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Development of an application to determine a technical flight plan for A330-200

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Dedication

I dedicate this work to:

My mother, who is a true model of strength, patience, and love for me. This thesis is especially dedicated to her, as a token of my deep admiration and gratitude.

My father, for his constant support, unwavering encouragement, protection, and his pure heart.

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ملخص

الهدف الرئيسي من هذه الرسالة هو تطوير تطبيق لتحسين خطة طيران طائرة.A330-200

يهدف هذا التطبيق إلى تسهيل وتحسين إعداد خطة الطيران من خلال دمج حسابات دقيقة لضمان الالتزام بحدود الوزن، وتقليل استهلاك الوقود، ووقت الطيران، وتحسين الأداء التشغيلي.

صُمم التطبيق بلغة بايثون، باستخدام مكتبة Tkinter للواجهة الرسومية، و pymysql لإدارة قواعد البيانات . يدمج التطبيق خوارزميات الاستيفاء وطريقة حسابية مُصممة خصيصًا لطائرة A330-200 لتحديد وقود الرحلة والوقت المطلوب، باستخدام جداول الصعود والنزول والانطلاق المستخرجة من بيانات الرحلة الجوية لطائرةA330-200 ، بالإضافة إلى بيانات الوزن الفارغ، وأقصى وزن للإقلاع، وأقصى وزن للهبوط لتجنب تجاوز الحد المسموح به.

تعتمد بنية البرنامج على واجهة سهلة الاستخدام تتيح للمستخدمين إدخال البيانات الأساسية والحصول على خطة طيران مُحسنة في الوقت الفعلي باستخدام قاعدة بيانات مُنشأة في .MySQL Workbench يهدف هذا الحل إلى تحسين دقة الحسابات، وتقليل وقت التحضير، وتوفير عملية اتخاذ قرارات أفضل لفرق تخطيط الرحلات .تُظهر النتائج المُحصلة أن التطبيق يُسهم بفعالية في تحسين خطط الطيران، مع فوائد من حيث توفير الوقت، والسلامة، وخفض تكاليف التشغيل .يفتح هذا العمل آفاقًا لدمج ميزات إضافية وتكييفه مع أنواع أخرى من الطائرات.

ABSTRACT

The main objective of this thesis is to develop an application for optimizing the flight plan of the A330-200 aircraft.

This application serves to facilitate and improve flight plan preparation by integrating precise calculations in order to respect the weight limit, reduce fuel consumption, flight time and optimize operational performance.

The application is designed in Python, using the Tkinter library for the graphical interface, and pymysql for database management. It integrates interpolation algorithms and a calculation method adapted to A330-200 to determine the trip fuel and the required time, utilizing the climb, descent, and cruise tables extracted from the A330-200 FCOM,

as well as data on empty weight, maximum takeoff weight, and maximum landing weight to avoid exceeding the allowable margin.

The software architecture is based on a user-friendly interface that allows users to enter essential data and obtain an optimized flight plan in real time using a database created in MySQL Workbench. This solution aims to improve calculation accuracy, reduce preparation time, and provide better decision-making for flight planning teams.

The results obtained demonstrate that the application can effectively contribute to flight plan optimization, with benefits in terms of time savings, safety, and reduced operational costs. This work opens up prospects for the integration of additional features and adaptation to other aircraft types.

RÉSUMÉ

L’objectif principal de ce mémoire est de développer une application destinée à l’optimisation du plan de vol de l’avion A330-200.

Cette application sert a faciliter et améliorer la préparation des plans de vol en intégrant des calculs précis de gestion du poids, du carburant et des paramètres de montée et descente, afin de réduire la consommation et d’optimiser les performances opérationnelles.

L’application est conçue avec le langage Python, utilisant la bibliothèque Tkinter pour l’interface graphique, et pymysql pour la gestion des bases de données. Elle intègre des algorithmes d’interpolation et une méthode de calcul adaptée aux contraintes spécifiques de l’A330-200 pour déterminer le délestage total du vol et le temps nécessaire, notamment les tables de montée et descente et de croisière que je les extrais depuis le FCOM de l’A330-200 ainsi que les données sur la masse à vide, la masse maximale au décollage et la masse maximale à l’atterrissage pour ne pas dépasser la marge admissible.

L’architecture logicielle repose sur une interface conviviale permettant aux utilisateurs de saisir les données essentielles et d’obtenir un plan de vol optimisé en temps réel en utilisant une base de données crée dans MySQL Workbench. Cette solution vise à améliorer la précision des calculs, à réduire le temps de préparation et à offrir une meilleure prise de décision aux équipes de planification de vol.

Les résultats obtenus démontrent que l’application peut contribuer efficacement à l’optimisation des plans de vol, avec des bénéfices en termes de gain de temps, de sécurité et de réduction des coûts opérationnels. Ce travail ouvre des perspectives pour l’intégration de fonctionnalités supplémentaires et l’adaptation à d’autres types d’aéronefs

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Abreviations

A/I OFF: Anti-Ice Off

ASK: Available Seat Kilometres

CAS: Calibrated Airspeed

CI: Cost Index

DOC: Direct Operating Cost

DOW: Dry Operating Weight

EASA: European Union Aviation Safety Agency

ETOW: Estimated Take-Off Weight

ELAW: Estimated Landing Weight

FCOM: Flight Crew Operating Manual

FL: Flight Level

FF: Hourly fuel consumption per engine

Fpdf: Free PDF Library for Python

GS: Ground Speed

ICAO: International Civil Aviation Organization

IATA: International Air Transport Association

ISO: International Organization for Standardization

IAS: Indicated Airspeed

ISA: International Standard Atmosphere

LW: Landing Weight

Mmc: Average cruise mass

M_{ECON}: Economic Mach Number

M_{LRC}: Long-Range Cruise Mach Number

M_{LW}: Maximum Landing Weight

M_{MO}/V_{MO}: Maximum Mach Number / Maximum Operating Speed

M_{MR}: Maximum Mach Number for Cruise

M_{toc}: Mass at Top of Climb

M_{tod}: Mass at Top of Descent

MTOW: Maximum Take-Off Weight

MTW: Maximum Taxi Weight

MZFW: Maximum Zero Fuel Weight

MSL: Mean Sea Level

Normal A/C: Normal Aircraft Configuration

OEW: Operating Empty Weight

OS: Operating System

PA: Pressure Altitude

PKM: Passenger Kilometres

pymysql : Python MySQL Database Connector

QFE: Atmospheric Pressure at Airfield Elevation

QNH: Altimeter Pressure Setting

RC: Rate of Climb

RD: Rate of Descent

SR: Specific Range

SQL: Structured Query Language

TAS: True Airspeed

Ttk: Themed Tkinter

TOW: Take-Off Weight

win32api: Windows API for Python

win32print: Windows Printing API

ZFW: Zero Fuel Weight

Introduction

Over the decades, the use of information technology devices provides benefits to a great number of industries. In particular, the introduction of such devices in the commercial aviation sector gives an improvement in operating safety and efficiency, which translates into major economic gains.

optimizing flight plans is essential for reducing fuel consumption, minimizing costs, and improving the overall efficiency of airline operations. Focusing on a single aircraft type which is the Airbus A330-200, a widely used long-haul aircraft, presents unique challenges and opportunities for flight planning due to its advanced systems, operational range, and performance characteristics.

Flight planning for commercial aircraft involves many factors, including aircraft performance, weather conditions and fuel management. Creating an optimal flight plan means finding a flight profile that meet safety, regulatory, and economic requirements. This process is complex and often requires the use of advanced algorithms and software tools

This thesis aims to develop an application specifically designed to optimize the flight plan of the Airbus A330-200. This application aims to help operators select the most efficient routes and flight profiles by integrating aircraft performance data, weather forecasts, and airspace rules. By using optimization algorithms and user-friendly interfaces, the software will support better decision-making and contribute to safer, more cost-effective, and environmentally friendly flights.

Through the development and testing of this application, the findings presented in this thesis are intended to demonstrate how modern software tools can improve flight planning processes and deliver tangible benefits for both airlines and passengers.

The structure of this thesis is organized as follows:

Chapter 1: presents an overview of Air Algerie, detailing the company's operational context and strategic objectives.

Chapter 2: provides a general overview of air operations.

Chapter 3: focuses on the Airbus A330-200 aircraft, the calculation methodology adopted, the design of the supporting database, and the development process of the application.

Chapter 4: discusses the results obtained from the application, including comparative analyses and the evaluation of its performance.

Chapter 1

Presentation of Air Algerie

1.1 Creation and Evolution

Air Algerie's development process dates back to 1947 with the establishment of the «Compagnie Générale de Transport» (CGT), which initially focused on routes primarily to France. In June 1953, CGT merged with the Compagnie Air Transport to form CGT Air Algerie. By 1954, at the onset of the Algerian War of Independence, the airline operated a fleet of four piston-engine Douglas DC-4 aircraft. The fleet expanded in the following years with the addition of Lockheed Constellation planes in 1956, and further acquisitions in 1957 including DC-4s, DC-3s, and Nord Atlas cargo planes. The first jet aircraft, the Caravelle, was introduced in 1959.

Following Algeria's independence in 1962, Air Algerie's fleet comprised four Caravelles, ten DC-4s, and three DC-3s. In 1963, the airline became a national company under the Ministry of Transport. This period marked the beginning of a gradual Algerianization of the workforce, especially after the departure of French personnel. The airline progressively expanded its international network to 35 foreign destinations across Europe, Africa, and the Middle East, alongside 26 domestic destinations.

By 1966, the Algerianization of commercial flight crews was completed, and in 1968, the Algerian government acquired the remaining shares held by foreign companies. This year also saw the introduction of four Convair G60 aircraft and the retirement of older DC-4 and DC-3 models. The state increased its ownership stake in Air Algerie in 1970, and in 1971 the airline introduced its first Boeing Superjet aircraft. This era also witnessed the formation of the first entirely Algerian flight crews [1].

Figure 1.1: The Douglas DC-4 aircraft operated by the American Airlines System [2].

Figure 1.2 :DC-3 [3].

The same company put the twin-engine SE 210 Caravelle into service on the Algiers-Paris route on December 15, 1959.this aircraft renowned for its significant contribution to the fleet and the innovative design as shown in figure1.3:

Figure 1.3 : Sud Aviation SE 210 Caravelle aircraft [4].

In 1974, the Algerian government purchased the remaining 17% stake held by Air France, achieving full ownership of the airline. The following year, Air Algerie was officially designated as a national air transport and aviation company. Throughout the 1980s, the company underwent organizational changes, including the division of domestic and international operations in 1983 and the near completion of Algerianization among technical flight personnel by 1984. In 1987, Air Algerie was relieved of its responsibility for managing airport lounges.

The airline transitioned to a joint-stock company in 1997 with a capital of 2.5 billion Algerian dinars, coinciding with the liberalization of air transport in 1998. A modernization plan launched in 1999 aimed to replace aging Boeing 727-200 (as shown in the figure 1.4) and 737-200 aircraft with newer generation models, improve maintenance facilities, and implement a market-oriented commercial strategy [1].

Figure 1.4 : Boeing 727 aircraft [5].

Between 2000 and 2010, Air Algerie's capital increased progressively from 6 billion to 43 billion dinars. The fleet was enhanced with the acquisition of five Airbus A330 aircraft in 2004, and new direct routes were opened to Montreal in 2007 and Beijing in 2009. In 2010, the fleet was further strengthened with four ATR turboprops and three Boeing 737-800s, while the company's capital reached 43 billion dinars.

In response to the European Union's carbon tax introduced in 2012, Air Algerie continued fleet modernization, receiving two Boeing 737-700C and eight Boeing 737-800 aircraft in 2014. The airline aimed to transform Algiers' Houari Boumediene Airport into a major hub, targeting an annual capacity of 10 million passengers. Expansion plans included a focus on African routes and new services to the United States and Asia.

In April 2015, Air Algerie took delivery of one of three Airbus A330-200s ordered in 2014 as part of its 2013-2017 development plan, marking a significant step in its ongoing growth and modernization strategy.

1.2 Missions of Air Algerie

Air Algerie is a company specialized in providing air transport services for both passengers and cargo. Its main missions are as follows:

- **Air transport**: to operate domestic and international air routes to ensure the public transportation of passengers, baggage, cargo, and mail.

- **Aerial work**: to offer commercial and scientific services aimed at sectors such as agriculture, civil protection, and public and sanitary hygiene.

- **Commercial operations**: to manage the sale and issuance of travel documents, aircraft chartering, as well as the handling, assistance, and refueling of aircraft.

- **Technical operations**: to obtain the necessary licenses, permits, and authorizations for overflight of foreign airspaces, and to carry out maintenance, repair, and overhaul of aircraft equipment, both for its own fleet and for third parties.

Since gaining autonomy and transforming into a joint-stock company, Air Algerie has become a public airline whose purpose, both in Algeria and abroad, is to:

- Organize and operate all public air transport services for passengers, cargo, and mail, whether scheduled or non-scheduled, domestic or international, as well as aerial work activities.
- Manage and operate all maintenance-related activities.
- Oversee all operations, regardless of their nature economic, legal, financial, movable or immovable property, industrial, civil, or commercial related to its business [1].

1.3 Fleet

Air Algerie's fleet composition represents a strategic balance between modernization and traditional operations. The airline operates a mix of Airbus, Boeing, and ATR aircraft. The Airbus fleet includes eight A330-200s and eighteen Boeing 737-800s, which form the backbone of its medium- and long-haul operations. Air Algerie also operates fifteen ATR 72s, providing regional connectivity. There is also a Lockheed L-100-30T, which is used for cargo, ensuring fleet optimization. confirming Air Algerie's transition to a fuel-efficient and profitable fleet. With 51 aircraft in operation, the airline's fleet strategy aligns with industry trends favoring capacity optimization and sustainability. Fleet details are summarized in Table 1.1 as shown below.

Table 1.1: Fleet Details for Company of Air Algerie [6].

AIRCRAFT	CURRENT ACTIVE FLEET	ON ORDER	TOTAL
Airbus A330-200	8	0	8
ATR72-500	12	0	12
ATR72-600	3	0	3
Boeing 737-600	5	0	5
Boeing 737-700C	1	1	2
Boeing 737-800	18	7	25

Boeing 767-300	3	0	3
Lockheed L-100-30T	1	0	1

As illustrated in figures below and according to [7], it shows some aircrafts of the company's fleet.

Figure 1.5 : Airbus A330-200.

Figure 1.6 : Boeing 737-800.

Figure 1.7 : Boeing 737-600.

Figure 1.8: Boeing 737-700C.

Figure 1.9 : ATR 72-600.

Figure 1.10 : ATR 72-500.

Figure 1.11: Boeing 767-300.

Figure 1.12 :Lockheed L-100-30T.

1.4 Destinations

Air Algerie transports more than 6.5 million passengers and nearly 20,000 tons of cargo annually, all with an air network spanning 96,400 kilometers. In 2018, the company rose to become the fourth largest airline in Africa, surpassing South African Airways and Kenya Airways, but placing behind Ethiopian Airlines, EgyptAir, and Royal Air Maroc.

Like any major airline, Air Algerie relies on an international network serving 45 cities in 30 countries, including destinations in Europe, the Middle East, Asia, Africa, and the Americas. Meanwhile, its domestic network optimally connects the 31 key cities in Algeria, while strengthening its position in the local market. In terms of operational capacity, Air Algerie offered nearly 5 billion seat kilometers (ASK) and recorded 3.3 billion passenger kilometers (PKM). The group has 40 local agencies and 27 agencies abroad.

The French market is positioned as its largest foreign market and its main international outlet. The airline carried 2,884,584 passengers in 2019, recording sustained growth of 8.1% compared to 2018, as well as 16,037 tons of cargo. With a 66% market share, it undeniably dominates air routes between France and Algeria, surpassing her competitors such as Air France, Transavia, and ASL Airlines France.

When it comes to long-haul flights, Air Algerie is strengthening its air network by launching several new routes (five routes) to Montreal, Beijing, Johannesburg, Doha, and Dubai using Airbus A330-200s. Its flights offer three classes of service: economy, business, and, since 2015, premium economy [7]. Table 1.2 shows Air Algerie's detailed destinations in August 2023 as it is mentioned below,

Table 1.2: Air Algerie national and international destinations in August 2023 [6, 8].

Country	City	Airport (code ICAO)	Code ICAO	Code IATA
ALGERIA	Adrar	Touat-Cheikh Sidi Mohamed Belkebir Airport	DAUA	AZR
	Algiers	Houari Boumediene Airport	DAAG	ALG
	Annaba	Rabah Bitat Airport	DAAB	AAE
	Batna	Mostapha Ben Boulaid Airport	DABT	BLJ
	Bachar	Boudghene Ben Ali Lotfi Airport	DAOR	CBH
	Bejaia	Abane Ramdane Airport	DAAE	BJA
	Biskra	Biskra Airport	DAUB	BSK
	Bordj Badji Mokhtar	Bordj Badji Mokhtar Airport	DATM	BMW
	Chlef	Chlef International Airport	DAOI	CFK
	Constantine	Mohamed Boudiaf International Airport	DABC	CZL
	Djanet	Djanet Inedbirene Airport	DAAJ	DJG
	El Bayadh	El Bayadh Airport	DAOY	EBH
	El Golea	El Golea Airport	DAUE	ELG
	El Oued	Guemar Airport	DAUO	ELU
	Ghardaïa	Noumerat – Moufdi Zakaria Airport	DAUG	GHA
	Hassi Messaoud	Oued Irara Krim Belkacem Airport	DAUH	HME

	Hassi RMel	Hassi R'Mel Airport	DAFH	HRM
	Illizi	Takhamalt Airport	DAAP	VVZ
	In Amenas	In Amenas Airport	DAUZ	IAM
	In Guezzam	In Guezzam Airport	DATG	INF
	In Salah	In Salah Airport	DAUI	INZ
	Jijel	Jijel Ferhat Abbas Airport	DAAV	LOO
	Laghouat	Laghouat Airport	DAUL	LOO
	Mascara	Ghriss Airport	DAOV	MUW
	Oran	Ahmed Ben Bella Airport	DAOO	ORN
	Ouargla	Ain Beida Airport	DAUU	OGX
	Setif	Ain Arnat Airport	DAAS	QSF
	Tamanrasset	Aguenar – Hadj Bey Akhamok Airport	DAAT	TMR
	Tebessa	Cheikh Larbi Tebessa Airport	DABS	TEE
	Tiaret	Abdelhafid Boussouf Bou Chekif Airport	DAOB	TID
	Tindouf	Commandant Ferradj Airport	DAOF	TIN
	Tlemcen	Zenata Messali El Hadj Airport	DAON	TLM
	Touggourt	Sidi Mahdi Airport	DAUK	TGR
Austria	Vienna	Vienna International Airport	LOWW	VIE
Belgium	Brussels	Brussels Airport	EBBR	BRU
	Charleroi	Brussels South Charleroi Airport	EBCI	CRL
Burkina Faso	Ouagadougou	Ouagadougou Airport	DFFD	OUA
Cameroon	Douala	Douala International Airport	FKKD	DLA
Canada	Montreal	Montreal Pierre Elliott Trudeau International Airport	CYUL	YUL
China	Beijing	Beijing Capital International Airport	ZBAA	PEK
Egypt	Cairo	Cairo International Airport	HECA	CAI

Ethiopia	Addis Ababa	Addis Ababa Bole International Airport	HAAB	ADD
France	Bordeaux	Bordeaux–Merignac Airport	LFBD	BOD
	Lille	Lille Airport	LFQQ	LIL
	Lyon	Lyon-Saint-Exupery Airport	LFLL	LYS
	Marseille	Marseille Provence Airport	LFML	MRS
	Metz	Metz–Nancy–Lorraine Airport	LFJL	ETZ
	Montpellier	Montpellier–Mediterranee Airport	LFMT	MPL
	Nice	Nice Côte d'Azur Airport	LFMN	NCE
	Paris	Charles de Gaulle Airport	LFPG	CDG
		Orly Airport	LFPO	ORY
	Toulouse	Toulouse Blagnac Airport	LFBO	TLS
Germany	Frankfurt	Frankfurt Airport	EDDF	FRA
Hungary	Budapest	Budapest Ferenc Liszt International Airport	LHBP	BUD
Italy	Milan	Milan Malpensa Airport	LIMC	MXP
	Rome	Leonardo da Vinci–Fiumicino Airport	LIRF	FCO
Ivory Coast	Abidjan	Felix Houphouet Boigny International Airport	DIAP	ABJ
Jordan	Amman	Queen Alia International Airport	OJAI	AMM
Lebanon	Beirut	Beirut Rafic Hariri International Airport	OLBA	BEY
Mali	Bamako	Modibo Keita International Airport	GABS	BKO
Mauritania	Nouakchott	Nouakchott–Oumtounsy International Airport	GQNO	NKC
Niger	Niamey	Diori Hamani International Airport	DRRN	NIM
Portugal	Lisbon	Lisbon Airport	LPPT	LIS
	Porto	Porto Francisco Sa Carneiro Airport	LPPR	OPO
Qatar	Doha	Hamad International Airport	OTHH	DOH

Russia	Moscow	Sheremetyevo International Airport	UUEE	SVO
	Saint Petersburg	Pulkovo Airport	ULLI	LED
Senegal	Dakar	Blaise Diagne International Airport	GOBD	DSS
Spain	Alicante	Alicante Elche Miguel Hernández Airport	LEAL	ALC
	Barcelona	Josep Tarradellas Barcelona El Prat Airport	LEBL	BCN
	Madrid	Madrid Barajas Airport	LEMD	MAD
	Palma de Mallorca	Palma de Mallorca Airport	LEPA	PMI
	Valencia	Valencia Airport	LEVC	VLC
Saudi Arabia	Jeddah	King Abdulaziz International Airport	OEJN	JED
	Medina	Medina Prince Mohammad bin Abdulaziz International Airport	OEMA	MED
South Africa	Johannesburg	Joahannesburg OR Tambo International Airport	FAOR	JNB
Switzerland	Geneva	Geneva international Airport	LSGG	GVA
Switzerland France Germany	Basel Mulhouse Freiburg	Basel Mulhouse-Freiburg EuroAirport	LFSB	BSL
Syria	Damascus	Damascus International Airport	OSDI	DAM
Tunisia	Tunis	Carthage International Airport	DTTA	TUN
Turkey	Antalya	Antalya Airport	LTAI	AYT
	Istanbul	Istanbul Airport	LTFM	IST
United Arab Emirates	Dubai	Dubai International Airport	OMDB	DXB
United Kingdom	London	London Heathrow Airport	EGLL	LHR
		London Stansted Airport	EGSS	STN

1.5 Affiliates

As part of its corporate structure, the national carrier Air Algerie operates four subsidiary companies.

1.5.1 Air Algerie Cargo

The first subsidiary is Air Algerie Cargo, which specializes in air freight transport. The latter operates with a fleet including a Lockheed L-100 Hercules and a Boeing 737-800BCF, this type of aircraft can be converted into cargo, and supplemented by two Boeing 737-700C, the latter can be configured in passenger or cargo mode in just 30 minutes. This subsidiary is based at Algiers-Houari Boumediene Airport, it provides cargo flights to Madrid, Lyon, Paris, Marseille and Nouakchott, while maximizing the use of available space in the hold of Air Algerie passenger aircraft.

1.5.2 Air Algerie Catering

The subsidiary specialized in in-flight catering of the Air Algerie group is Air Algerie Catering. It focuses on catering on board aircraft. It expands its activities by integrating services including the management of charter flights, the management of duty-free shops, as well as ground handling services. The subsidiary also extends its expertise to catering at events and various logistical support services. In terms of partnerships, Air Algerie Catering provides its services to more than fifteen international airlines, including Emirates, EgyptAir, Air France, Turkish Airlines and Royal Air Maroc. Among its significant achievements, its strategic contract with the SNTF (National Railway Transport Company) for which it provides the meal trays served on board Algerian trains, demonstrating its multi-sector expertise and its ability to adapt to different transport sectors.

1.5.3 Air Algerie Handling

The third subsidiary of the company takes care of airport handling operations such as baggage check-in, passenger boarding at Algerian airports. It takes care of handling for Air Algerie as well as foreign companies on Algerian territory.

1.5.4 Air Algerie Technics

To ensure aircraft maintenance and repair, there is a subsidiary specializing in all of this, called Air Algerie Technics. This subsidiary handles the Air Algerie fleet as well as the maintenance and repair of aircraft from other airlines, such as the Boeing 737NG of ASL Airlines France and the Boeing 737-800 of Tassili Airlines, as well as the Algerian presidential fleet, such as the ATR 72-600.

Its activities cover various technical areas, including engines, hydraulics, electronics, and pneumatics. It has its facilities in dedicated hangars at Algiers Houari Boumediene Airport, but also operates in other Algerian airports.
On the regulatory front, the company holds certifications specific to aircraft maintenance, such as:

- ISO standards, guaranteeing the quality of its processes;
- EASA Part 145 certification, attesting to its compliance with the requirements of the European Aviation Safety Agency;
- Validation by the International Air Transport Association (IATA).

These certifications enable it to provide maintenance and repair services in compliance with international aviation safety standards, such as those defined by the International Civil Aviation Organization (ICAO). It is also approved by local authorities, such as the Algerian Civil Aviation Authority.

1.6 Air Algerie's activities

In accordance with Decree No. 84-347 of November 24, 1984, Air Algerie's core missions are:
Management of national and international airlines;
Carrying out passenger, cargo, and mail services;
Technical and commercial assistance to foreign airlines;
Maintenance and repair of aircraft fleets;
Sale of tickets for its own network as well as for partner carriers.
Air Algerie is positioned among the leaders in air transport among third-world airlines thanks to its reliable operational infrastructure, extensive destination network, certified quality services, and qualified staff [9].

Chapter 2

General Overview of Air Operations

This chapter aims to provide the fundamental knowledge necessary to understand how flight operations are conducted, regulated, and influenced by aircraft limitations.

2.1 Definitions

International Standard Atmosphere (ISA)

The atmosphere, which is a gaseous envelope surrounding the Earth, has characteristics such as temperature, pressure, and density that vary significantly from one location to another. To standardize performance calculations, a reference model called the International Standard Atmosphere (ISA) is used.

The ISA establishes fixed atmospheric parameters for different altitudes. At sea level, it assumes:

- a pressure of 1013.25 hPa,
- a temperature of 15°C,
- a temperature lapse rate of 2°C per 1000 ft up to the tropopause (approximately 36,000 ft),
- and standard values for density and the speed of sound [10].

QFE

It refers to the pressure measured at the airport reference point. When the QFE setting is applied on the altimeter, it indicates the altitude above the airport reference point, assuming standard temperature conditions [10].

QNH

It represents the Mean Sea Level pressure. It is derived by adjusting the pressure measured at the airport reference point to Mean Sea Level, using the standard pressure law. With the QNH setting, the altimeter displays the altitude above Mean Sea Level, provided the temperature is standard. Therefore, under ISA conditions, the altimeter will indicate the topographic altitude of the airport terrain [10].

Standard

It refers to a fixed pressure value of 1013 hPa. When the standard setting is selected, the altimeter shows the altitude above the 1013 hPa isobaric surface, assuming standard temperature. This setting is used to ensure vertical separation between aircraft by removing the influence of local pressure variations. After takeoff, once the aircraft passes a designated level known as the Transition Altitude, the altimeter is adjusted to the standard setting [10].

Flight Load Factors

It is the ratio between the aerodynamic force component acting perpendicular to the airplane's longitudinal axis and the aircraft's weight.

$$n_z = \frac{\text{Lift}}{\text{Weigh}}$$

A positive load factor occurs when this aerodynamic force is directed upward relative to the airplane [10].

Calibrated Air Speed (CAS)

The Calibrated Air Speed (CAS) is determined from the difference between the total pressure (Pt) and the static pressure (Ps). This difference is known as the dynamic pressure (q).

Since dynamic pressure cannot be measured directly, it is obtained using two probes typically a Pitot tube (for total pressure) and a static port (for static pressure). The CAS corresponds to the speed derived from this dynamic pressure, corrected for known instrument and position errors [10].

$$CAS = f\ (Pt - P) = f\ (q)$$

Indicated Air Speed (IAS)

The Indicated Air Speed (IAS) is the value shown on the aircraft's airspeed indicator. Ideally, if the pressure measurement were perfectly accurate under all flight conditions, the IAS would be equal to the Calibrated Air Speed (CAS).

However, several factors such as the aircraft's angle of attack, the flaps configuration, ground proximity, wind direction, and other influencing parameters introduce errors, particularly in the static pressure measurement. These inaccuracies create a slight difference between IAS and CAS, which is known as the instrumental correction or antenna error, denoted as Ki [10].

$$IAS = CAS + Ki$$

True Air Speed (TAS)

In flight, an aircraft moves within an air mass that is itself in motion relative to the Earth. The True Air Speed (TAS) represents the aircraft's speed with respect to this moving reference system in other words, the aircraft's speed within the airflow.

The TAS can be determined from the Calibrated Air Speed (CAS) by accounting for the air density (ρ) and applying a compressibility correction factor, denoted as K [10].

$$TAS = \sqrt{(\rho o / \rho)} \quad K \ CAS$$

Ground Speed (GS)

The Ground Speed (GS) is the aircraft's speed relative to a fixed ground reference system. It is calculated by adjusting the True Air Speed (TAS) for the effect of the wind component [10].

$$\text{Ground Speed} = \text{True Air Speed} + \text{Wind Component}$$

Mach Number

The Mach Number is defined as the ratio between the True Air Speed (TAS) and the speed of sound at the aircraft’s flight altitude [10]. It expresses how fast the aircraft is moving relative to the local speed of sound:

$$M=\frac{TAS}{a}$$

Where:

- TAS = True Air Speed
- a = Speed of sound at altitude

The speed of sound in knots is calculated using the Static Air Temperature (SAT) in Kelvin:

$$a\,(\mathrm{kt})=39\times\sqrt{\mathrm{SAT(K)}}$$

Level

A generic term relating to the vertical position of an aircraft in flight and meaning variously, height, altitude or flight level [11].

Altitude

It is the vertical distance of a level, measured from mean sea level (MSL) [11].

Pressure-altitude

An atmospheric pressure expressed in terms of altitude which corresponds to that pressure in the Standard Atmosphere [11].

Flight level

It corresponds to the Indicated Altitude in feet divided by 100, provided the standard setting of constant atmospheric pressure which is related to a specific pressure datum, 1 013.2 hectopascals (hPa), and is separated from other such surfaces by specific pressure intervals [11].

Runway

A defined rectangular area on a land aerodrome prepared for the landing and take-off of aircraft [11].

Aerodrome

A defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft [11].

Alternate aerodrome: An aerodrome to which an aircraft may proceed when it becomes either impossible or inadvisable to proceed to or to land at the aerodrome of intended landing where the necessary services and facilities are available, where aircraft performance requirements can be met and which is operational at the expected time of use. Alternate aerodromes include the following:

- Take-off alternate
- En-route alternate
- Destination alternate [11].

Flight time: The total time from the moment an aeroplane first moves for the purpose of taking off until the moment it finally comes to rest at the end of the flight [10].

2.3. Aircraft Weight Definitions and Limitations

2.3.1 Definitions

2.3.1.1 Manufacturer's Empty Weight (MEW)

The Manufacturer's Empty Weight (MEW) refers to the weight of the aircraft structure, power plant, furnishings, systems, and any other equipment considered an integral part of the aircraft. It generally represents the dry weight, meaning it includes only fluids contained in closed systems, while excluding usable fuel, oil, and any payload [10].

2.3.1.2 Operational Empty Weight (OEW)

The Operational Empty Weight (OEW) is the sum of the MEW and additional items provided by the operator, such as the flight and cabin crew, their baggage, unusable fuel, engine oil, emergency equipment, toilet chemicals and fluids, galley structure, catering equipment, seats, documentation, and other operational necessities [10].

2.3.1.3 Dry Operating Weight (DOW)

The Dry Operating Weight (DOW) represents the total weight of the aircraft configured for a specific operation, excluding all usable fuel and the traffic load. It includes the Operational Empty Weight, plus items specific to the flight, such as catering, newspapers, and pantry equipment [10].

2.3.1.4 Zero Fuel Weight (ZFW)

The Zero Fuel Weight (ZFW) is obtained by adding the total traffic load (which consists of passengers, baggage, and cargo) to the Dry Operating Weight. At this weight, the aircraft carries no usable fuel [10].

2.3.1.5 Takeoff Weight (TOW)

The Takeoff Weight (TOW) is the total aircraft weight at the departure airport at the moment of brake release. It can be defined in two ways:

- As the Landing Weight (LW) plus the trip fuel (the fuel required for the flight), or
- As the Zero Fuel Weight (ZFW) plus the takeoff fuel (including both trip fuel and reserves) [10].

2.3.1.6 Landing Weight (LW)

The Landing Weight (LW) is the aircraft's total weight upon arrival at the destination airport. It is calculated by adding the fuel reserves to the Zero Fuel Weight (ZFW) [10].

Figure (2.1) illustrates the various aircraft weights as they are defined by the regulations.

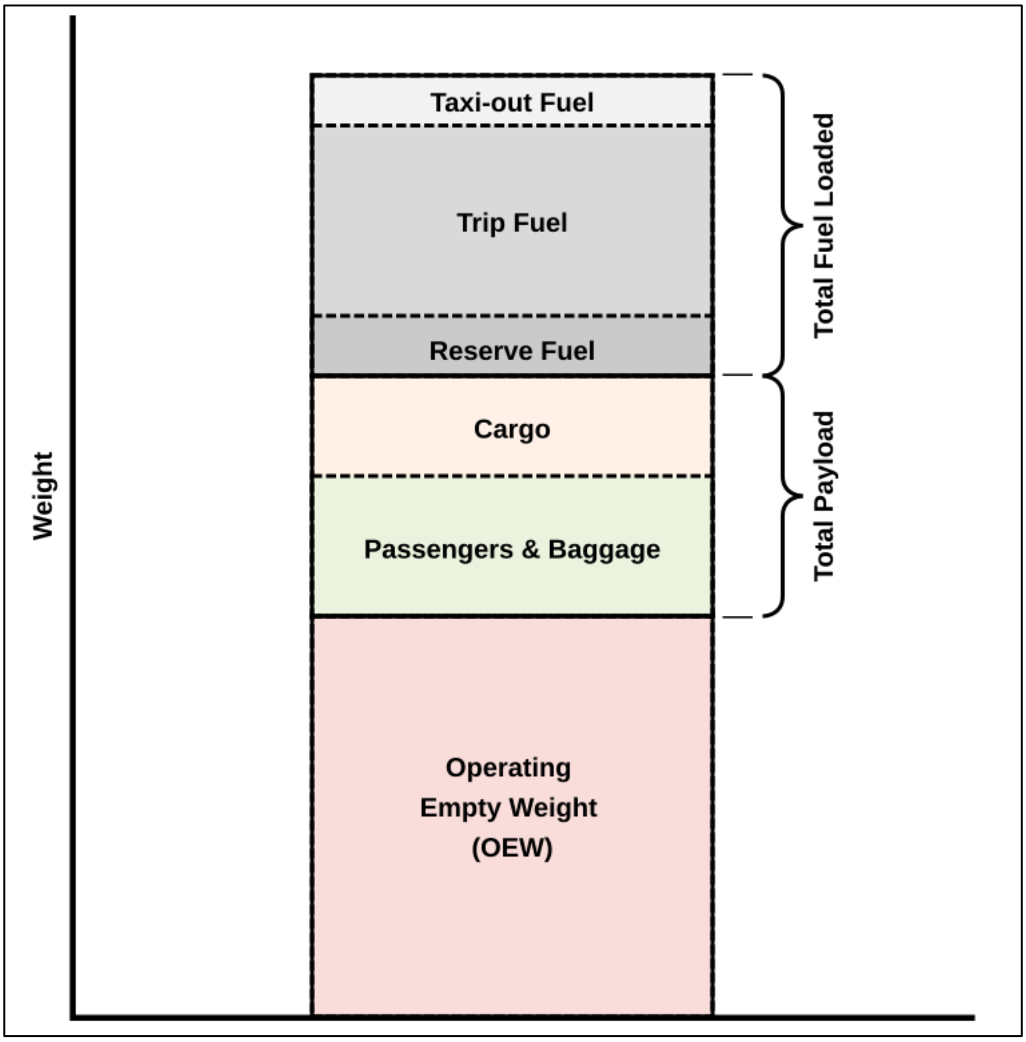


Figure 2.1: Aircraft Weights [12].

2.3.2 Weight Limitations

2.3.2.1 Maximum Structural Takeoff Weight (MTOW)

The Takeoff Weight (TOW) must never exceed the Maximum Structural Takeoff Weight (MTOW). This limit is determined based on criteria related to in-flight structural resistance, as well as the strength of the landing gear and the airframe's ability to withstand a landing impact with a vertical speed of -1.83 m/s (equivalent to -360 feet per minute) [10].

TOW = DOW + traffic load + fuel reserves + trip fuel

LW = DOW + traffic load + fuel reserves

ZFW = DOW + traffic load

2.3.2.2 Maximum Structural Landing Weight (MLW)

The Landing Weight (LW) is constrained by the aircraft's ability to absorb a vertical landing impact speed of -3.05 m/s (or -600 feet per minute). The maximum allowable weight under these conditions is referred to as the Maximum Structural Landing Weight (MLW). The actual Landing Weight must comply with this limitation [10].

$$\text{actual LW} = \text{TOW} - \text{Trip Fuel} \leq \text{MLW}$$

or

$$\text{actual TOW} \leq \text{MLW} + \text{Trip Fuel}$$

2.3.2.3 Maximum Structural Zero Fuel Weight (MZFW)

The bending moments at the wing root reach their maximum when the fuel quantity in the wings is minimal (see Figure 2.2). During flight, as the fuel mass in the wings decreases, these bending forces increase. Therefore, to ensure structural integrity when the fuel tanks are empty, the aircraft weight must not exceed the Maximum Zero Fuel Weight (MZFW) [10].

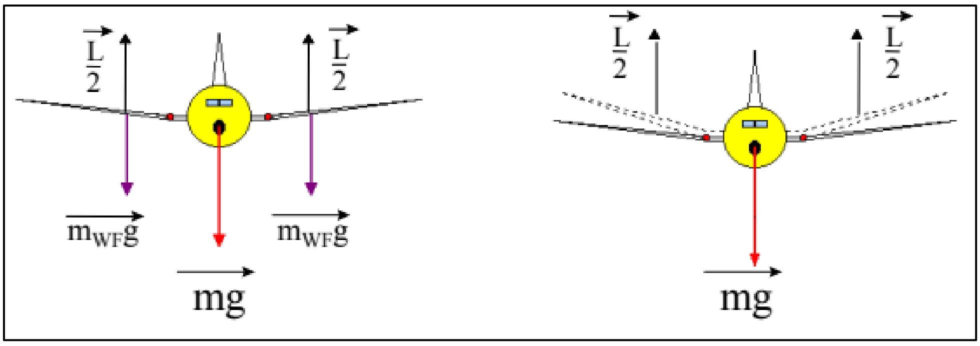


Figure 2.2: Fuel weight-induced wing bending relief [10].

As a result, the limitation can be expressed as: Actual Zero Fuel Weight (ZFW) must be less than or equal to the Maximum Zero Fuel Weight (MZFW):

$$\text{actual ZFW} \leq \text{MZFW}$$

Since Takeoff Fuel consists of both the trip fuel and the fuel reserves, the following condition must also be met:

$$\text{actual TOW} \leq \text{MZFW} + \text{Trip Fuel}$$

2.3.2.4 Maximum Structural Taxi Weight (MTW)

The Maximum Taxi Weight (MTW) is limited by the loads imposed on the shock absorbers and the potential bending of the landing gear during ground maneuvers such as turning [10]. However, the MTW is generally not a limiting factor and is typically defined based on the MTOW, with the relationship:

$$\text{MTW} - \text{Taxi Fuel} > \text{MTOW}$$

2.3.3 MINIMUM STRUCTURAL WEIGHT

The minimum weight corresponds to the lowest weight chosen by the applicant for which compliance is demonstrated with all relevant structural loading conditions and applicable flight requirements. Typically, gust loads and turbulence effects are among the key criteria used to establish this minimum structural weight [10].

2.4 FUEL MANAGEMENT

2.4.1 Fuel definitions

2.4.1.1 Taxi Fuel

Under A Taxi Fuel is the quantity that expected to be used prior to take-off. Local conditions at the departure aerodrome and APU consumption must be taken into account [10].

2.4.1.2 Trip Fuel

Trip Fuel is the fuel required from brake release at departure to landing touchdown at destination. It covers:

1. Take-off
2. Climb to cruise level
3. Cruise (including any step climb/descent)
4. Descent to the start of approach
5. Approach
6. Landing at the destination airport [10].

2.4.1.3 Contingency Fuel

Contingency Fuel is the greater of two values:

1. Fuel to fly 5 minutes at 1 500 ft above destination at holding speed in ISA conditions, or
2. One of the following:

- 5 % of Trip Fuel,
- 3 % of Trip Fuel (with airworthiness approval and an en-route alternate),
- Fuel for 15 minutes at 1 500 ft above,
- Fuel for 20 minutes based on Trip-Fuel consumption (operator uses individual-aircraft data) [10].

2.4.1.4 Alternate Fuel

Alternate Fuel provides for a diversion and includes:

1. Missed approach at destination
2. Climb to cruise
3. Cruise to the alternate
4. Descent to approach
5. Approach
6. Landing at the alternate airport

If two alternates are required, fuel must cover the more demanding alternate [10].

2.4.1.5 Final Reserve Fuel

Final Reserve Fuel is the minimum fuel to fly 30 minutes at 1 500 ft above the alternate (or above the destination when no alternate is required) at holding speed in ISA conditions [10].

2.4.1.6 Additional Fuel

Additional Fuel must permit:

- When operating IFR without a destination alternate, a 15 minutes hold at 1 500 ft above the aerodrome.
- Following a power-unit failure or loss of pressurization at the most critical point en route:

➢ Descent as necessary and flight to an adequate aerodrome,
➢ 15-minute hold at 1 500 ft there,
➢ Approach and landing [10].

2.4.2Fuel policy

Although fuel quantity requirements may vary slightly between national regulations, the core principles are very similar across authorities. In particular [10].

The minimum fuel quantity (Q) required for flight planning is defined by the following equation:

$$Q = \text{Taxi Fuel} + TF + CF + AF + FR + Add + XF$$

Where:

TF = Trip Fuel

CF = Contingency Fuel

AF = Alternate Fuel

FR = Final Reserve Fuel

Add = Additional Fuel

XF = Extra Fuel

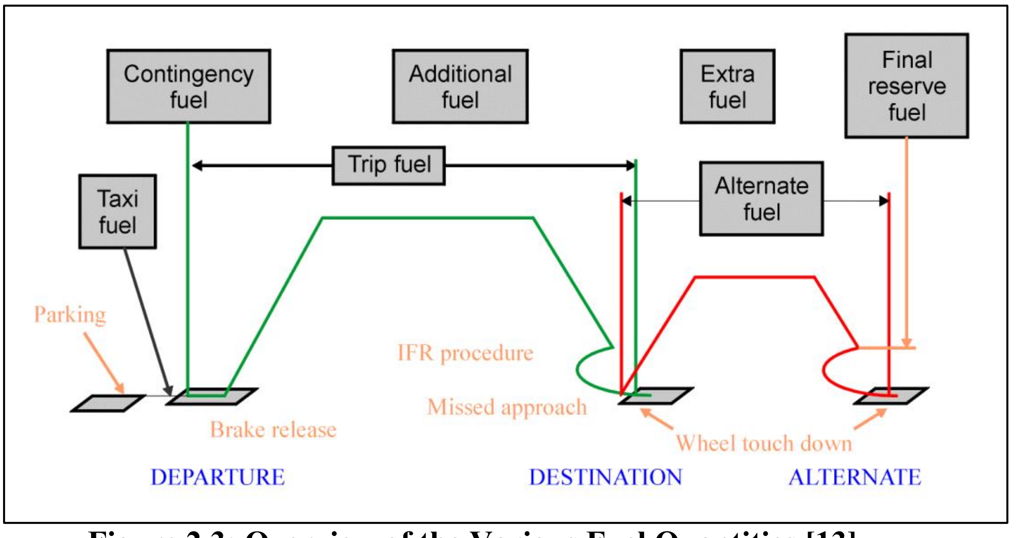


Figure 2.3: Overview of the Various Fuel Quantities [13].

This total quantity ensures that the aircraft has sufficient fuel not only for the planned route, but also for potential contingencies and regulatory reserves.

2.5 Flight Phases: Cruise, Climb, and Descent

2.5.1 Cruise Phase

The cruise phase of flight is critical not only for maintaining airworthiness but also for optimizing the aircraft's operational economy. this section emphasizes the importance of reducing Direct Operating Costs (DOC). These costs include:

- Fixed costs (taxes, insurance, etc.…),
- Flight-time related costs (crew, hourly maintenance costs, depreciation),
- Fuel-consumption related costs.

Choosing the optimal cruise speed and altitude is essential to minimize DOC. Since time and fuel consumption are closely linked, the selection of cruise parameters must balance these factors to achieve economic efficiency.

2.5.1.1 Specific Range

The **specific range (SR)** is a fundamental performance metric defined as the distance traveled per unit of fuel consumed. It can be expressed as:

- Ground distance basis:

$$SR_{ground} = \frac{GS}{FF}$$

- Air distance basis:

$$SR_{air} = \frac{TAS}{FF}$$

where:

- GS = ground speed (nautical miles per hour),
- TAS = true airspeed (nautical miles per hour),
- FF = fuel flow (kilograms per hour).

The unit of SR is nautical miles per kilogram (NM/kg) or nautical miles per ton (NM/ton) [10].

2.5.1.2 Speed Optimization

- **Maximum Range Mach Number (M_{MR})**

Figure 2.4 illustrates the relationship between specific range and Mach number at given weight for a fixed altitude. It is shown that the specific range is maximized with the use of Maximum Range Mach Number (M_{MR}), so in order to minimize fuel consumption for a given distance it is obvious that the aircraft needs to fly at M_{MR}.

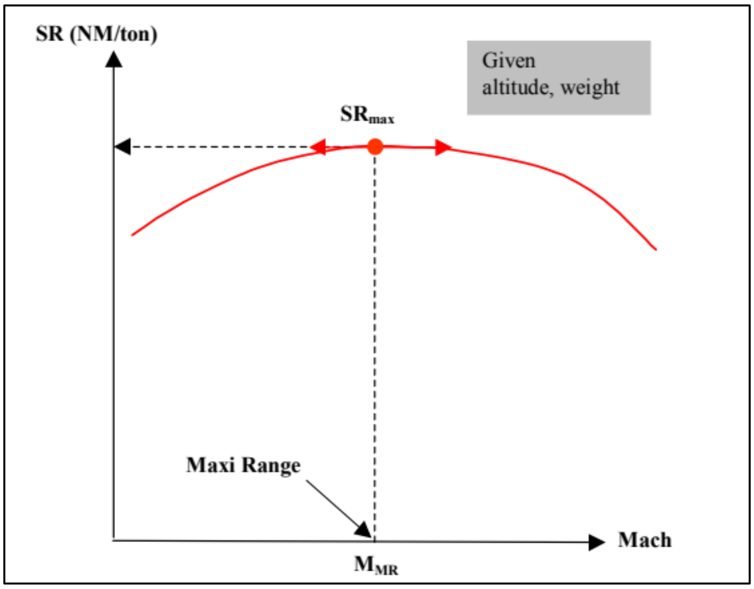


Figure 2.4: Maximum Range Mach Number (M_{MR}).

As the aircraft burns fuel and becomes lighter, the optimal Mach number decreases, requiring continuous adjustment during cruise.

- **Long-Range Cruise Mach Number (M_{LRC})**

The Long-Range Cruise Mach Number (M_{LRC}) is slightly higher than M_{MR}, offering about 99% of the maximum specific range but at a higher speed. This trade-off reduces flight time with minimal fuel penalty, often preferred operationally (see figure 2.5).

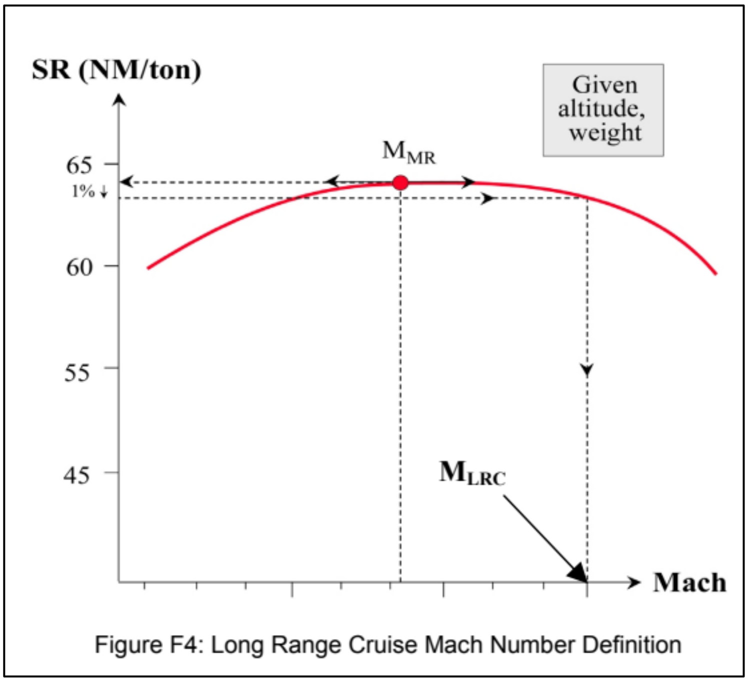


Figure 2.5: Long Range Cruise Mach Number Definition (M_{LRC}).

Like M_{MR}, ML_{RC} decreases as aircraft weight decreases.

➢ Economic Mach Number (M_{ECON})

When considering Direct Operating Costs, the Economic Mach Number (M_{ECON}) as shown in figure 2.6 becomes relevant. DOC includes fixed costs, fuel costs, and time-related costs, expressed as:

$$DOC = CC + CF \times \Delta F + CT \times \Delta T$$

where:

- CC = fixed costs,
- CF = unit fuel cost,
- ΔF = trip fuel,
- CT = hourly time cost,
- ΔT = trip time.

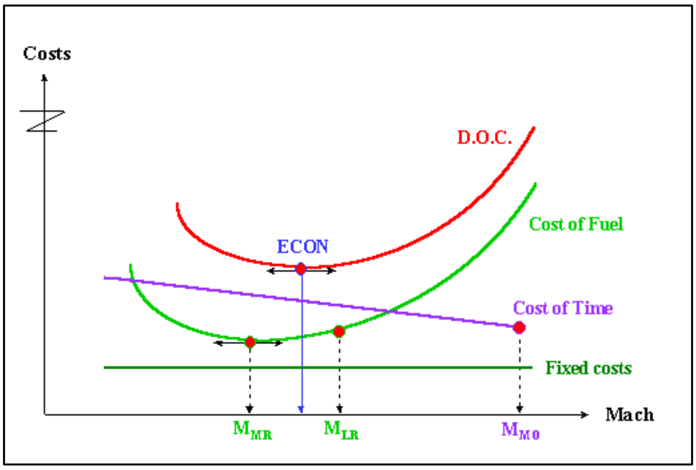


Figure 13.6: Mach Number (MECON) and Costs.

The Cost Index (CI), defined as the ratio of time cost to fuel cost, determines M_{ECON}. A higher CI favors faster speeds to reduce time costs, while a lower CI favors slower speeds to save fuel.

The Cost Index is given with the following formula:

The MECON value depends on the time and fuel cost ratio. This ratio is called cost index (CI), and is usually expressed in kg/min or 100lb/h:

$$\text{Cost Index (CI)} = C_T / C_F$$

- **Constant Mach Number**

Although optimal Mach number varies with weight, aircraft often cruise at a constant Mach number for operational simplicity. This results in suboptimal fuel efficiency as weight decreases during flight (see figure 2.7).

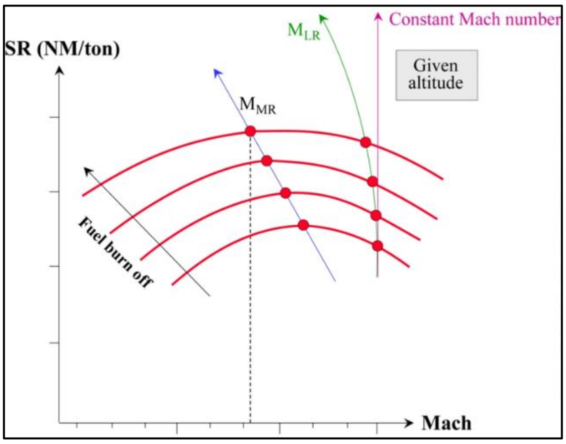


Figure 2.7: Constant Mach Number.

2.5.1.3 Altitude Optimization

- **Optimum Cruise Altitude**

For each weight and Mach number, there is an altitude where specific range is maximized. This **optimum altitude** corresponds to the altitude where the aircraft achieves the best aerodynamic efficiency for the selected speed.

As weight decreases, the optimum altitude increases (see Figure 2.8).

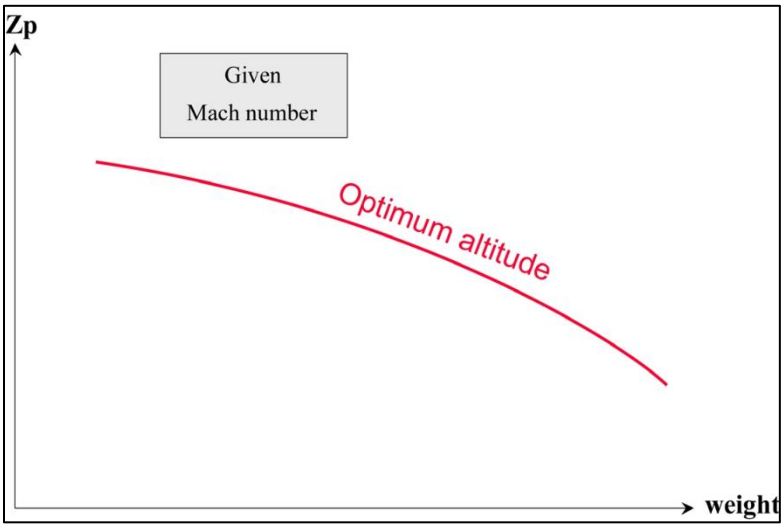


Figure 2.8: Optimum Altitude and Weight at Constant Mach Number.

Wind Effects

Wind impacts ground-specific range. Tailwinds improve ground range, while headwinds reduce it. Sometimes, descending to a lower altitude with more favorable winds yields better ground range than flying at optimum altitude without wind assistance. Figure 2.9 shows the Maximum Range Mach number versus wind variations.

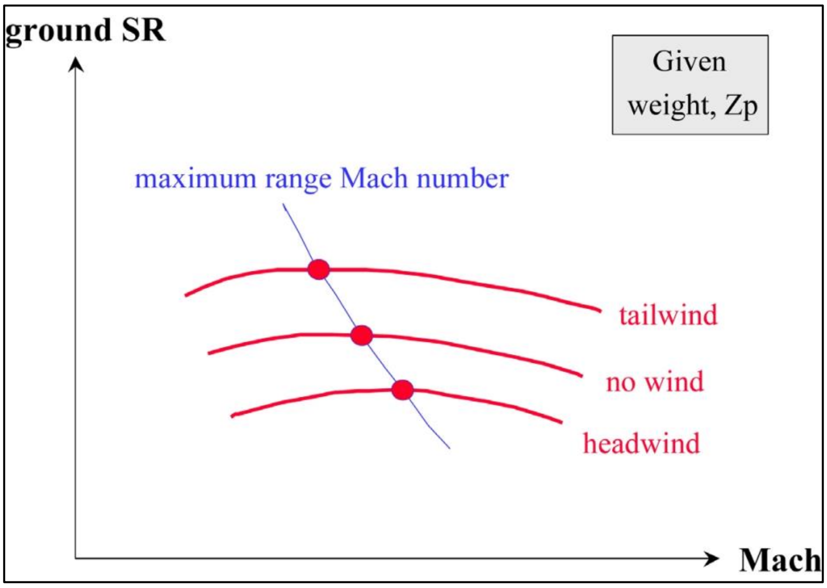


Figure 2.9: M_{MR} and wind influence.

- **Maximum Cruise Altitude**

The maximum cruise altitude is limited by engine thrust capability, which depends on temperature and altitude. At higher temperatures, thrust decreases, limiting maximum altitude at a given Mach number and weight.

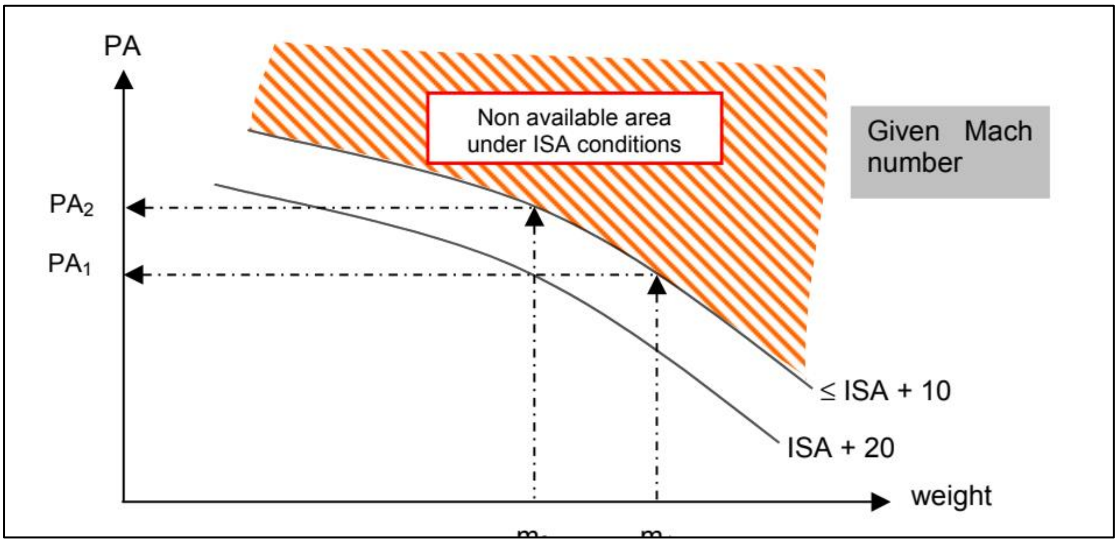


Figure 2.10: Maximum Altitudes at Maximum Cruise Thrust.

From Figure 2.10, it can be deduced that:

- At m1, the maximum altitude is PA_1 for temperatures less than ISA + 10

• At m2, the maximum altitude is PA_2 for temperatures less than ISA + 10, but PA_1 for temperatures equal to ISA + 20

2.5.2 Climb Phase

2.5.2.1 Flight Mechanics

Definitions and Forces

Figure 2.11 illustrates forces acting on an aircraft during climb. The key parameters are:

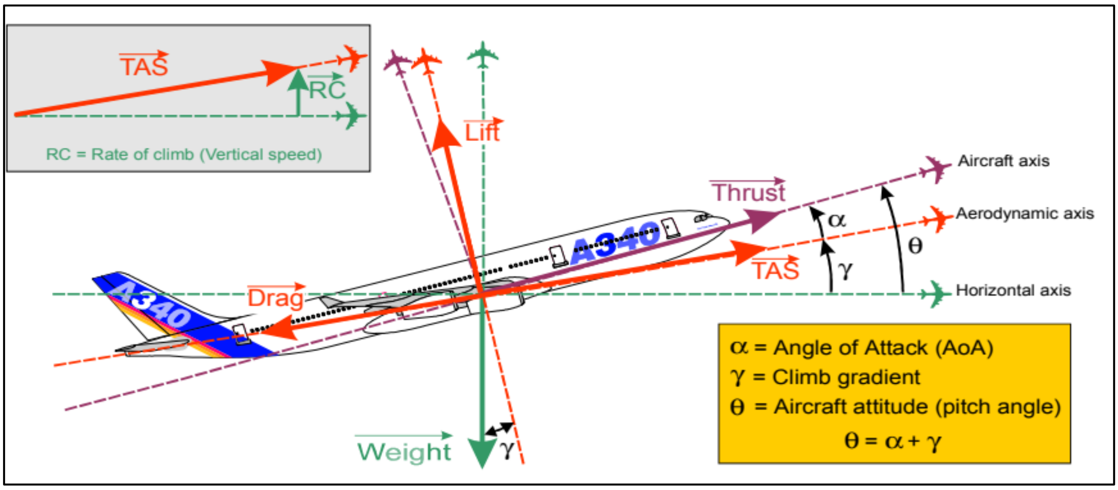


Figure 2.11: Balance of Forces in Climb.

- **Angle of Attack (α):** Angle between aircraft axis and aerodynamic axis.
- **Climb Gradient (γ):** Angle between horizontal axis and aerodynamic axis.
- **Aircraft Attitude (θ):** Pitch angle relative to horizontal.
- **Rate of Climb (RC):** Vertical speed component, positive and measured in feet per minute.

The relationship between these angles is:

$$\theta = \alpha + \gamma$$

Climb Equations

Along the aerodynamic axis, forces balance as:

$$T\cos\ \alpha = D + W\sin\ \gamma$$

Vertically:

$$L = W\cos\ \gamma$$

Assuming small angles ($\sin\ \gamma \approx \gamma$, $\cos\ \gamma \approx 1$, $\cos\ \alpha \approx 1$), climb gradient simplifies to:

$$\gamma = \frac{T - D}{W}$$

Expressed in percentage:

$$\gamma(\%) = 100 \times \left(\frac{T}{W} - \frac{1}{L/D}\right)$$

This shows climb gradient is maximized when excess thrust $(T - D)$ is highest, which occurs near the **Green Dot speed,** the speed for best lift-to-drag ratio.

Rate of Climb (RC)

The rate of climb is:

$$RC = TAS \times \sin\ \gamma \approx TAS \times \gamma = TAS \times \frac{T - D}{W}$$

Maximizing $TAS \times (T - D)$ maximizes rate of climb.

Speed Polar

Figure 2.12 shows thrust and drag versus true airspeed. Climb is possible only when available thrust exceeds required thrust (drag). Climbing below Green Dot speed is inefficient, requiring longer distance and time.

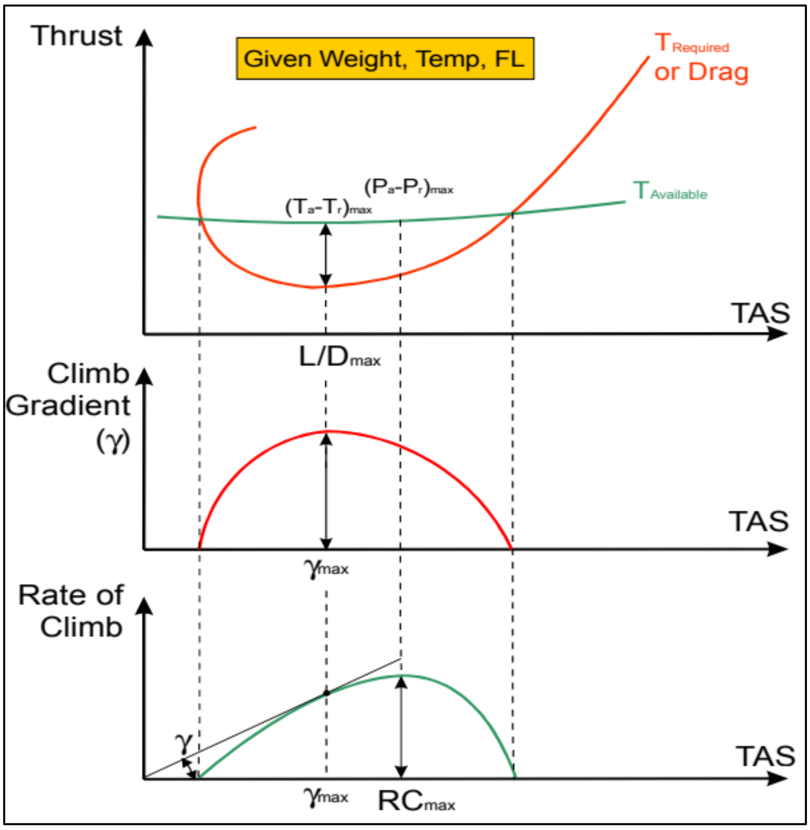


Figure 2.12: Thrust Curves and Speed Polar.

2.5.2.2 Influencing Parameters

- **Altitude:** Increasing altitude reduces air density, lowering thrust and drag, but thrust decreases faster, reducing climb gradient and rate.
- **Temperature:** Higher temperatures reduce thrust and climb performance.
- **Weight:** Increased weight reduces climb gradient and rate.
- **Wind:** Wind affects ground path but not air climb gradient or rate.

2.5.2.4 Climb Speeds

- **IAS/Mach Law:** Climb is usually performed using a constant Indicated Air Speed (IAS) and Mach number. Standard climb profile for A330 family is 250 kt below 10,000 ft, 300 kt up to crossover altitude, then Mach 0.80 above [14].

250 kt / 300 kt / M0.80

- **Maximum Gradient Climb:** At Green Dot speed, minimizing distance to altitude.
- **Maximum Rate Climb:** Minimizes time to altitude.
- **Minimum Cost Climb:** Optimized by Cost Index balancing fuel and time costs.

Cabin Climb

Cabin pressurization is controlled to maintain passenger comfort and limit pressure differential (ΔP). Cabin altitude follows a programmed profile, with climb rate limited to ~1,000 ft/min in fly-by-wire aircraft (Figure 2.13).

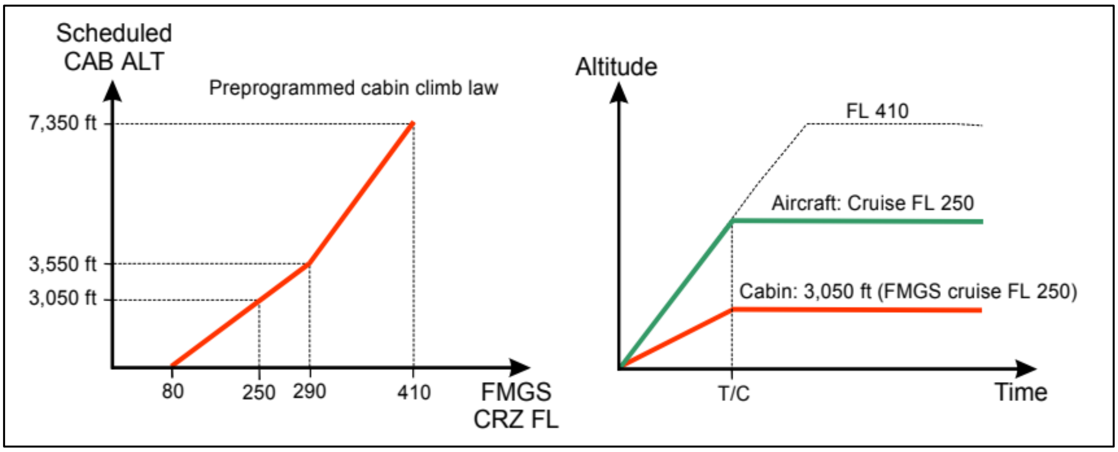


Figure 2.13: A340-200/300 Cabin Climb Law Example.

2.5.3 Descent Phase

2.5.3.1 Flight Mechanics

Definitions and Forces

Figure 2.14 shows forces during descent. The **rate of descent (RD)** is the vertical speed component, negative and in feet per minute.

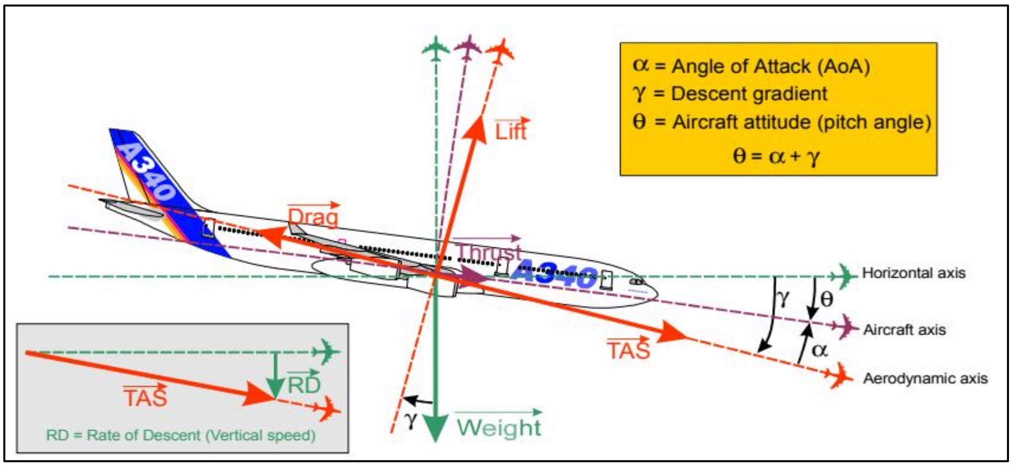


Figure 2.14: Balance of Forces in Descent.

Descent Equations

Descent occurs due to thrust being less than drag. At flight idle thrust:

$$\gamma = \frac{T - D}{W} \approx -\frac{D}{W}$$

Expressed with lift-to-drag ratio:

$$\gamma = -\frac{1}{L/D}$$

In percentage:

$$\gamma(\%) = -100 \times \frac{1}{L/D}$$

Minimum descent gradient magnitude occurs at Green Dot speed.

Rate of Descent (RD)

Rate of descent is:

$$RD = TAS \times \sin\,\gamma \approx TAS \times \gamma = -TAS \times \frac{D}{W}$$

Minimum RD occurs when $TAS \times D$ is minimized.

Speed Polar

Figure 2.15 illustrates drag and descent parameters versus TAS. Minimum descent gradient and rate occur near Green Dot speed.

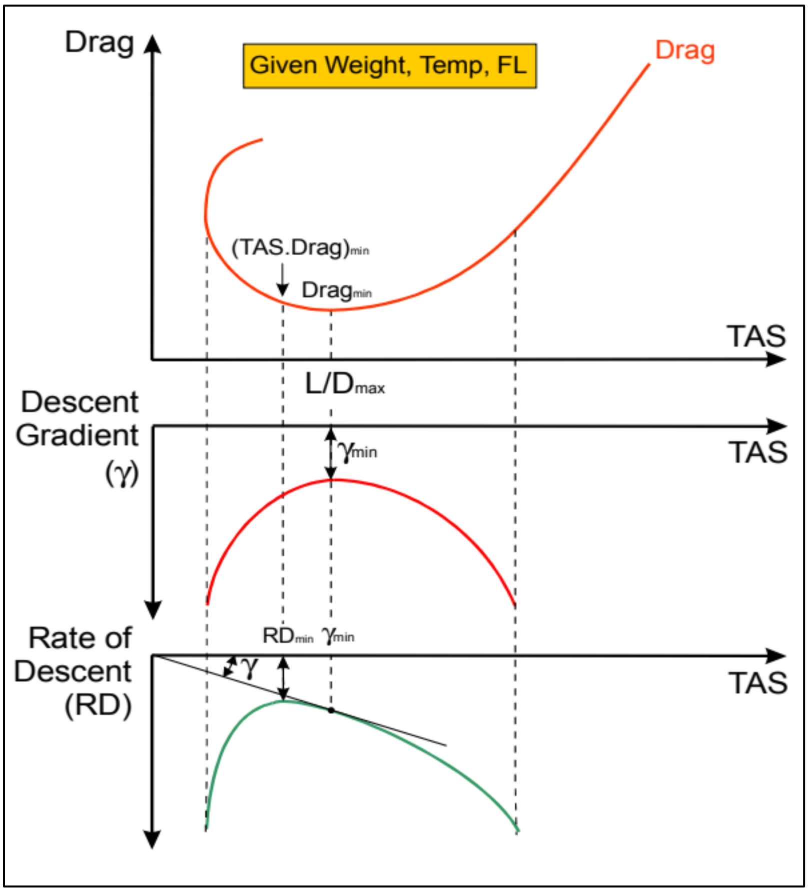


Figure 2.15: Drag Curve and Speed Polar.

2.5.3.2 Influencing Parameters

- **Altitude:** Air density changes affect drag and descent parameters variably.
- **Temperature:** TAS increases with temperature at constant Mach or IAS, offsetting drag changes.
- **Weight:** Heavier weight reduces descent gradient and rate.
- **Wind:** Wind affects ground path but not air descent gradient or rate [10].

2.5.3.3 Descent Speeds

Mach/IAS Law: Descent is typically conducted using a constant Mach number followed by constant Indicated Air Speed (IAS).

For the A330 family, the standard descent profile is:

M0.80 / 300 kt / 250 kt

- Above crossover altitude: descend at Mach 0.80.
- Below crossover altitude: descend at 300 kt IAS, then slow to 250 kt IAS below 10,000 ft [14].

Minimum Gradient Descent: At Green Dot speed, maximizing altitude over distance; used in engine failure (drift down).

Minimum Rate Descent: Lower than Green Dot speed but operationally inefficient.

Minimum Cost Descent: Optimized by Cost Index.

Emergency Descent: Performed at M_{MO}/V_{MO} for rapid altitude loss, possibly with airbrakes extended.

Cabin Descent

Cabin pressurization is managed to maintain comfort and pressure limits. FMGS calculates cabin descent time with vertical speed limits (-750 ft/min). Repressurization segments limit aircraft vertical speed to protect cabin integrity if cabin descent time exceeds aircraft descent time.

Chapter 3

Aircraft, Calculation Methodology, Database Design, and Application Development

This chapter details the methodology applied for the development of the flight plan optimization application for the A330-200 in order to determine the trip fuel and flight time, articulating:

- The theoretical foundations (use of climb, descent, and cruise tables, calculation formulas).
- The software architecture (pymysql, Tkinter/TTK, Pillow, traceback).

3.1 Aircraft

3.1.1 Dimensions of Airbus A330-200

The physical dimensions of the Airbus A330-200 are summarized in Table 3.1. This aircraft features a length of 58.8 meters and a wingspan measuring 60.3 meters, providing a balanced aerodynamic profile suitable for long-haul flights. The height of the aircraft reaches 17.40 meters, while the fuselage diameter is 5.64 meters. The cabin width is approximately 5.26 meters, and the cabin length extends to 45 meters, allowing for flexible seating configurations and passenger comfort (see figure 3.1).

Table 3.1: Dimensions of the Airbus A330-200 [15].

Parameter	Value
Length	58.8 m
Wingspan	60.3 m
Height	17.40 m
Fuselage Diameter	5.64 m
Maximum Cabin Width	5.26 m
Cabin Length	45 m

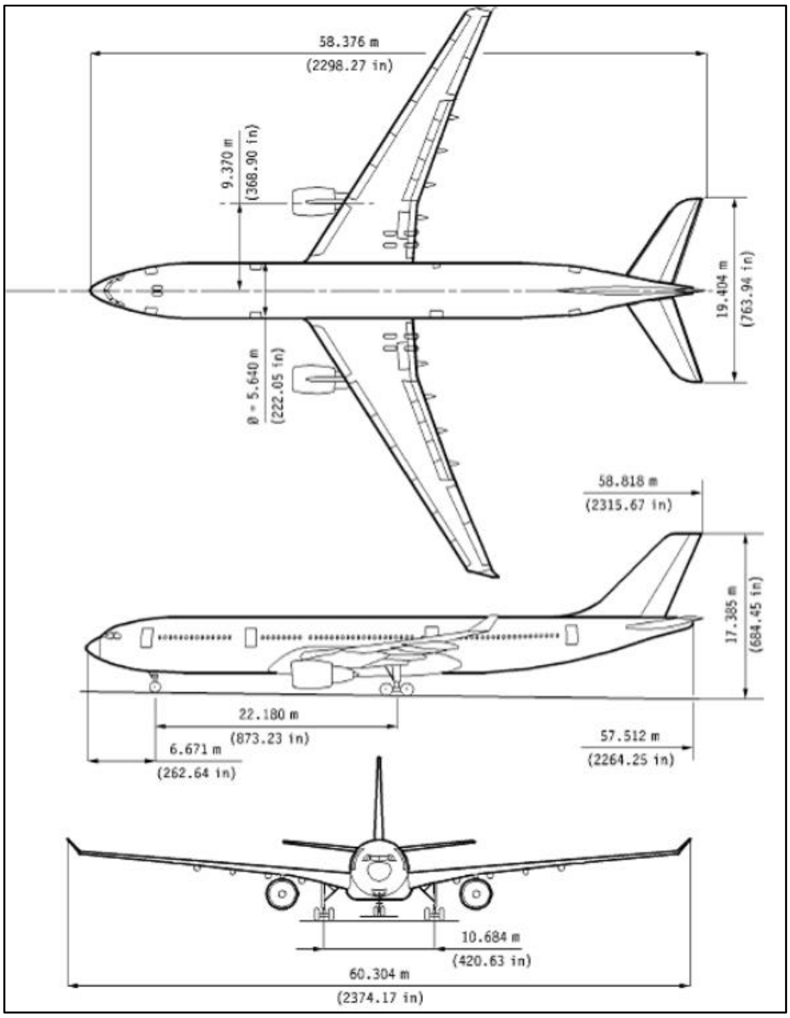


Figure 3.1: Dimensions of the Airbus A330-200 [15].

3.1.2 Technical Characteristics and Performance of the Airbus A330-200

Table 3.2 presents the key technical specifications and performance parameters of the Airbus A330-200. The aircraft is equipped with engines delivering a unit thrust ranging from 302 to 320 kilonewtons. It can accommodate 253 passengers in a three-class layout, 293 passengers in a two-class layout, and up to 380 passengers in a single-class configuration. The A330-200 boasts a maximum range of 13,400 kilometers, with a cruise speed of Mach 0.82 (approximately 896 km/h) and a maximum speed of Mach 0.86. The takeoff distance required is 2,220 meters. The maximum takeoff weight varies between 202 and 230 tonnes, while the maximum landing weight is 182 tonnes.

Table 3.2: Characteristics and Performance of the Airbus A330-200 [15].

Parameter	Value
Engine Thrust (per engine)	302 - 320 kN
Passenger Capacity	253 (3-class) / 293 (2-class) / 380 max (single class)
Maximum Range	13,400 km
Cruise Speed	Mach 0.82 (896 km/h)
Maximum Speed	Mach 0.86
Takeoff Distance	2,220 m
Maximum Takeoff Weight (MTOW)	202 - 230 tonnes
Maximum Landing Weight	182 tonnes

3.2 Calculation Methods and Mathematical Modeling

The calculation process is modular and follows the actual sequence of a flight, divided into climb, cruise, and descent, with operational procedures included at the end.

3.2.1 Determination of Mass at Top of Climb (M_{toc})

Query the climb table for the selected flight level (FL) and Estimated Take-Off Weight (E_{TOW}).

Extract $Fuel_{climb}$, $Distance_{climb}$, and time of climb (t_{climb}).

Calculate Mtoc:

$$M_{toc} = E_{TOW} - Fuel_{climb}$$

where E_{TOW} is the Estimated Takeoff Weight (in tons) and $Fuel_{climb}$ is the fuel consumed during climb.

3.2.2 Determination of Mass at Top of Descent (M_{TOD})

First, let's calculate the cruise air distance D_{cruise}. The total air distance D_{air} is given by:

$$D_{air} = D_{climb} + D_{cruise} + D_{descent}$$

We start with an arbitrary mass and the flight level (FL) in the descent table to extract the following information:

$D_{descent}$: air distance of descent

$t_{descent}$: descent time

$Fuel_{descent}$: fuel consumption during descent

For converting ground distances to air distances and vice versa, we use the formula:

$$\frac{D_{air}}{D_{ground}} = \frac{TAS}{TAS + V_{wind}}$$

or equivalently,

$$D_{cruise} = D_{air} - (D_{climb} + D_{descent})$$

Next, we calculate the average cruise mass M_{mc} as:

$$M_{mc} = \frac{M_{toc} + M_{tod\_estimated}}{2}$$

To estimate M_{tod}, proceed as follows:

Using the flight level and an estimated cruise mass M_{mc}, enter the cruise table to obtain:

FF: hourly fuel consumption per engine

TAS: true airspeed during cruise

SR: Specific Range

The cruise fuel consumption is then:

$$Fuel_{cruise} = FF \times n \times \frac{D_{cruise}}{TAS}$$

where n is the number of engines.

Or with:

$$\mathrm{Fuel}_{\mathrm{cruise}} = \frac{\mathrm{D}_{\mathrm{cruise}}}{\mathrm{SR}}$$

The estimated M_{tod} is:

$$\mathrm{M}_{\mathrm{tod\_estimated}} = \mathrm{M}_{\mathrm{toc}} - \mathrm{Fuel}_{\mathrm{c}}$$

Thus,

$$\mathrm{M}_{\mathrm{mc}} = \frac{\mathrm{M}_{\mathrm{toc}} + \mathrm{M}_{\mathrm{tod\_estimated}}}{2}$$

With this average cruise mass and the flight level, re-enter the cruise table for a second iteration to refine the estimate and obtain:

FF_n: new hourly fuel consumption

TAS_n: new true airspeed during cruise

SR_n: new Specific Range

The new cruise fuel consumption is:

$$\mathrm{Fuel}_{\mathrm{cruise\_n}} = \mathrm{FF}_{\mathrm{n}} \times \mathrm{n} \times \frac{\mathrm{D}_{\mathrm{acruise}}}{\mathrm{TAS}_{\mathrm{n}}}$$

Or with:

$$\mathrm{Fuel}_{\mathrm{cruise\_n}} = \frac{\mathrm{D}_{\mathrm{cruise}}}{\mathrm{SRn}}$$

The cruise time is:

$$\mathrm{t}_{\mathrm{cruise}} = \frac{\mathrm{D}_{\mathrm{cruise}}}{\mathrm{TAS}_{\mathrm{n}}}$$

Finally, the actual M_{tod} mass is:

$$M_{tod\_actual} = M_{toc} - Fuel_{cruise\_n}$$

3.2.3 Determination of the landing mass $M_{landing}$

To refine the estimate of the previously calculated descent distance, re-enter the descent table using the actual TOD mass M_{tod_actual} to finally obtain updated data:

$t_{descent\_n}$: new descent time

$Fuel_{descent\_n}$: new descent fuel consumption

$D_{descent\_n}$: new descent distance

Thus, the landing mass is:

$$M_{landing} = M_{tod\_actual} - Fuel_{descent\_n} - Fuel_{procedure}$$

where the procedure fuel consumption is fixed by operational instructions.

3.2.4 Trip fuel and Flight time

The trip fuel is given by:

$$\text{trip fuel} = M_{tow} - M_{landing}$$

The planned flight time is:

$$\text{time flight} = t_{climb} + t_{cruise\_n} + t_{descent\_n} + t_{procedure}$$

3.2.5 Linear Interpolation

When the exact value of a parameter (such as weight or flight level) is not listed in the reference tables, linear interpolation is used to estimate the corresponding variable. This method calculates a value proportionally between two known points and provides a practical and accurate approximation for intermediate values.

The formula for linear interpolation is:

$$y = y_1 + \frac{(x - x_1)}{(x_2 - x_1)} \times (y_2 - y_1)$$

where:

x is the intermediate value for which we want to estimate y,

x_1 and x_2 are the known values surrounding x,

y_1 and y_2 are the corresponding values of the function at x_1 and x_2 [16].

3.2.6 Use of the A330-200 FCOM and Associated Tables

In this study, the data are extracted from the official tables of the Flight Crew Operating Manual (FCOM) for the Airbus A330-200.

The FCOM is a comprehensive technical manual intended for flight crews, providing detailed information on operational procedures, aircraft performance, and limitations. The tables used in this work are taken from the sections covering climb, cruise, and descent. They contain precise data on fuel consumption, flight times, distances air covered, and true airspeeds (TAS) as functions of flight level (FL) and aircraft weight.

These tables are essential for accurately estimating flight parameters and optimizing fuel and weight management. They also enable interpolation when exact values are not directly available, ensuring reliable modeling that complies with manufacturer recommendations.

For reference and completeness, the original performance tables from the FCOM are provided in Annex A.

3.3 Application development

3.3.1 Code Structure

The flowchart below illustrates the main operational workflow of the Do-Plan application.

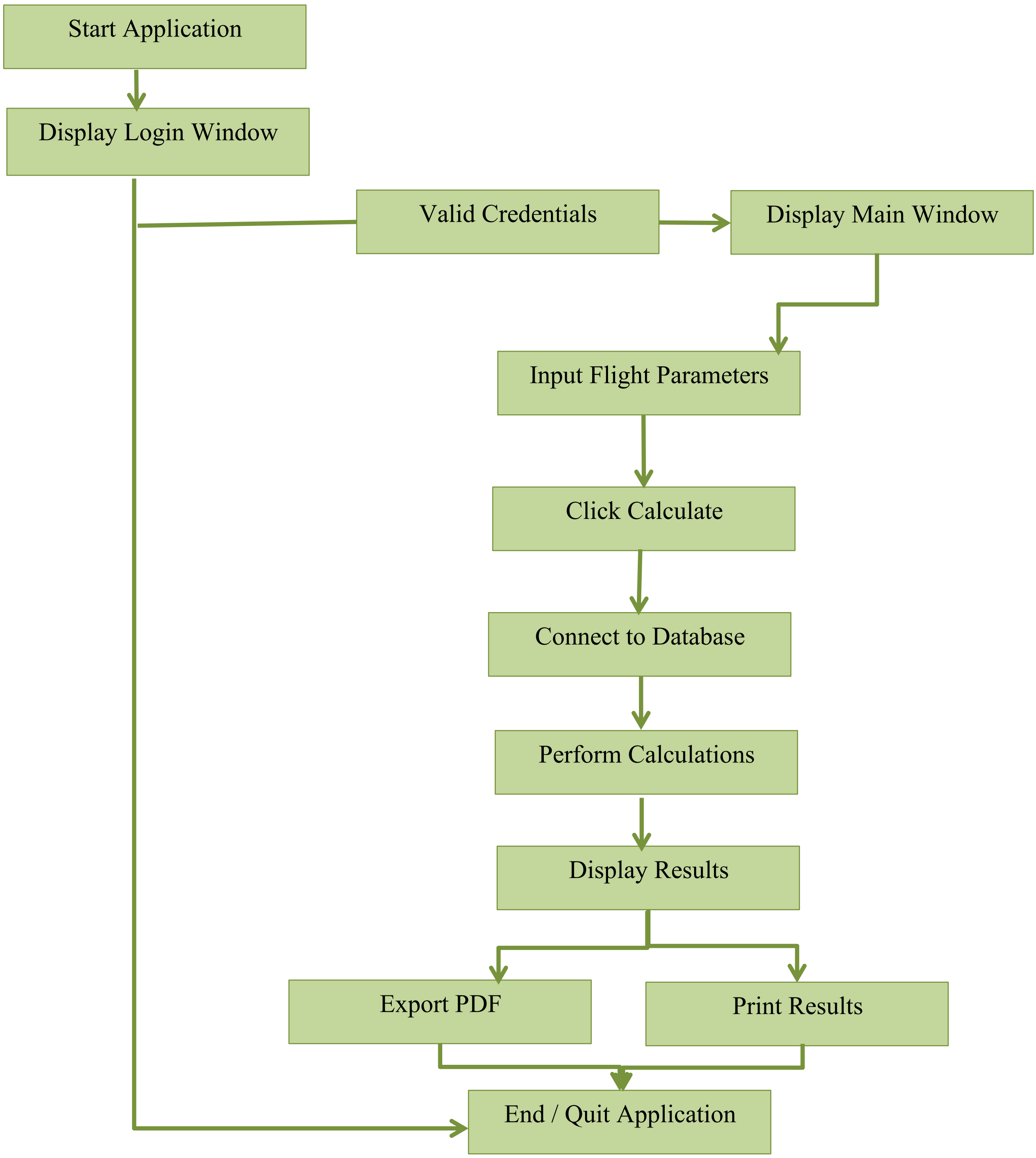


Figure 3.2: Functional Flowchart of the Do-Plan Application.

3.3.1 Environment and Tool

3.3.1.1 MySQL Workbench

It is a visual tool for designing, creating, and maintaining MySQL databases. It offers data modeling, SQL development, and comprehensive administration tools for configuration, management, and backup [17].

- **Database and Table Creation**

The use of an example from SQL code will provide the keys steps of the creation of the database:

```
USE Flight_Data;
CREATE TABLE IF NOT EXISTS Descent_M80(
 id INT AUTO_INCREMENT PRIMARY KEY,
  FL INT NOT NULL,
  Weight INT NOT NULL,
  Time float NOT NULL,
  Fuel INT NOT NULL,
   Distance INT NOT NULL


);
```

Figure 3.3: commands used to create the table Descent_M80.

This script creates a table Descent_M80 in the Flight_Data database, defining columns for flight level (FL), weight, time, fuel, and distance, with an auto-increment primary key id.

- **Data Insertion:**

This inserts multiple rows representing descent performance data at various flight levels and weights as shown below in Figure 3.4:

```sql
TRUNCATE TABLE Descent_M80;
INSERT INTO Descent_M80 (FL, Weight, Time, Fuel, Distance) VALUES
(410, 150, 20.7, 367, 128),
(390, 150, 19.8, 354, 121),
(390, 200, 23.0, 410, 141),
(15, 150, 0, 0, 0),
(15, 200, 0, 0, 0);
```

Figure 3.4: commands used to insert data.

- **Data Cleaning and Constraints:**

This removes duplicate rows and adds a unique index to ensure data integrity as shown below.

```sql
DELETE FROM Descent_M80
WHERE id NOT IN (
  SELECT MIN_id FROM (
    SELECT MIN(id) AS MIN_id
    FROM Descent_M80
    GROUP BY FL, Weight, Time, Fuel, Distance
  ) AS subquery
);
ALTER TABLE Descent_M80
ADD UNIQUE INDEX unique_performance (FL, Weight, Time, Fuel, Distance);
```

Figure 3.5: SQL commands used to remove duplicate rows and add a unique index.

- **Data Querying and Aggregation**

The Figure 3.6 illustrates the queries count records per flight level and retrieve detailed descent data with formatted time values.

```
SELECT FL, COUNT(*) AS nb_lignes
FROM  Descent_M80
GROUP BY FL
ORDER BY FL DESC;

SELECT
    id,
    FL,
    Weight,
    CAST(Time AS DECIMAL(4,1)) AS Time,
    Fuel,
    Distance
FROM Descent_M80;
```

Figure 3.6: commands used to count records.

The following tables are central to the application:

Table 3.3: Tables used in database.

Table Name	Description	Main Fields
Climb_Stats (for table of climb M80 & ISA)	Climb performance data	FL, Weight, Time, Fuel, Distance, TAS
Cruise_ISAM80	Cruise performance data at M80 (fuel, speed)	FL, Weight, FF, TAS
Cruise_ISAM82	Cruise performance data at M82 (fuel, speed)	FL, Weight, FF, TAS
Descent_M80	Descent performance data	FL, Weight, Distance, Time, Fuel

3.3.1.2 Python 3.13

It is the latest release in the Python 3.x series. A high-level, general-purpose programming language, Python 3.13 introduces new syntax features, performance improvements, and updated standard libraries, while remaining compatible with most existing Python 3 code. It focuses on code readability and developer productivity [18].

As part of the technical plan, several Python libraries were used to facilitate the project's objectives:

- **pymysql**

  This library allows you to connect to a MySQL database. It provides functionality for executing SQL queries, managing transactions, and interacting with data [19].

- **traceback**

  This library is used to trace and display errors in a readable manner. It diagnoses problems in the code [18].

- **tkinter**

  This is Python's native graphical interface. It allows you to create windows, buttons, menus, input fields, etc. It is used here to design the application's user interface. It uses add-ons such as:

  - ttk: Provides modern widgets (drop-down menus, tabs, etc.).

  - filedialog: Allows you to select files via a dialog box.

  - messagebox: Displays information, error, or confirmation messages [18].

- **Pillow (PIL)**

  A library specialized in image processing: opening, displaying, resizing, and saving in various formats [20].

- **fpdf**

  A library used to add text, images, tables, and organize the layout of a document. Its main function is to generate PDF files [21].

- **OS**

  A standard library providing functions for interacting with the operating system [18].

- **platform**

  Standard library used to identify the operating system (Windows, Linux, macOS) and the version of Python used [18].

- **win32print and win32api**

  These are two libraries specific to the Windows environment, provided by the pywin32 module.

  - win32print: Manages interaction with printers (list, selection, status, etc.).

- win32api: Provides access to Windows system features (executing commands, accessing the registry, etc.) [22].

The figure 3.7 below illustrate these libraries in order.

```
import pymysql
import traceback
import tkinter as tk
from tkinter import ttk, filedialog, messagebox
from PIL import Image, ImageTk
from fpdf import FPDF
import os
import platform

# For Windows printing
if platform.system() == "Windows":
    import win32print
    import win32api
```

Figure 3.7: libraries used in the code.

- **Database Parameters**

Connection to the MySQL database is configured using a set of parameters:

```
# -------------------- Database Parameters --------------------
DB_HOST = 'localhost'
DB_NAME = 'Flight_Data'
DB_USER = 'root'
DB_PASSWORD = 'Dorsafme'
```

Figure 3.8: Commands for data import.

These parameters specify the database location, name, and user credentials. They are used whenever the program needs to fetch or interpolate aircraft performance data.

- **Database connection**

All aircraft performance data is managed in a MySQL relational database, designed and maintained using MySQL Workbench. This tool enables graphical modeling, table creation, data import, and query testing, ensuring data integrity and scalability.

- **Querying the database:**

Here, an SQL query and fetch a row from the Climb_Stats table.

```
with connection.cursor() as cursor:
    query = """
        SELECT FL, Weight, Time, Fuel, Distance, TAS
        FROM Climb_Stats
        WHERE FL = %s AND Weight = %s
        LIMIT 1;
    """
    cursor.execute(query, (fl, weight))
    row = cursor.fetchone()
```

Figure 3.9: Command to execute a SQL query and fetch a row from the Climb_Stats table.

- **Helper Functions**

The code defines several helper functions to support calculations and data formatting:

Linear interpolation:

Allows estimation of performance values (fuel, time, speed) between known data points in the database.

This is a standard Python function for linear interpolation.

```
def linear_interpolation(x, x1, y1, x2, y2):  3 usages
    if x2 == x1:
        return y1
    return y1 + (x - x1) * (y2 - y1) / (x2 - x1)
```

Figure 3.10: linear interpolation function.

Time formatting:

Converts decimal hours to a human-readable «hours and minutes» format for display.

```
def format_hours_to_hm(decimal_hours):  5 usages
    hours = int(decimal_hours)
    minutes = int(round((decimal_hours - hours) * 60))
    return f"{hours} h {minutes} min"
```

Figure 3.11: Time convertor.

Wind correction:

Adjusts the ground distance to air distance using wind speed and true airspeed, ensuring accurate fuel and time calculations.

```
def adjust_for_wind(ground_distance, tas, wind_speed):  1 usage
    denominator = tas + wind_speed
    if denominator == 0:
        return ground_distance
    return ground_distance * tas / denominator
```

Figure 3.12: Wind correction function.

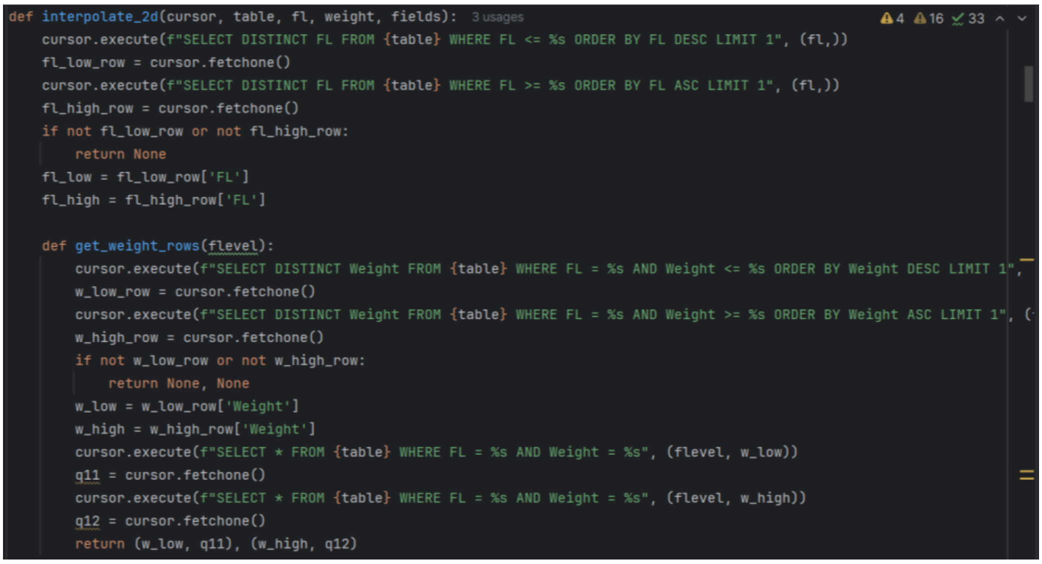
Insert a screenshot or code snippet showing one or two of these helper functions.

- **Calculation Functions**

These functions form the computational core of the application:

2D Interpolation:

Fetches and interpolates performance data (such as fuel burn, time, or speed) for any given combination of flight level and weight, even if the exact values are not present in the database.



```
def interpolate_2d(cursor, table, fl, weight, fields):
    cursor.execute(f"SELECT DISTINCT FL FROM {table} WHERE FL <= %s ORDER BY FL DESC LIMIT 1", (fl,))
    fl_low_row = cursor.fetchone()
    cursor.execute(f"SELECT DISTINCT FL FROM {table} WHERE FL >= %s ORDER BY FL ASC LIMIT 1", (fl,))
    fl_high_row = cursor.fetchone()
    if not fl_low_row or not fl_high_row:
        return None
    fl_low = fl_low_row['FL']
    fl_high = fl_high_row['FL']

    def get_weight_rows(flevel):
        cursor.execute(f"SELECT DISTINCT Weight FROM {table} WHERE FL = %s AND Weight <= %s ORDER BY Weight DESC LIMIT 1",
        w_low_row = cursor.fetchone()
        cursor.execute(f"SELECT DISTINCT Weight FROM {table} WHERE FL = %s AND Weight >= %s ORDER BY Weight ASC LIMIT 1", (
        w_high_row = cursor.fetchone()
        if not w_low_row or not w_high_row:
            return None, None
        w_low = w_low_row['Weight']
        w_high = w_high_row['Weight']
        cursor.execute(f"SELECT * FROM {table} WHERE FL = %s AND Weight = %s", (flevel, w_low))
        q11 = cursor.fetchone()
        cursor.execute(f"SELECT * FROM {table} WHERE FL = %s AND Weight = %s", (flevel, w_high))
        q12 = cursor.fetchone()
        return (w_low, q11), (w_high, q12)
```

Figure 3.13: Interpolation Function.

Climb, Cruise, and Descent Calculations:

Each phase of flight (climb, cruise, descent) is handled by a dedicated function that uses interpolated data to compute fuel consumption and elapsed time as the figure 3.14 shows.

```python
def get_cruise_data_interpolated(cursor, fl, cruise_weight, mach, isa, output_text):
    if mach == "M82" and isa == "ISA":
        table = "Cruise_ISAM82"
    elif mach == "M82" and isa == "ISA+10":
        table = "Cruise_M82_ISA10"
    elif mach == "M80" and isa == "ISA":
        table = "Cruise_ISAM80"
    else:
        output_text.insert(tk.END, "Invalid Mach/ISA combination\n")
        return None, None

    data = interpolate_2d(cursor, table, fl, cruise_weight, ['KG_H_ENG', 'TAS_KT'])
    if data is None:
        output_text.insert(tk.END, "No cruise data (even after interpolation)\n")
        raise ValueError("No cruise data")
    output_text.insert(tk.END, f"Cruise interpolation: consumption={data['KG_H_ENG']:.2f} kg/h, speed={data['TAS_KT']:.2f} kt\n")
    return data['KG_H_ENG'], data['TAS_KT']
```

Figure 3.14: Calculation Workflow for Fuel Consumption and Elapsed Time Using Interpolated Data.

Iterative Calculation:

The program uses an iterative approach to refine the estimate mass at top of descent (Mtod), taking into account all fuel burns and required reserves.

```python
def calculate_mtod_iterative_with_conditions(cursor, fl, engines, mtoc_kg, mtod_init_kg, dac, output_text, mach, isa, tol
    mtod_estimate = mtod_init_kg
    output_text.insert(tk.END, "Starting MTOD iteration\n")
    for i in range(1, max_iter+1):
        mmc = (mtoc_kg + mtod_estimate) / 2
        mmc_t = mmc / 1000
        output_text.insert(tk.END, f"Iteration {i}: Mmc = {mmc_t:.3f} t\n")
        ff, tas = get_cruise_data_interpolated(cursor, fl, mmc_t, mach, isa, output_text)
        if ff is None or tas is None:
            output_text.insert(tk.END, "Error in cruise data\n")
            return None, i
        fuel_cruise = ff * engines * (dac / tas)
        mtod_new = mtoc_kg - fuel_cruise
        delta = abs(mtod_estimate - mtod_new)
        output_text.insert(tk.END, f"  FF={ff:.3f} kg/h, TAS={tas:.3f} kt, Fuel cruise={fuel_cruise:.3f} kg, Mtod={mtod_new/1000:.3f} t, del
        if delta < tolerance:
            output_text.insert(tk.END, f"Converged after {i} iterations\n")
            break
        mtod_estimate = mtod_new
    else:
        output_text.insert(tk.END, "No convergence\n")
    return mtod_new, i
```

Figure 3.15: Iterative Calculation.

- **Tkinter Interface**

The graphical user interface is constructed using Tkinter and ttk, and is logically divided into several sections:

Input Fields:

Users can enter flight parameters such as Flight Level, Weight, Distance, Wind, Mach, and ISA conditions. Dropdown menus are used for categorical data to minimize input errors.

```python
class ApplicationDoPlan(tk.Tk):
    def __init__(self):
        super().__init__()
        self.title("Do-Plan")
        self.geometry("900x700")
        self.configure(bg="#001f3f")

        style = ttk.Style(self)
        style.theme_use('clam')
        style.configure("DoFlight.TLabelframe",
                        background="#001f3f",
                        bordercolor="#001f3f",
                        borderwidth=2,
                        relief="groove")
        style.configure("DoFlight.TLabelframe.Label",
                        background="#001f3f",
                        foreground="white",
                        font=("Arial", 14, "bold"))
        style.configure("DoFlight.TFrame", background="#001f3f")
        style.configure("TLabel", background="#001f3f", foreground="white", font=("Arial", 12))
        style.configure("Blue.TButton", background="#0074D9", foreground="white", font=("Arial", 12, "bold"))
        style.map("Blue.TButton", background=[('active', '#005fa3')])
        style.configure("Red.TButton", background="#FF4136", foreground="white", font=("Arial", 12, "bold"))
        style.map("Red.TButton", background=[('active', '#cc342a')])
        style.configure("Green.TButton", background="#2ECC40", foreground="white", font=("Arial", 12, "bold"))
        style.map("Green.TButton", background=[('active', '#28a737')])

        self.fl_var = tk.StringVar(value="410")
        self.weight_var = tk.StringVar(value="200")
        self.distance_var = tk.StringVar(value="500")
        self.distance_type_var = tk.StringVar(value="Air Distance")
        self.engines_var = tk.StringVar(value="2")
        self.mtod_initial_var = tk.StringVar(value="150")
        self.wind_var = tk.StringVar(value="0")
        self.mach_var = tk.StringVar(value="M82")
        self.isa_var = tk.StringVar(value="ISA")
        self.procedure_value = 240
        self.procedure_time_value = 6

        self.create_widgets()

    def create_widgets(self):
        input_frame = ttk.LabelFrame(self, text="Flight Parameters", padding=10, style="DoFlight.TLabelframe")
        input_frame.pack(fill="x", padx=10, pady=10)

        self.add_field(input_frame, "Flight Level (FL)", self.fl_var, 0)
        self.add_field(input_frame, "Weight (tonnes)", self.weight_var, 1)
        self.add_field(input_frame, "Distance (NM)", self.distance_var, 2)
```

Figure 3.16: Generate the interface.

- **User Interface Description**

The application developed for this study includes a secure login system and a user-friendly main interface for flight planning calculations.

Login Window:

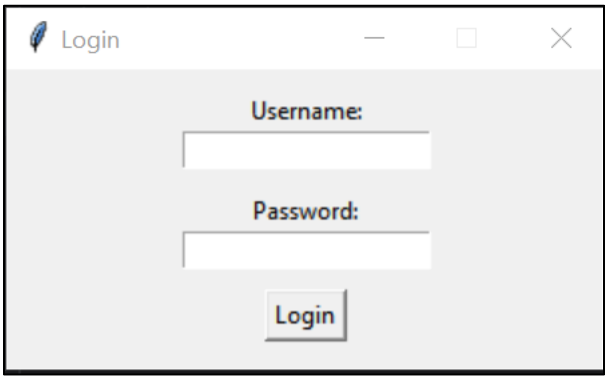


Figure 3.17: The login window.

As shown in Figure 3.18, when the application is launched, a login window appears, requiring the user to enter a username and password. This security feature ensures that only authorized users can access the main functionalities of the program. The user must enter valid credentials to proceed. If the credentials are incorrect, access is denied and an error message is displayed.

Main Application Interface:

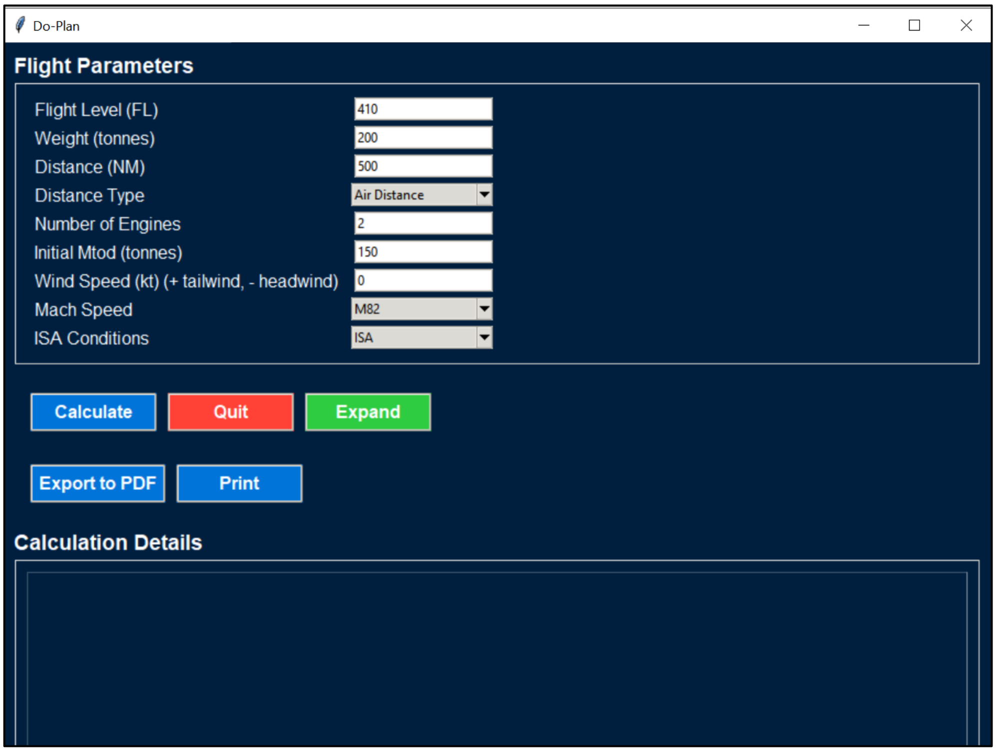


Figure 3.18: The technical flight plan interface.

Once logged in, the user is presented with the main interface (Figure 3.19), which is organized into three main sections:

Flight Parameters Panel:

This section allows the user to input all necessary flight parameters. The fields include:

- Flight Level (FL): the planned cruising altitude,
- Weight (tons): the estimated takeoff weight,
- Distance (NM): the intended flight distance,
- Distance Type: a dropdown to select either air distance or ground distance,
- Number of Engines: the total number of engines on the aircraft,
- Initial Mtod (tons): the initial estimate for the mass at top of descent,
- Wind Speed: the expected wind component (positive for tailwind, negative for headwind),
- Mach Speed: the selected Mach number (M0.82 or M0.80),
- ISA Conditions: the selected standard atmosphere condition (ISA or ISA+10).

Action Buttons:

Below the parameters panel, several buttons allow the user to interact with the application:

- Calculate: runs the flight calculation based on the entered parameters,
- Quit: closes the application,
- Expand: enlarges the window for better visibility,
- Export to PDF: saves the calculation results as a PDF file,
- Print: sends the results to the default printer.

Calculation Details Display:

The lower part of the interface contains a large text area where the results of the calculations are displayed. This section provides a detailed breakdown of each phase of the flight, including climb, cruise, descent, the real Mtod after iterations fuel trip and flight time.

3.4 Summary

This chapter presents the Airbus A330-200, detailing its main technical characteristics. Then it has presented the integration of a database in coding steps, the structure and logic of the tables used, the mathematical modeling and calculation methods, and the software architecture of the application. The chosen approach ensures reliability, precision, and scalability for optimizing the A330-200 flight plan.

Chapter 4

Results Discussion

4.1 Introduction

This chapter presents a comprehensive evaluation of the results produced by the software, Do-Plan, using the code methodology and calculations developed in Chapter 3 and the context of operational flight planning for the Airbus A330-200. This approach is structured in two main phases.

Initially, a detailed worked example is presented to illustrate the calculation process and computational logic embedded within the Do-Plan application. This example serves to elucidate the operational workflow, the step-by-step progression of the algorithm, and the underlying mathematical models employed for flight performance estimation.

Subsequently, a series of comparative analyses is conducted, where-in the outputs generated by Do-Plan are systematically compared to those produced by JetPlan software. These comparisons are for a flight scenarios and destinations, in order to thoroughly assess the reliability, robustness, and generalizability of the Do-Plan tool for each scenario.

The objective of this work is to understand in detail the logic and accuracy of Do-Plan calculations through a representative example and a comparative analysis of its results against a recognized reference such as the operational Jetplan. This approach provides an assessment of the practical applicability and performance of the developed software in real flight planning environments.

4.2 Example Calculation

Scenario:

- Aircraft type: Airbus A330-200
- M.82 Normal A/C – A/I OFF
- Route: Algiers (DAAG) – Johannesburg (FAOR)
- Flight Level: FL 370
- Distance:4120 NM.
- Weather: [Conditions: ISA, wind (0 kt)]
- ETOW: 200,000 kg

- Procedure Fuel: 240 kg (6 min IFR)

Calculation Steps:

- Input all scenario data into the developed program.
- Run the calculation to obtain:

1. Fuel consumption (climb, cruise, descent, reserves)
2. Flight time
3. Trip fuel and other intermediate results
4. Mass at top of descent, landing weight

Sample Output:

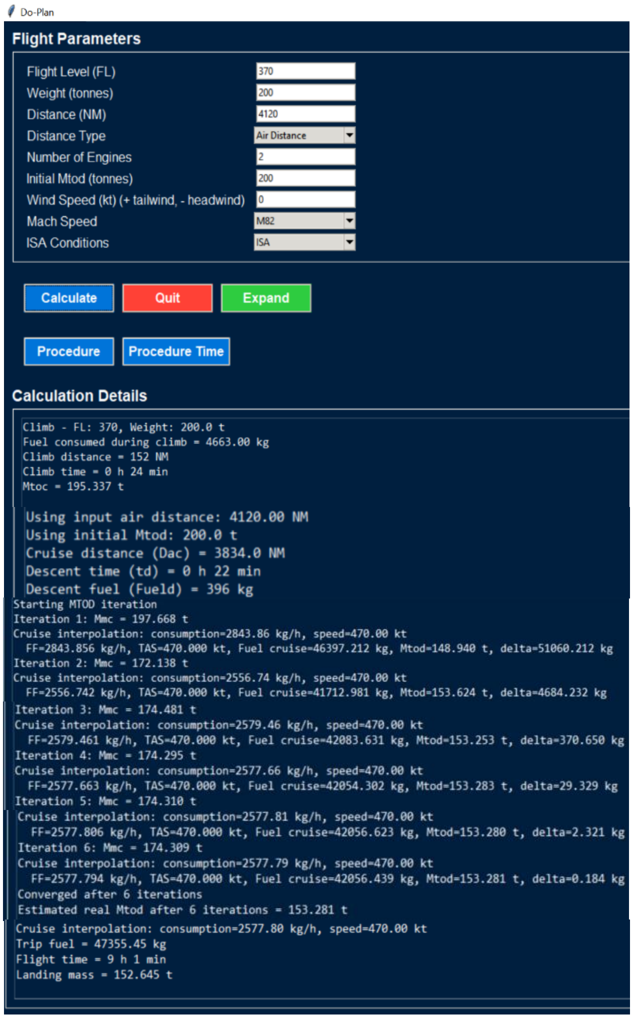


Figure 4.1: Calculation inputs and outputs.

Under ISA conditions with a Mach 0.82 cruise speed, the flight performance calculations for a climb to FL 370 starting at 200 tonnes show a climb fuel consumption of 4663 kg over 152 NM in 24 minutes, resulting in a mass at top of climb (Mtoc) of 195.337 tons. Using an input air distance of 4120 NM and an initial Mtod guess of 200 tons (It is possible to use 150 tons too), the cruise distance is computed as 3854 NM after subtracting climb and descent distances. The descent phase consumes 396 kg of fuel over 134 NM in 22 minutes. The iterative calculation of the mass at top of descent (Mtod) converges after six iterations, starting with a mid-cruise mass (Mmc) of 197.668 t and an initial fuel flow (FF) of approximately 2843.86 kg/h at 470 kt true airspeed. Fuel consumed during cruise begins at about 46,397 kg and is refined through iterations, with Mtod stabilizing at 153.281 t and a landing mass of 152.696 t after descent fuel is accounted for. The small delta values in later iterations indicate high precision in the solution. The total estimated flight time is approximately 8 hours and 59 minutes, with a step dump (fuel reserve) of 47.064 t, consistent with operational safety margins. These results align well with current aircraft fuel consumption models, demonstrating that the iterative approach effectively captures the nonlinear relationships between aircraft weight, fuel burn, and flight dynamics, providing accurate and reliable estimates for flight planning and fuel management

4.3 Comparison with JetPlan

JetPlan

JetPlan is a tool used for flight planning and performance calculations. It automates and optimizes fuel calculations such as fuel trip, it also provides payload, takeoff weight, landing weight and flight time, etc., thus reducing the risk of human error and ensuring regulatory compliance.[35].

The examples below are taken from a real JetPlans that were used by the Air Algerie company (check Annex B).

Exemple 1 : PLAN 0349 DAAG TO OEJN

- Aircraft type: Airbus A330-200
- FL 370
- M.82 Normal A/C – A/I OFF
- Weather: [Conditions: ISA, WIND P050 (+50 kt)]
- ETOW: 177.256 tonnes

- Distance ground: 2180 NM
- Distance air : 1973NM
- Procedure Fuel: 240 kg (6 min IFR)

Table 4.1: Comparison between JetPlan and Do-Plan results according to PLAN 0349 DAAG TO OEJN.

Parameter	Do_Plan Result	JetPlan Result	Difference/Comment
Trip fuel	22.63241 t	22.5 t	+0.132 t (<1% difference)
Flight time	4 h 7 min	4 h 26 min	-19 min (Do-Plan lower)
Landing weight	154.624 t	154.756 t	-0.132 t (almost identical)

Trip Fuel: The Do-Plan application produced a trip fuel estimate of 22.632 tons, which is only marginally higher than JetPlan's value of 22.5 tons. This difference, amounting to less than 1%, indicates a high level of concordance between Do-Plan's interpolation algorithms and fuel calculation methodology and those employed by the main code. Such a minimal deviation underscores the reliability of the Do-Plan system in replicating standard fuel consumption estimates for the Airbus A330-200.

Flight Time: The total flight time calculated by Do-Plan was 4 hours and 7 minutes, 19 minutes less than the 4 hours and 26 minutes reported by JetPlan. This discrepancy may be due to variations in the implementation of wind correction procedures, such as differences in the cruise and descent speed profiles adopted by each system, and to the time of each phase.

Landing Weight: The estimated landing weights provided by both applications are nearly identical, with a difference of only 0.132 tons. This close agreement confirms the accuracy of Do-Plan's fuel burn modeling and weight tracking throughout the flight profile, further validating its suitability for operational use in flight planning for the Airbus A330-200.

Example2 : PLAN 0350 DAAG TO OEJN

- Aircraft type: Airbus A330-200
- FL 370
- M.82 Normal A/C – A/I OFF
- Weather: [Conditions: ISA, WIND P050 (+50 kt)]
- ETOW:142.364 tonnes
- Distance ground: 2180 NM
- Distance air : 1962NM
- Procedure Fuel: 240 kg (6 min IFR)

Table 4.2: Comparison between JetPlan and Do-Plan results according to PLAN 0350 DAAG TO OEJN.

Parameter	Do_Plan Result	JetPlan Result	Difference/Comment
Trip fuel	20.43357 t	20.523 t	-0.089 t (negligible)
Flight time	4 h 11 min	4 h 31 min	-20 min (Do-Plan lower)
Landing weight	121.930 t	121.841 t	+0.089 t (marginal)

Trip Fuel: For this scenario, Do-Plan estimated the trip fuel requirement at 20.434 tons, which is 0.089 tons lower than the value provided by JetPlan. This difference is minimal and can be considered operationally insignificant, thereby confirming the reliability and robustness of Do-Plan's cruise and descent fuel modeling across varying aircraft weights.

Flight Time: The flight time calculated by Do-Plan is consistently shorter by approximately 20 minutes compared to JetPlan. This systematic variance is primarily attributable to methodological differences in the inclusion of certain procedural segments. Specifically, in the current version of Do-Plan, holding time, alternate routing time, and taxi time are not incorporated into the total flight time calculation.

Landing Weight: The difference in estimated landing weights between the two systems is only 0.089 tons, which further validates the precision of the Do-Plan application in modeling fuel consumption and tracking weight reduction throughout the flight. This close agreement demonstrates the tool's suitability for use in professional flight planning environments.

Example 3: PLAN 5493 DAHTEST DAAG TO WMKK A332

- Aircraft: Airbus A330-200
- Flight Level: FL 330
- Mach: 0.82
- Weather: ISA, Wind -01 kt M01
- ETOW: 238 t
- Ground Distance: 5917 NM
- Air Distance: 5939 NM

Table 4.3: Comparison between JetPlan and Do-Plan results according to PLAN 5493 DAAG TO WMKK.

Parameter	Do-Plan Result	JetPlan Result	Difference/Comment
Trip Fuel	77.42892 t	75.733 t+1200 kg	+ 0.49592 t (Do-Plan estimates higher fuel)
Flight Time	12 h 17 min	12 h 44 min	-27 min (Do-Plan estimates shorter time)
Landing Weight	160.571 t	162.267 t	-1.696 t (Do-Plan estimates lower landing weight)

The comparative analysis of the long-haul flight PLAN 5493 from DAAG to WMKK using the Airbus A330-200 reveals differences between the Do-Plan application and the JetPlan software.

Trip Fuel:Do-Plan estimates a trip fuel requirement of 77.429 tons, compared to JetPlan's value of 75.733 tons plus an additional 1.2 tons, resulting in a net difference of +0.496 tons. This modest increase (less than 1%) in Do-Plan's estimate may be attributed to differences in fuel calculation methodology, such as the handling of reserves, wind correction, or the inclusion of operational margins. Although a slightly high fuel estimate does offer an operational advantage, such as having more room for unexpected maneuvers

Flight Time: Do-Plan calculates a flight time of 12 hours and 17 minutes, which is 27 minutes shorter than JetPlan's estimate. This systematic difference is consistent with previous comparative findings and likely results from the exclusion of certain procedural segments in Do-Plan's model, whereas JetPlan typically incorporates these into its block time calculations.

Landing Weight: The landing weight predicted by Do-Plan is 160.571 tons, which is 1.696 tons lower than JetPlan's estimate. This is consistent with the higher trip fuel consumption calculated by Do-Plan, indicating internal consistency in its mass tracking and fuel burn computations.

4.4 Conclusion

This chapter presented an in-depth comparative evaluation of the Do-Plan application and JetPlan in various operational scenarios, considering a variety of input parameters. The results reveal that Do-Plan provides remarkably consistent fuel burn and landing weight estimates with JetPlan, with differences generally less than 1%. These results attest to the robustness of Do-Plan's modeling across different flight conditions and aircraft weights.

However, Do-Plan consistently generates shorter flight time estimates, primarily due to the omission of procedural segments such as taxiing, holding, and alternate routing, which are integrated into JetPlan's calculations.

General Conclusion

The project described in this thesis was developed as the result of training at the Air Algerie Company.

This thesis focused on the development of an application to determine a technical flight plan only for the Airbus A330-200, integrating operational theory and computer science practices to address flight planning challenges.

The first chapter provide a detailed presentation of the company, its fleet and its destinations as well as its subsidiaries. This context demonstrated the practical relevance and the need to develop a flight planning solution.

Chapter 2 delivered a comprehensive overview of air operations, starting with key definitions, maximum structural weights, fuel management, and the principal flight phases: climb, cruise, and descent.

Chapter 3 focused on the technical development of the application. It gave an overview of the characteristics of the Airbus A330-200, the calculations used for the determination of trip fuel, flight time, landing weight and other results such as air cruise distance etc., and the methodologies of database design via MySQL, code development, highlighting the integration of Python. All this to provide a functional application.

Chapter 4 presented an evaluation of the results, through an example of the application's operation and other examples of its comparison with JetPlan. The results demonstrated that the application provides accurate and reliable estimates of key flight parameters, such as trip fuel, flight time, and landing weight.

In conclusion, this research has led to the development of a flight planning application adapted to the Airbus A330-200. This work contributes to the advancement of flight planning methodologies by combining theory with practice. Future research areas include extending the application's capabilities to other aircraft types. This thesis thus represents a significant step forward towards more efficient and reliable flight planning solutions in commercial aviation.

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Annexe A

Flight Performance Tables from the A330-200 FCOM

This appendix contains the original flight performance tables extracted from the Flight Crew Operating Manual (FCOM) of the Airbus A330-200. These tables provide key data such as flight levels, weights, times, fuel consumption, and distances used throughout the calculations presented in this report.

The figures below illustrate the performance data tables referenced in the main chapters. They serve as the primary source for the interpolation and calculation methods implemented in the software.

CLIMB - 250KT/300KT/M.80														
MAX. CLIMB THRUST NORMAL AIR CONDITIONING ANTI-ICING OFF						ISA CG=30.0%			**FROM BRAKE** RELEASE **TIME (MIN)** **FUEL (KG)** **DISTANCE (NM)** **TAS (KT)**					
	WEIGHT AT BRAKE RELEASE (1000KG)													
FL	**120**		**140**		**160**		**180**		**200**		**220**		**240**	
410	14	2636	17	3187	21	3839	27	4717						
	91	387	113	391	140	395	182	401						
390	13	2498	15	3000	19	3573	23	4258						
	81	380	99	382	120	386	147	390						
370	12	2370	14	2834	17	3352	20	3947	24	4663				
	72	372	87	374	104	377	125	380	152	384				
350	11	2254	13	2688	15	3165	18	3702	21	4325	25	5077	30	6089
	65	364	78	366	93	368	110	371	130	374	157	378	196	385
330	10	2148	12	2555	14	3000	16	3495	19	4057	22	4713	26	5509
	58	356	70	358	83	360	98	362	115	365	136	368	162	372
310	9	2045	11	2428	13	2844	15	3304	17	3820	20	4411	23	5106
	53	348	63	350	75	351	88	353	102	355	120	358	141	361
290	8	1912	10	2266	12	2649	13	3068	16	3535	18	4060	21	4664
	47	336	56	338	65	339	76	340	88	342	103	344	119	347
270	8	1781	9	2107	10	2459	12	2841	14	3263	16	3733	18	4265
	41	324	48	326	57	327	66	328	76	329	88	331	101	333
250	7	1656	8	1957	9	2280	11	2630	12	3013	14	3437	16	3911
	36	312	42	314	49	315	57	316	66	317	76	319	87	320
240	6	1596	8	1884	9	2194	10	2529	12	2895	13	3298	15	3748
	33	307	39	308	46	309	53	310	61	311	70	312	80	314
220	6	1479	7	1744	8	2029	9	2336	11	2669	12	3036	14	3442
	29	295	34	296	40	297	46	298	53	299	61	300	69	302
200	5	1365	6	1609	7	1870	8	2151	10	2456	11	2789	12	3156
	25	284	30	285	35	286	40	287	46	288	52	289	60	290
180	5	1255	6	1478	7	1716	8	1973	9	2250	10	2553	11	2886
	22	272	26	273	30	274	35	275	40	276	45	277	51	278
160	4	1147	5	1350	6	1567	7	1800	8	2052	9	2326	10	2627
	19	259	22	260	26	261	30	262	34	263	39	264	44	265
140	4	1042	5	1224	5	1421	6	1631	7	1859	8	2107	9	2378
	16	246	19	247	22	248	25	249	29	250	33	251	37	252
120	3	938	4	1102	5	1278	5	1467	6	1672	7	1894	8	2138
	13	232	16	233	18	234	21	235	24	236	27	237	31	238
100	3	765	3	897	4	1040	4	1194	5	1361	6	1542	6	1740
	9	206	11	207	13	208	15	209	17	210	19	212	22	213
50	2	519	2	605	2	700	3	802	3	912	4	1032	4	1161
	5	169	6	170	7	170	8	172	9	173	10	175	12	176
15	1	345	1	400	2	460	2	527	2	599	2	677	3	761
	2	122	3	121	3	121	4	122	4	124	5	126	5	128
PACK FLOW LO △FUEL = – 0.5 %			**PACK FLOW HI OR/ AND CARGO COOL ON** △FUEL = + 1.5 %				**ENGINE ANTI ICE ON** △FUEL = + 1 %				**TOTAL ANTI ICE ON** △FUEL = + 3 %			

Figure A.1: Climb table from the FCOM of the A330-200 at M80.

CRUISE - M.80							
MAX. CRUISE THRUST LIMITS NORMAL AIR CONDITIONING ANTI-ICING OFF				ISA CG=37.0%	**N1 (%)** **KG/H/ENG** **NM/1000KG**		**MACH** **IAS (KT)** **TAS (KT)**
WEIGHT (1000KG)	**FL290**	**FL310**	**FL330**	**FL350**	**FL370**	**FL390**	**FL410**
130	87.8 .800 2791 311 84.8 473	87.6 .800 2594 297 90.5 469	87.5 .800 2417 284 96.2 465	87.5 .800 2251 272 102.4 461	87.9 .800 2116 260 108.4 459	88.9 .800 2016 248 113.8 459	90.1 .800 1931 237 118.8 459
140	88.2 .800 2835 311 83.5 473	88.0 .800 2643 297 88.8 469	88.0 .800 2465 284 94.4 465	88.1 .800 2305 272 100.0 461	88.6 .800 2181 260 105.2 459	89.7 .800 2087 248 109.9 459	91.1 .800 2014 237 113.9 459
150	88.6 .800 2884 311 82.1 473	88.5 .800 2693 297 87.2 469	88.5 .800 2520 284 92.3 465	88.7 .800 2370 272 97.3 461	89.3 .800 2252 260 101.9 459	90.6 .800 2168 248 105.8 459	92.1 .800 2108 237 108.8 459
160	89.0 .800 2936 311 80.6 473	89.0 .800 2747 297 85.4 469	89.1 .800 2581 284 90.1 465	89.3 .800 2439 272 94.5 461	90.1 .800 2328 260 98.5 459	91.6 .800 2259 248 101.6 459	93.5 .800 2224 237 103.2 459
170	89.4 .800 2989 311 79.2 473	89.5 .800 2806 297 83.7 469	89.7 .800 2651 284 87.8 465	90.1 .800 2515 272 91.7 461	91.0 .800 2416 260 95.0 459	92.6 .800 2361 248 97.2 459	95.2 .800 2372 237 96.7 459
180	89.9 .800 3047 311 77.7 473	90.1 .800 2874 297 81.7 469	90.4 .800 2726 284 85.4 465	90.9 .800 2598 272 88.8 461	91.9 .800 2513 260 91.3 459	94.0 .800 2492 248 92.1 459	
190	90.4 .800 3111 311 76.1 473	90.7 .800 2948 297 79.6 469	91.1 .800 2806 284 82.9 465	91.6 .800 2691 272 85.7 461	92.9 .800 2624 260 87.4 459	95.7 .800 2649 248 86.6 459	
200	91.0 .800 3184 311 74.3 473	91.3 .800 3027 297 77.5 469	91.8 .800 2894 284 80.4 465	92.5 .800 2792 272 82.6 461	94.3 .800 2762 260 83.1 459		
210	91.5 .800 3262 311 72.6 473	91.9 .800 3111 297 75.4 469	92.6 .800 2992 284 77.8 465	93.5 .800 2910 272 79.2 461	95.9 .800 2924 260 78.5 459		
220	92.1 .800 3345 311 70.8 473	92.7 .800 3204 297 73.2 469	93.4 .800 3097 284 75.1 465	94.7 .800 3052 272 75.5 461			
230	92.7 .800 3432 311 69.0 473	93.3 .800 3305 297 71.0 469	94.3 .800 3219 284 72.3 465	96.3 .800 3217 272 71.7 461			
240	93.4 .800 3529 311 67.1 473	94.1 .800 3414 297 68.8 469	95.4 .800 3363 284 69.2 465				
PACK FLOW LO ΔFUEL = – 0.5 %		**PACK FLOW HI OR/ AND CARGO COOL ON** ΔFUEL = + 1 %		**ENGINE ANTI ICE ON** ΔFUEL = + 1.5 %		**TOTAL ANTI ICE ON** ΔFUEL = + 3 %	

Figure A.2: Cruise table from the FCOM of the A330-200 at M80.

CRUISE - M.80							
MAX. CRUISE THRUST LIMITS NORMAL AIR CONDITIONING ANTI-ICING OFF				ISA+10 CG=37.0%	**N1 (%)** **KG/H/ENG** **NM/1000KG**		**MACH** **IAS (KT)** **TAS (KT)**
WEIGHT (1000KG)	**FL290**	**FL310**	**FL330**	**FL350**	**FL370**	**FL390**	**FL410**
130	89.7 .800 2871 311 84.2 484	89.6 .800 2669 297 89.9 480	89.5 .800 2486 284 95.6 476	89.5 .800 2315 272 101.8 472	90.0 .800 2179 260 107.7 469	91.0 .800 2075 248 113.1 469	92.2 .800 1989 237 118.0 469
140	90.1 .800 2917 311 82.9 484	90.0 .800 2719 297 88.2 480	90.0 .800 2536 284 93.8 476	90.1 .800 2372 272 99.4 472	90.7 .800 2245 260 104.5 469	91.8 .800 2149 248 109.2 469	93.2 .800 2076 237 113.1 469
150	90.5 .800 2967 311 81.5 484	90.5 .800 2771 297 86.5 480	90.6 .800 2592 284 91.7 476	90.7 .800 2439 272 96.7 472	91.4 .800 2318 260 101.2 469	92.7 .800 2232 248 105.1 469	94.3 .800 2173 237 108.0 469
160	91.0 .800 3021 311 80.1 484	91.0 .800 2827 297 84.8 480	91.2 .800 2657 284 89.5 476	91.4 .800 2511 272 93.9 472	92.2 .800 2398 260 97.9 469	93.7 .800 2327 248 100.8 469	95.6 .800 2294 237 102.3 469
170	91.4 .800 3075 311 78.6 484	91.6 .800 2888 297 83.0 480	91.8 .800 2729 284 87.1 476	92.1 .800 2589 272 91.1 472	93.1 .800 2489 260 94.3 469	94.8 .800 2434 248 96.4 469	97.3 .800 2448 237 95.9 469
180	91.9 .800 3136 311 77.1 484	92.1 .800 2960 297 81.0 480	92.4 .800 2806 284 84.7 476	92.9 .800 2675 272 88.1 472	94.0 .800 2589 260 90.6 469	96.1 .800 2570 248 91.3 469	
190	92.4 .800 3203 311 75.5 484	92.7 .800 3036 297 79.0 480	93.1 .800 2889 284 82.3 476	93.7 .800 2772 272 85.1 472	95.1 .800 2706 260 86.7 469	97.9 .800 2733 248 85.9 469	
200	93.0 .800 3279 311 73.8 484	93.3 .800 3118 297 76.9 480	93.9 .800 2982 284 79.8 476	94.6 .800 2876 272 82.0 472	96.4 .800 2849 260 82.4 469		
210	93.5 .800 3359 311 72.0 484	94.0 .800 3205 297 74.8 480	94.6 .800 3083 284 77.1 476	95.6 .800 3000 272 78.6 472	98.1 .800 3017 260 77.8 469		
220	94.1 .800 3445 311 70.2 484	94.7 .800 3302 297 72.6 480	95.4 .800 3191 284 74.5 476	96.9 .800 3148 272 74.9 472			
230	94.8 .800 3536 311 68.4 484	95.4 .800 3407 297 70.4 480	96.4 .800 3319 284 71.6 476	98.4 .800 3318 272 71.1 472			
240	95.4 .800 3636 311 66.5 484	96.2 .800 3519 297 68.2 480	97.6 .800 3469 284 68.5 476				
PACK FLOW LO ΔFUEL = – 0.5 %		**PACK FLOW HI OR/ AND CARGO COOL ON** ΔFUEL = + 1 %		**ENGINE ANTI ICE ON** ΔFUEL = + 1.5 %		**TOTAL ANTI ICE ON** ΔFUEL = + 3 %	

Figure A.3: Cruise- M80 table from the FCOM of the A330-200 at ISA+10.

CRUISE - M.82							
MAX. CRUISE THRUST LIMITS NORMAL AIR CONDITIONING ANTI-ICING OFF				ISA CG = 37.0%	N1 (%) KG/H/ENG NM/1000KG		MACH IAS (KT) TAS (KT)
WEIGHT (1000KG)	FL290	FL310	FL330	FL350	FL370	FL390	FL410
130	89.2 .820 2999 319 80.9 485	89.0 .820 2781 306 86.5 481	88.8 .820 2581 292 92.4 477	88.7 .820 2402 279 98.4 473	89.0 .820 2249 267 104.6 470	89.9 .820 2129 255 110.4 470	90.9 .820 2029 243 115.9 470
140	89.5 .820 3041 319 79.8 485	89.4 .820 2826 306 85.1 481	89.3 .820 2632 292 90.6 477	89.2 .820 2454 279 96.3 473	89.6 .820 2307 267 101.9 470	90.6 .820 2195 255 107.2 470	91.8 .820 2114 243 111.3 470
150	89.9 .820 3087 319 78.6 485	89.8 .820 2877 306 83.6 481	89.7 .820 2684 292 88.8 477	89.7 .820 2512 279 94.1 473	90.2 .820 2371 267 99.2 470	91.4 .820 2277 255 103.3 470	92.9 .820 2208 243 106.5 470
160	90.3 .820 3137 319 77.4 485	90.2 .820 2929 306 82.1 481	90.2 .820 2742 292 87.0 477	90.3 .820 2576 279 91.8 473	91.0 .820 2447 267 96.1 470	92.3 .820 2369 255 99.3 470	94.2 .820 2321 243 101.3 470
170	90.7 .820 3190 319 76.1 485	90.7 .820 2987 306 80.5 481	90.7 .820 2806 292 85.0 477	90.9 .820 2646 279 89.3 473	91.8 .820 2536 267 92.7 470	93.4 .820 2475 255 95.0 470	95.7 .820 2451 243 95.9 470
180	91.1 .820 3247 319 74.7 485	91.1 .820 3050 306 78.9 481	91.3 .820 2874 292 83.0 477	91.7 .820 2731 279 86.5 473	92.6 .820 2633 267 89.3 470	94.7 .820 2594 255 90.7 470	
190	91.5 .820 3310 319 73.3 485	91.7 .820 3118 306 77.1 481	91.9 .820 2950 292 80.8 477	92.4 .820 2825 279 83.6 473	93.7 .820 2748 267 85.6 470	96.3 .820 2737 255 85.9 470	
200	92.0 .820 3377 319 71.9 485	92.2 .820 3191 306 75.4 481	92.6 .820 3043 292 78.4 477	93.3 .820 2928 279 80.7 473	94.9 .820 2873 267 81.9 470		
210	92.5 .820 3449 319 70.3 485	92.8 .820 3274 306 73.5 481	93.3 .820 3143 292 75.9 477	94.3 .820 3049 279 77.5 473	96.5 .820 3021 267 77.8 470		
220	93.0 .820 3526 319 68.8 485	93.5 .820 3371 306 71.4 481	94.1 .820 3251 292 73.4 477	95.4 .820 3177 279 74.4 473			
230	93.6 .820 3613 319 67.2 485	94.1 .820 3475 306 69.2 481	95.1 .820 3376 292 70.6 477	96.8 .820 3328 279 71.0 473			
240	94.2 .820 3714 319 65.3 485	94.9 .820 3586 306 67.1 481	96.2 .820 3507 292 68.0 477				
PACK FLOW LO ΔFUEL = − 0.5 %		PACK FLOW HI OR/ AND CARGO COOL ON ΔFUEL = − 1.5 %		ENGINE ANTI ICE ON ΔFUEL = + 3 %		TOTAL ANTI ICE ON ΔFUEL = + 5 %	

Figure A.4: Cruise table from the FCOM of the A330-200 at M82.

DESCENT - M.80/300KT/250KT									
IDLE THRUST NORMAL AIR CONDITIONING ANTI-ICING OFF			ISA CG=30.0%	MAXIMUM CABIN RATE OF DESCENT 350FT/MIN					
WEIGHT (1000KG)	150				200				
FL	TIME (MIN)	FUEL (KG)	DIST. (NM)	N1	TIME (MIN)	FUEL (KG)	DIST. (NM)	N1	IAS (KT)
410	20.7	367	128	IDLE					237
390	19.8	354	121	IDLE	23.0	410	141	IDLE	248
370	18.9	341	114	IDLE	22.1	396	134	IDLE	260
350	18.1	329	108	IDLE	21.2	384	127	IDLE	272
330	17.4	318	103	IDLE	20.4	372	121	IDLE	284
310	16.8	309	98	IDLE	19.7	361	115	IDLE	297
290	16.0	297	91	IDLE	18.7	346	108	IDLE	300
270	15.1	283	85	IDLE	17.7	331	100	IDLE	300
250	14.2	269	78	IDLE	16.6	314	92	IDLE	300
240	13.7	262	75	IDLE	16.1	306	88	IDLE	300
220	12.8	248	69	IDLE	15.0	288	81	IDLE	300
200	11.9	232	63	IDLE	13.9	270	73	IDLE	300
180	11.0	216	56	IDLE	12.7	251	66	IDLE	300
160	10.0	200	50	IDLE	11.6	231	58	IDLE	300
140	9.0	182	44	IDLE	10.4	210	51	IDLE	300
120	8.1	164	38	IDLE	9.2	188	44	IDLE	300
100	7.1	146	33	IDLE	8.0	165	37	IDLE	300
50	2.6	56	11	IDLE	2.9	64	13	IDLE	250
15	.0	0	0	IDLE	.0	0	0	IDLE	250
CORRECTIONS	PACK FLOW LO	PACK FLOW HI OR/ AND CARGO COOL ON		ENGINE ANTI ICE ON		TOTAL ANTI ICE ON		per 1° above ISA	
TIME	–	–		+ 10 %		+ 10 %		-	
FUEL	– 2 %	+ 4.5 %		+ 60 %		+ 70 %		+ 0.4 %	
DISTANCE	–	+ 1 %		+ 13 %		+ 13 %		+ 0.4 %	

Figure A.5 :Descent table from the FCOM of the A330-200 at M80.

Annexe B

JetPlan Flight Planning Data

This annex contains selected JetPlan outputs used for comparative analysis with the developed Do-Plan application. The data focus on Airbus A330-200 flight scenarios and provide reference benchmarks for fuel consumption, flight time, and weight calculations.

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PLAN 0349 DAAG TO OEJN A33E 30/FIFR 13/05/14

NONSTOP COMPUTED 0951Z FOR ETD 1200Z PROGS 1306UK VJV KGS

E.FUEL A.FUEL E.TME NM NAM FL

DEST OEJN 022500 . . . . . 04/26 2180 1973 370

R.R. 001125 . . . . . 00/17

ALT OEMA 003411 . . . . . 00/34 0193 0195 240

HOLD 002400 . . . . . 00/30

XTR 000000 . . . . . 00/00 SIGN CDB .......

TOF 029436 . . .. 05/46

TAXI 000300 CORR. + / -

BLOCK 029736 . . . . . 05/46 BLOCK FUEL .......

FL 370

FUEL BURN ADJUSTMENT FOR 4000 FT DECREASE IN CRZ ALTITUDE:1264KGS

FUEL BURN ADJUSTMENT FOR 4000 FT INCREASE IN CRZ ALTITUDE: KGS

FUEL BURN ADJUSTMENT FOR 1000KGS INCREASE/DECREASE IN TOW:0084KGS

ALT AIRPORT . . . . . . CIE NAME . . . . . . COST INDEX . . . . .

BLOCK . . . . . . NUMERO B/L. . . . . .

CMD (-) . . . . . . QUANTITY . . . . . .

MAX B/O . . . . . .

E. WT CORR. OP. LIMIT STRUC. REASONS FOR OP. LIMIT

BASIC 122820 . . . . .

EPLD 025000 . . . . .
```

EZFW 147820 . . . . . ZFW . . . . . 168000 / . . . .

TOF 029437 . . . . .

ETOW 177256 . . . . . OTOW. . . . . 230000 / . . . .

EB/O 022500 . . . . .

ELAW 154756 . . . . . LAW . . . . . 180000 / . . . .

DAAG SID4 BABOR UA31 TBS UP128 TANLI A411 BRN UP751 LXR UM999 IMLER

IMLE34 OEJN

BLOCK OFF . . . . . . LANDING . . . . . . FOB. TO . . . . . .

BLOCK ON . . . . . . TAKE OFF . . . . . . FOB. LAW . . . . . .

CODE

TIME . . . . . . TIME . . . . . . DELAI . . . . . .

WIND P050 MXSH 5/AST

MET /

CLEARANCE /

DISPATCH BRIEFING INFO DISP:

```
PLAN 0350 DAAG TO OEJN 767C 30/FIFR 13/05/14

NONSTOP COMPUTED 0953Z FOR ETD 1200Z PROGS 1306UK VJG KGS

E.FUEL A.FUEL E.TME NM NAM FL

DEST OEJN 020523 . . . . . 04/31 2180 1962 370

R.R. 001026 . . . . . 00/16

ALT OEMA 003108 . . . . . 00/33 0193 0195 240

HOLD 002000 . . . . . 00/30

XTR 000000 . . . . . 00/00 SIGN CDB .......

TOF 026657 . . . . . 05/50

TAXI 000300 CORR. + / -

BLOCK 026957 . . . . . 05/50 BLOCK FUEL .......

FL 370

FUEL BURN ADJUSTMENT FOR 4000 FT DECREASE IN CRZ ALTITUDE:0655KGS

FUEL BURN ADJUSTMENT FOR 4000 FT INCREASE IN CRZ ALTITUDE: KGS

FUEL BURN ADJUSTMENT FOR 1000KGS INCREASE/DECREASE IN TOW:0122KGS

ALT AIRPORT . . . . . . CIE NAME . . . . . . COST INDEX . . . . .

BLOCK . . . . . . NUMERO B/L. . . . . .

CMD (-) . . . . . . QUANTITY . . . . . .

MAX B/O . . . . . .

E. WT CORR. OP. LIMIT STRUC. REASONS FOR OP. LIMIT

BASIC 090707 . . . . .

EPLD 025000 . . . . .

EZFW 115707 . . . . . ZFW . . . . . 126098 / . . . . . . . . .

TOF 026657 . . . . .

ETOW 142364 . . . . . OTOW. . . . . 156489 / . . . . . . . . .

EB/O 020523 . . . . .

ELAW 121841 . . . . . LAW . . . . . 136077 / . . . . . . . . .

DAAG SID4 BABOR UA31 TBS UP128 TANLI A411 BRN UP751 LXR UM999 IMLER
```

IMLE34 OEJN

BLOCK OFF . . . . . . LANDING . . . . . . FOB. TO . . . . . .

BLOCK ON . . . . . . TAKE OFF . . . . . . FOB. LAW . . . . . .

CODE

TIME . . . . . . TIME . . . . . . DELAI . . . . . .

WIND P050 MXSH 5/AST

MET /

CLEARANCE /

DISPATCH BRIEFING INFO DISP:

PLAN 5493 DAHTEST DAAG TO WMKK A332 30/FIFR 21/04/21

NONSTOP COMPUTED 0853Z FOR ETD 1200Z PROGS 0000ADF 7TVJA KGS

///// THIS FLIGHT PLAN COMPLIES WITH THE 120 MIN ETOPS RULE /////

ETOPS FLIGHT/MAX DIVERSION TIME IN STILL AIR LIMITED TO 120 MINUTES

SUBJECT TO THE FOLLOWING CONDITIONS

FROM THE FOLLOWING ETOPS ALTERNATE AIRPORTS - VIDP/DEL

OPKC/KHI

WMKK/KUL

VOHS/HYD

E.FUEL A.FUEL E.TME NM NAM FL

DEST WMKK 075733+1200 . . . . . 12/44 5917 5939 330

R.R. 003787 . . . . . 00/47

ALT VTBD 008585 . . . . . 01/35 0670 0655

F.R. 002400 . . . . . 00/30

ETOPS XTR 000000 . . . . . 00/00

XTR 000000 . . . . . 00/00 SIGN CDB ....

TOF 090505 . . . . . 15/36

TAXI 000300 CORR. + / -

BLOCK 090805 . . . . . 15/36 BLOCK FUEL ....

FL 330/ARLOS 350/DATOB 370/ENTUG 390

FUEL BURN ADJUSTMENT FOR 4000 FT DECREASE IN CRZ ALTITUDE:5468KGS

FUEL BURN ADJUSTMENT FOR 4000 FT INCREASE IN CRZ ALTITUDE: KGS

FUEL BURN ADJUSTMENT FOR 1000KGS INCREASE/DECREASE IN TOW:0285KGS

ALT AIRPORT . . . . CIE NAME . . . . COST INDEX . . . . .

BLOCK . . . . . . NUMERO B/L. . . . . .

CMD (-) . . . . QUANTITY . . . . . .

MAX B/O . . . . . .

E. WT CORR. OP. LIMIT STRUC. REASONS FOR OP. LIMIT

BASIC 124406 . . . . .

EPLD 023090 . . . . .

EZFW 147496 . . . . . ZFW . . . . . 168000 / . . . .

TOF 090505 . . . . .

ETOW 238000 . . . . . OTOW. . . . . 238000 / . . . .

EB/O 075733 . . . . .

ELAW 162267 . . . . . LAW . . . . . 182000 / . . . .

DAAG RWY 27 BABO1B BABOR UA31 CSO UW254 DIMAO UL874 OMENI..KUTOS

P868 ARLOS UN4 SALUN Q680 DBA M872 WEJ L604 KFA N687 ROTEL T872

DAVRI P559 NALPO P559 AMBOV M322 LOVEM L562 SERSA P307 PARAR N571

GUNIP B466 VBA KIKAL3 RWY 14L WMKK

BLOCK OFF . . . . . . LANDING . . . . . . FOB. TO . . . . . .

BLOCK ON . . . . . . TAKE OFF . . . . . . FOB. LAW . . . . . .

CODE

TIME . . . . . . TIME . . . . . . DELAI . . . . . .

WIND M001 MXSH 9/SUGID

ENROUTE ALTERNATES

VIDP SUITABLE FROM 2137 UTC / TO 0010 UTC

OPKC SUITABLE FROM 2140 UTC / TO 0234 UTC

WMKK SUITABLE FROM 2343 UTC / TO 0236 UTC

VOHS SUITABLE FROM 2343 UTC / TO 0417 UTC

MOST CRITICAL FUEL SCENARIO AT : ETP02 FUEL EXCESS OF 4072

TIME TO

DIST W/C CFR FOB EXC POINT / ALT

ETP1 VIDP/OPKC 0759/0774 M007/P000 015674 033141 17467 08.49/02.24

N15528 E077006

ETP2 OPKC/WMKK 1219/1195 M002/M012 023612 027684 4072 09.51/03.53

N12240 E084066

ETP3 WMKK/VOHS 0805/0821 M009/M001 016184 023123 6939 10.45/02.36

N09306 E090030

MET /

CLEARA