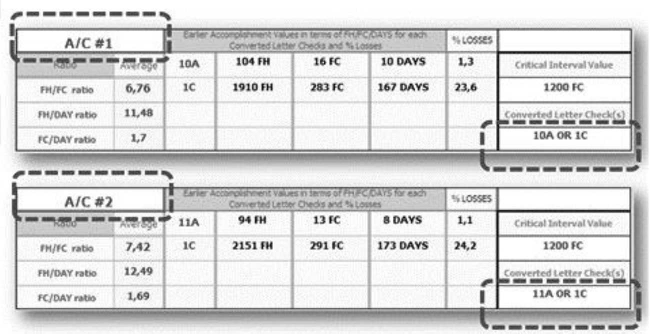


Figure 1.28 Comparison of conclusions

The software calculates 11A for the aircraft A/C#2 by taking into account the real-time utilization values of this aircraft.

If we take into account the average utilization assumption for the whole fleet, we lose 2A for this single maintenance task accomplishment for the aircraft A/C#2. In other words instead of performing this maintenance task in every 11A check, we have to perform it every 9A check and 2A check earlier accomplishment occurs. In long term we perform this maintenance task several times more than needed (instead of 9 applications, we perform 11 applications without the software – 2 additional unnecessary checks for this example). (Fig.1.29)

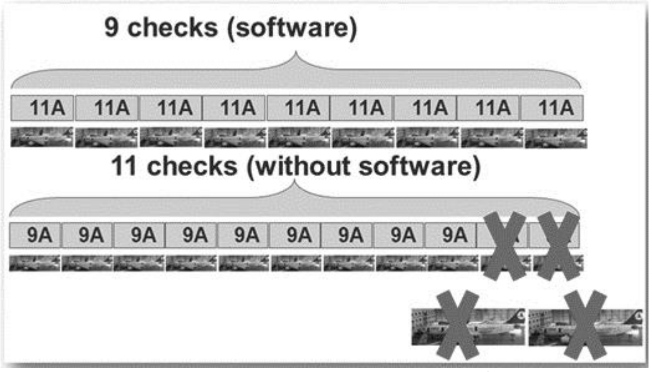


Figure 1.29 Extra additional checks without using the software

If we consider the existence of several maintenance tasks (around four thousands in the maintenance program), we can easily understand the benefit of using this software for the scheduling purposes in airline companies. An airline company can prevent unnecessary accomplishments of maintenance tasks and in this way they can profit from maintenance cost, man-hour and material costs. Furthermore the availability of aircraft for flight (aircraft maximization) increases and this increases the aircraft utilization in long term consequently.
The total man hour lost during a maintenance check may be calculated with the formula given below (2):

$$\sum_{j=1}^{A} \sum_{i=1}^{n} \left(\frac{S_{i,j} - R_{i,j}}{S_{i,j} x\, R_{i,j}} \right) x M_i \qquad (2)$$

where:
n is the number of maintenance tasks given in the maintenance program.
$\mathrm{M_i}$ is the man hour required for the accomplishment of the $\mathrm{i^{th}}$ maintenance task.
$\mathrm{S_{i,j}}$ is the interval proposed by the software for of the $\mathrm{i^{th}}$ maintenance task for the $\mathrm{j^{th}}$ aircraft.
$\mathrm{R_{i,j}}$ is the interval applied by the airline company for of the $\mathrm{i^{th}}$ maintenance task for the $\mathrm{j^{th}}$ aircraft.
A is the number of aircraft in a specific fleet of the airline company.
$\mathrm{S_{i,j} - R_{i,j}}$ is the earlier accomplishment of the $\mathrm{i^{th}}$ maintenance task for the $\mathrm{j^{th}}$ aircraft.
$\mathrm{S_{i,j} - R_{i,j}}$ is the earlier accomplishment of the $\mathrm{i^{th}}$ maintenance task for the $\mathrm{j^{th}}$ aircraft.

$\frac{\mathrm{S_{i,j} - R_{i,j}}}{\mathrm{S_{i,j} x\, R_{i,j}}}$ is the unnecessary accomplishment of the $\mathrm{i^{th}}$ maintenance task for the $\mathrm{j^{th}}$ aircraft per unit interval (unit maintenance check).

$\sum_{i=1}^{n} \left(\frac{\mathrm{S_{i,j} - R_{i,j}}}{\mathrm{S_{i,j} x\, R_{i,j}}} \right) \mathrm{xM_i}$ is the unnecessary man hour lost for the n maintenance tasks for the $\mathrm{j^{th}}$ aircraft during the unit maintenance check.

For the case study in Fig. 1.30, if we assume that there are 600 maintenance tasks similar to the example given in case study related Fig. 1.29, for one aircraft we lose 36 man hours per unit maintenance check. (In order to facilitate the calculations, all maintenance task man hours are assumed to be 3.)
For this case study, for one aircraft we lose approximately one day per unit maintenance check without using the software. If we use the software and assign the more accurate letter check for this aircraft taking into account its real time utilization values, we have a cost saving of 60.000 US$ for one aircraft for a number of maintenance tasks (600 in this example case study) in 18 years. If we assume that the airline company has 200 aircraft in its fleet and there are more than 3.000 maintenance task in the maintenance program, the size of the cost saving becomes very important for the airline by using this software.
Another advantage of the software, it may help the user to prevent late accomplishment of some maintenance tasks in some aircraft. If this occurs, it is subject of severe penalties by civil aviation authorities.

n	1	2	3	4	.	.	.	600
S	11A	11A	11A	11A	11A	11A	11A	11A
R	9A	9A	9A	9A	9A	9A	9A	9A
S-R	2	2	2	2	2	2	2	2
SxR	99	99	99	99	99	99	99	99
(S-R)/SxR	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
M	3	3	3	3	3	3	3	3
((S-R)/SxR)xM	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06
Total	36,36							

Figure 1.30 Man hour lost per unit maintenance without using the software

Conclusion

The major purpose of this article is to keep the aircraft less time on the ground for any purposes especially for maintenance purposes and thus to increase the duration of flight availability. In this article it is intended to propose alternative ways of performing maintenance in order to keep the aircraft less time on the ground. One of the ways to increase the aircraft utilization (flight hours spent in a period of time) is to reduce ground time spent for maintenance. In this article a method to reduce ground time spent for maintenance is studied. A couple of case studies accomplished in an airline company to support this method are given. The single task-oriented maintenance concept allows us to establish a more flexible structure in the accomplishment of maintenance tasks and consequently to perform the maintenance in every opportunity when the aircraft is already on the ground. By utilizing the advantages of single task-oriented maintenance concept, maintenance checks may be divided into smaller checks which require the aircraft to be kept less time on the ground. Some case studies on dividing the maintenance content into smaller parts were observed in the content of this article.

The second method given in this article to support single task-oriented concept is to prevent earlier accomplishment of some maintenance tasks and to develop a software for this purpose. In order to prevent earlier accomplishment of some maintenance tasks, the real time utilization values of aircraft have to be taken into account and the most appropriate letter check alternatives according to real time utilization values should be calculated by means of the software.

This software allows the user to find the most appropriate letter check alternatives for a specific maintenance task with different interval values. It calculates the most critical interval among the intervals input by the user and during this calculation process the real time utilization values of the selected fleet are evaluated. All the calculations are based on these real time utilization values accomplished by this fleet during the last twelve months. No estimated values are used in the calculations. Therefore, results that are more accurate are obtained by using this software. By using this software the earlier or later accomplishment of some maintenance tasks in some aircraft may be prevented and therefore scheduled maintenance downtime of aircraft may be reduced consequently.

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