

**IBN HALDUN UNIVERSITY  
SCHOOL OF GRADUATE STUDIES  
MASTER OF SCIENCE IN AIR TRANSPORT MANAGEMENT**

**MASTER'S THESIS**

**AN ANALYSIS OF THE BIOMETRIC AND  
ANTHROPOMETRIC CHARACTERISTICS OF AIRLINE  
PASSENGERS; AND THE IMPACT OF THESE  
CHARACTERISTICS ON AIRLINE SAFETY AND  
ENVIRONMENTAL PERFORMANCE.**

**ARDAK KARTAYEV**

**THESIS SUPERVISOR: ASSIST. PROF. AHMET KAPLAN**

**ISTANBUL, 2020**

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by

**ARDAK KARTAYEV**

**A thesis submitted to the School of Graduate Studies in partial  
fulfillment of the requirements for the degree of Master of Science in  
Air Transport Management.**

**THESIS SUPERVISOR: ASSIST. PROF. AHMET KAPLAN**

**ISTANBUL, 2020**

APPROVAL PAGE

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science in Air Transport Management.

Thesis Jury Members

Title - Name Surname

Opinion

Signature

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This is to confirm that this thesis complies with all the standards set by the School of Graduate Studies, Ibn Haldun University:

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name Surname: Adnan Kartayev  
Signature: 



## ÖZ

### HAVAYOLU YOLCULARININ BİYOMETRİK VE ANTROPOMETRİK ÖZELLİKLERİNİN ANALİZİ; VE BU ÖZELLİKLERİN HAVAYOLU GÜVENLİĞİ VE ÇEVRESEL PERFORMANS ÜZERİNDEKİ ETKİSİ

Yazar Kartayev, Arda

Hava Taşımacılığı Yönetimi Yüksek Lisans Programı

Tez Danışmanı: Dr. Öğr. Üyesi Ahmet Kaplan

Ağustos 2020, 69 sayfa

Havacılık güvenliği ile ilgili en büyük sorunlardan bir tanesi, yolcuların tam ağırlık değerleridir. Doğru ağırlık değerleri olmayan bir uçağın, buna bağlı olarak ağırlık merkezinin yanlış hesaplanması kazalara ve ölümlere neden olabilir. Bu araştırmanın temel amacı, havacılıkta standart sayılan ağırlık değerlerinin üzerinde olan yolcuların uçağın güvenliğini nasıl etkileyebileceğini göstermektir. Farklı antropometrik ve biyometrik özellikler nedeniyle, bir yolcunun standart sayılabilecek ağırlık verisi dünyanın değişik yerlerinde farklılıklar gösterebilir. Bu nedenle, dünyanın bir yerinde geçerli olan ağırlık değeri standartları, dünyanın farklı bir yerindeki standartlarıyla uyumsuz olabilir. Uçuş güvenliği sorununun yanı sıra, insan antropometrisiyle doğrudan bağlantılı olan bir diğer önemli husus, bir uçağın yakıt tüketiminin yükselebilmesidir. Reelde, havayolu sisteminde geçerli olan standart ağırlık değerinin üzerinde ağırlığa sahip her yolcu uçuş sırasında ekstra ağırlığı oranında fazladan yakıt tüketimine sebep olur ve sonuç olarak atmosfere daha fazla CO<sub>2</sub> salınır. Bu da havayolunun çevresel performansını düşürür. Yukarıdaki nedenlere ek olarak, yolcuların konforu ve havayolunun ekonomik verimliliği de bu sorunun diğer yönleridir. Ek olarak; bu anket, karar vericiler için yeni olasılıklar, fırsatlar ve potansiyel çözümler hakkında bazı ipuçları verecektir. Ayrıca, bu çalışmadan elde edilen bilgiler, arka plan bilgileri sunar ve yeni analizler ve gelecekteki diğer projeler için bir temel olarak kullanılabilir.

**Anahtar Kelimeler:** Havayolu, Antropometri, Güvenlik, Performans, Yolcular, Verimlilik.

## ABSTRACT

### AN ANALYSIS OF THE BIOMETRIC AND ANTHROPOMETRIC CHARACTERISTICS OF AIRLINE PASSENGERS; AND THE IMPACT OF THESE CHARACTERISTICS ON AIRLINE SAFETY AND ENVIRONMENTAL PERFORMANCE.

Student Name Kartayev, Ardak

MSc in Air Transport Management.

Thesis Supervisor: Assist. Prof. Ahmet Kaplan

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One of the biggest problems related to aviation safety issues is exact weight values. Calculating the center of gravity of an aircraft without the correct weight values may be a cause of fatalities. The main aim of this research is to show how some passengers' obesity may affect the safety of the aircraft. Because of different anthropometric and biometric characteristics, the standard weight of a passenger used in balance calculations may vary across the world. Thus, weight-value standards may not at times be applicable in some specific places or indeed countries. Besides the issue of flight safety, another important matter which is directly connected to human anthropometry is the fact that an aircraft's fuel consumption may rise. The more passengers weigh, the more fuel is consumed during the flight and, as a result, the more CO<sub>2</sub> is released into the atmosphere. This in turn lowers the airline's environmental performance. In addition to the above reasons, passengers' comfort and the airline's economic efficiency are other aspects of this problem. Additionally, this survey will provide some clues to the new possibilities, opportunities and potential solutions for decision makers. In addition, information from this study presents background information and may be used as a base for new analyses and other future projects.

**Keywords:** Airline, Anthropometry, Safety, Performance, Passengers, Efficiency.

## DEDICATION

This study is dedicated to my mum, my wife Zhanar and my sons, Rassul and Ilyas.



## ACKNOWLEDGEMENT

First of all, I would like to thank my advisor, Dr. Ahmet KAPLAN, for guiding me through the entire thesis process. I greatly appreciate his invaluable advice, support and encouragement.

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Ardak Kartayev

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## LIST OF ABBREVIATIONS

Clb	Climb
Cr	Cruise
Des	Descend
DOW	Dry Operation Weight
Ldg	Landing
Loi	Loiter
LTO	Landing – Take-Off Cycle
MFW	Maximum Fuel Weight
MZFW	Maximum Zero Fuel Weight
Res	Reserve
TO	Take-Off
Payload	
DCS	Departure Control System
MAC	Mean Aerodynamic Chord
ETOPS	Extended-range Twin-engine Operational Standards
FOB	Fuel on Board
ALTN	Alternate airport
APU	Auxiliary Power Unit

## LIST OF SYMBOLS

$\Delta$	Difference
<b>B</b>	Breguet Range Factor
<b>c</b>	Specific Fuel Flow Jet. Specific Fuel Flow Prop
<b>D</b>	Drag
<b>E</b>	Glide Ratio
<b>G</b>	Earth Acceleration m Mass
<b>M<sub>fr</sub></b>	Fuel Fraction
<b>P<sub>D</sub></b>	Shaft Power
<b>R</b>	Range
<b>t</b>	Time
<b>V</b>	Velocity
<b>w</b>	Weight
<b>Q</b>	Fuel Mass Flow
$\eta_p$	Efficiency Propeller

# CHAPTER I

## INTRODUCTION

### 1.1. Motivation

Throughout the history of aviation there has been a question concerning the reliability of take-off mass data. If standard take-off data such as aircraft weight, jet fuel, cargo and spare parts is measurable and controlled, the weight of passengers, their clothes and hand luggage is not always possible to determine. As a rule, the calculation uses a standard weight that has been used over a long period. However, this criterion is not always standard; and often entails using inaccurate data in the calculations, which in turn directly affects flight safety. In addition, due to people's different characteristics, anthropometry and biometrics, weight standards appear to be different in different parts of the world. For example; people in Southeast Asia are much lighter in weight than those in North America or Europe. In this regard, passenger weight standards should be applied in accordance with the regional anthropometry. This already takes place in different parts of the world: for example, Hawaiian Airlines implemented passenger weighting on flights between Honolulu and Pago Pago (Schlappig, 2016).

“Ignoring the anthropometric characteristics of passengers is a serious problem for the aviation industry, especially in area of maintaining and improving passenger safety. Identifying the influence of passengers' anthropometric characteristics on various disciplines of aerospace engineering and aviation is thus important for future research. This thesis presents a new approach in the field of passenger anthropometry and its potential effects in areas such as flight safety, aircraft fuel consumption, and cabin design.” (Melis, Silva, & Yeun, Impact of biometric and anthropometric characteristics of passengers on aircraft safety and performance, 2018)

The key areas (such as flight safety, fuel consumption, and passengers' comfort) are discussed in the next section and are supported by schematic representations that

highlight both the current aspects studied in the literature and existing knowledge gaps in these areas.

## **1.2 Scope**

The scope of this thesis to focus on fields that are subject to the biometric and anthropometric characteristics of airline passengers, namely: flight safety; aircraft fuel consumption; airline economy; and passenger comfort. Because this study was conducted in Kazakhstan, at Nur-Sultan airport, the majority of the ethnic group involved was from the local population. The anthropometric characteristics were therefore similar. The survey was conducted using parameters such as gender, age, ethnicity, and weight. The research was carried out on international flights and this brought into play the ethnic factor of other regions or even countries.

## **1.3 Research problem**

The questions raised within this study are:

1. Across different anthropometric characteristics, what is the influence of passengers' weight on flight safety, fuel consumption, and comfort?
2. What is the impact of passengers' ethnicity on weight standards?

## **1.4 Academic Contribution**

Since this topic is directly related to flight safety, it is currently very relevant. Publication of this study will raise new ideas for both academic and practical implementation. All previous works have used only officially published data, while in this research direct questionnaires relating to a specific region were used. It therefore provides a clear vision of the influence of ethnic characteristics on this issue. The direct-questionnaire approach, which served as the basis for the empirical component of this study, provides a unique opportunity to collect data directly from passengers. This method of data collection for conducting the survey in no way violates the ethical and rights of passengers and carries purely scientific interest. The results and subsequent analysis of the questionnaire data allow us to improve and clearly see the gaps in the existing standards. Thus, using the example of this study and the results of the ethnic characteristics of only one region, we can confidently assume that a more in-depth study of this problem and ways to solve them is

possible. As a result of further research, possible new solutions and the optimization of such systems as booking systems, passenger registration systems, DCS systems, and airline dispatcher systems will it may be assumed bring safer flights.



## **CHAPTER II**

### **LITERATURE REVIEW**

#### **2.1 Background**

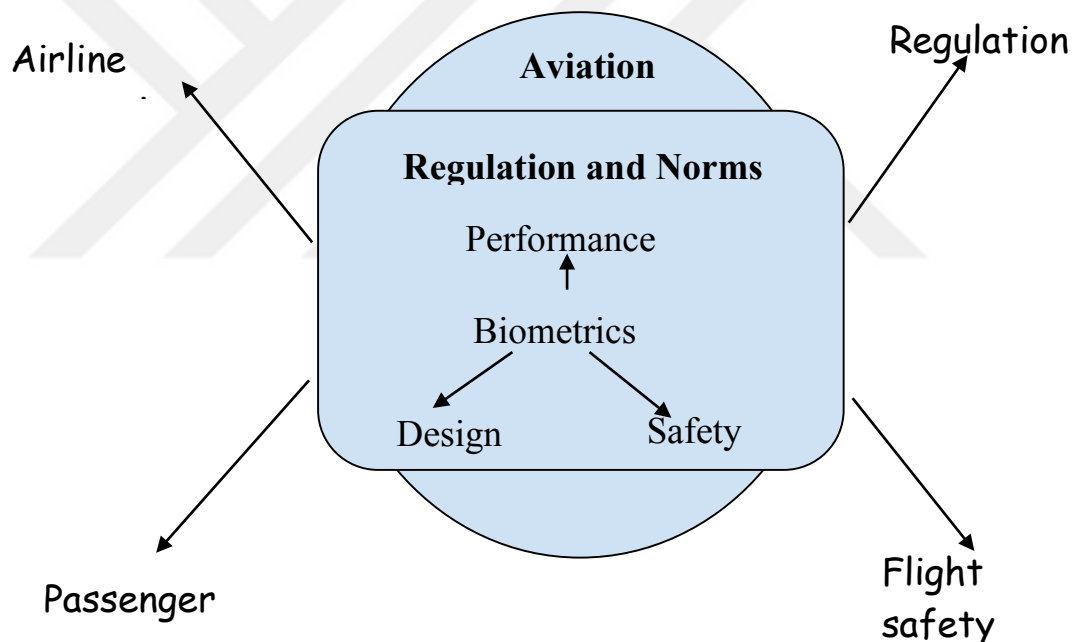
Each parameter in aviation is not ambiguous and any kind of calculation data is based on precise numbers. The importance of flight safety is an indisputable aspect, and at the same time, other aspects such as CO2 emissions, profitability and passengers' comfort are also important factors that should be taken into account. In this work, the author has tried to create a precise model for calculating passengers' weight according to passengers' anthropometric data, taking into account all other criteria.

#### **2.2 Biometrics and Anthropometry in aviation**

One of the key aspects in aviation safety and flight safety overall is the characteristics of biometrics and anthropometry. There are earlier surveys in this area of study (for example; Melis, Silva, & Yeun, 2018) that focus on the effect of passengers' weight on the operational aspect of commercial aircraft performance. In other categories, such as aircraft characteristics (e.g. fuel consumption) and safety design (e.g. seat map), there is limited research that looks closely into the biometric and anthropometric status of passengers. Previous studies also fail to provide a basis for understanding how the aforementioned parameters can affect other aspects of flight activity. Research related to anthropometry examines aspects of performance, design, or safety only individually and in a specific regulatory environment. In addition, only in some cases are there coincidences between these aspects; and a simultaneous integrated approach across all three dimensions is absent. This is how a change in passengers' anthropometric parameters affects the characteristics, design and safety of an aircraft. The main goal of this work is to show the importance of considering these three elements together, provided all the standards and rules that exist in these areas are maintained.

In a previous survey by Melis, Silva, & Yeun, 2018, the authors presented a comprehensive model (Fig. 2.1) in which there is a connection between biometrics, safety, performance, and design within regulating standards. This model was compiled on the basis of the available literature and taking into account the main elements and relationships where safety requirements are a priority.

In this model, the design phase is considered as having a direct impact on performance, since performance and safety cannot be separated, given their interconnection in many areas. In this case, human biometry (anthropometry, metabolism and biomechanics) is a key part of this triad; and therefore the main problem of this design is a multi-faceted one.



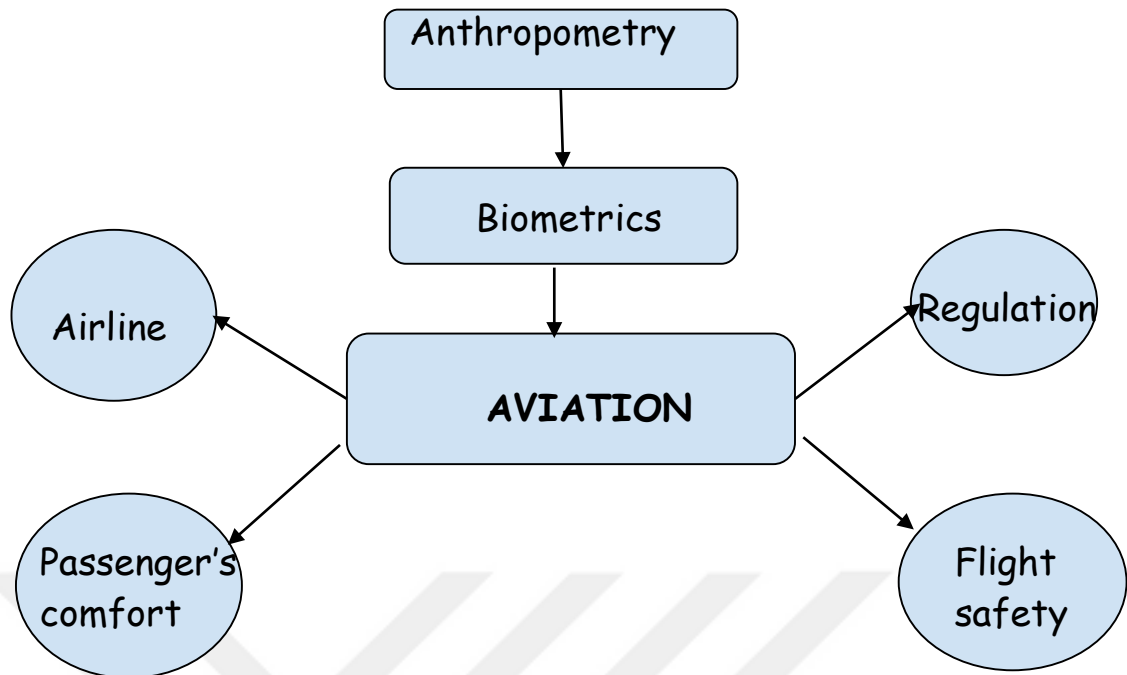
**Figure 2.1 “Schematic interweaving of key elements related to the design and operation of commercial airline aircraft and the impact of passenger biometric characteristics.” (Melis, Silva, & Yeun, 2018)**

From Figure 2.1, using the example of a seat in the cabin, the advantage of using a holistic model can be clearly seen. The structure of a seat is designed to meet all the characteristics of safety, ergonomics, and durability.

The main competing design requirement for maximizing aircraft performance is compliance with all the requirements while reducing the weight of the passenger seat itself. Taking into account all the competing requirements and to improve design decisions, the anthropometric and biometric characteristics of the passenger should be taken into account as a common denominator.

Areas of prospective further research, as indicated in Figure 2.2, should be explored as part of a holistic approach, as indicated in Figure 2.1.

The first factor to consider is metabolic rate, which includes consumption and waste (solids or gases) as present in the body, since these gases can also include consumption of oxygen by human body and carbon dioxide release. At the same time, this level is always different depending on the the person's level of physical fitness. This aspect may affect the performance of some of the aircraft's components and systems. Another important factor is biomechanics. This factor largely depends on the physical characteristics of passengers and whether passengers can freely move inside the cabin. Thus, for convenience, the design characteristics of luggage racks and passenger seats play an important role. Despite the fact that open sources pay more attention to biometric parameters such as height and weight, a better approach is to take a holistic view based on the relationship between anthropometric and biometric characteristics, such as how weight affects a person's mobility.



**Figure 2.2 “Influences of the passenger’s biometrics on aircraft performance, safety, economics and regulatory framework in aviation.” (Melis, Silva, & Yeun, 2018)**

Influenced by the approach to anthropometry in aviation implemented by Hawaiian Airlines in weighing passengers (Schlappig, 2016), the author of this research has tried to demonstrate the close relationship between flight safety and passengers’ weight.

### **2.2.1 Anthropometric Characteristics of Observed Region**

The distribution of payload relative to the center of gravity of the aircraft is a decisive factor in determining the characteristics for calculating stability and other flight parameters. “General aviation pilots usually use the actual weights of their passengers for weight and balance needs. However, for the category of widebody aircrafts, weighing individual passengers is not considered reliable. In 2009, the International Civil Aviation Organization (ICAO) determined the standard for calculating the average weight of a passenger as 100 kg per passenger, including 20 kg per baggage (2009). This standard was obtained from 28 global airlines that responded to a brief survey conducted by the International Air Transport Association at the request of ICAO.” (Melis, Silva, & Yeun, Impact of biometric and anthropometric characteristics of passengers on aircraft safety and performance, 2018)

As a rule, aviation regulators differentiate the standardized weight for different aircraft capabilities, segmented by gender and category of children in some cases. Some regulators also have different schedules of passenger weights for winter and summer, as well as charter and regular flights. It is anticipated that passengers will weigh more during the winter period due to seasonal weight gain and extra clothing. Charter flight operators suggest that their passengers are lighter because they will travel to warmer holiday destinations with lighter clothing. Different standards define different criteria and may indicate whether hand luggage and clothing are included in the passenger's weight. However, a generally accepted standard weight worldwide is now between 70 to 88 kg. This range clearly shows how standard weights can widely vary between carriers, which increases uncertainty about their accuracy. The problem is to determine the rules themselves, when and under what conditions the latest updates were made, which makes it difficult to determine the conformity of standards to the current parameters of anthropometry.

“The main problem with current methods is that the anthropometry of people is changing, and norms are becoming obsolete Berdowski, et al., (2009) conducted a study commissioned by the European Aviation Safety Agency (EASA) to update passenger weight standards in Europe based on a thorough survey of airline passengers at various European airports. The results led to revised recommended weights of 94 kg for adult men and 74 kg for adult women or 88 kg for adults with a male to female ratio of 70:30. These figures show a marked increase in existing standard passenger weights of 88 kg for men and 70 kg for adult women for aircraft with more than 20 seats.” (Melis, Silva, & Yeun, 2018).

An early study of weight standards was conducted by the New Zealand Civil Aviation Authority, which found that between 1999 and 2003 there was a weight gain (including carry-on baggage) for men and women which showed an increase by 1.4 to 3.1 kg (Zealand, 2003). This study showed how ethnicity can influence weight standards, as the sample Maori population was significantly heavier than those with European ancestors, while the population of Asian origin was quite light. This study, carried out by Bil & Hanlon, (2016), clearly emphasizes how ethnic groups can influence the weight standards of a particular region. Similarly, Gritsch, Bil, and Hanlon (2017) stated that Australia's weight standards had become outdated within ten years of their

introduction. Moreover, the authors of this study suggested using statistics on health and weight as a reference for changing standards when the difference in run-up reaches 2%.

Based on current FAA regulations, it becomes clear that the average weight of passengers (including hand luggage) during summer navigation is 85 kg for men, 74 kg for adult women and 30 kg for children under 13 years old or 79 kg for adults in the ratio of men and women 50:50 (FAA, 2005). In addition to this, it is stated in Section 3.2 of this document that for safety reasons inaccuracies in the scales can add additional costs to airlines related to fuel consumption and time. The challenge is to calculate fuel consumption due to the extra weight of the passenger, since there is no single authority governing this standard.

Weight and weight-operating protocols and updated weight standards are key elements that need to be observed. Current weight standards are potentially outdated because they either overestimate or underestimate the actual weight of passengers.

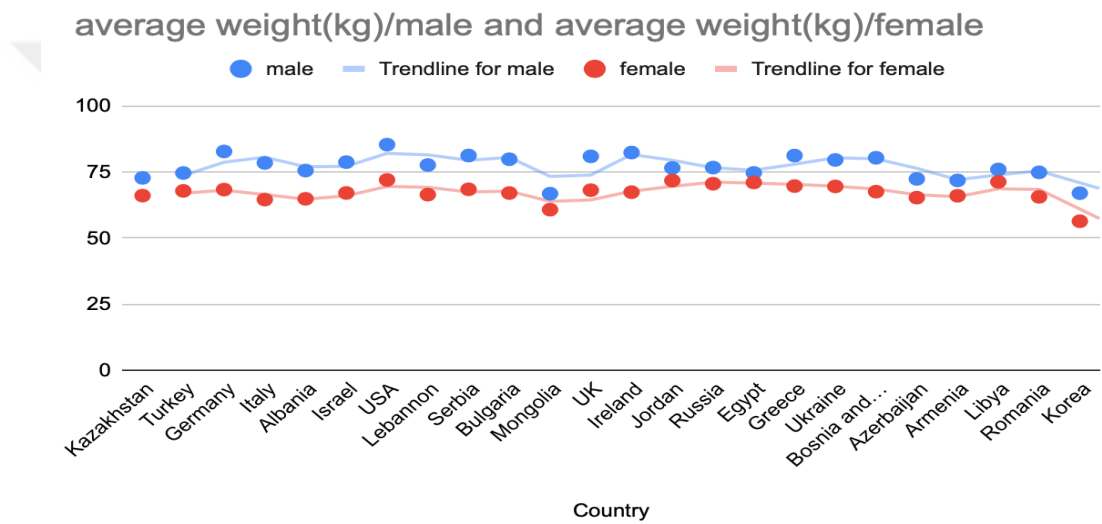
This includes the average weight of men and women. Obviously, many countries overestimate the weight of passengers, for example, Turkey, Ghana and Costa Rica. However other countries such as the USA, Australia and the European countries are considered to be underestimating passenger weight. Many of these standards have not been updated for decades. Only EASA recently updated its weight standards to accurately reflect passengers in Europe.

Weight standards should be periodically updated through surveys to reflect actual trends in passenger weight according to FAA, CAA UK and EASA requirements. This means that in these countries the anthropometric characteristics of their populations are not taken into account. Moreover, many countries apply weight standards used in other parts of the world and which may not reflect the actual statistics of their flying public. For example, the standards set by the UK regulator are used in El Salvador where the demographic composition is different and the average weights for women and men are 63 and 72 kg respectively.

These averages cover wider socioeconomic communities within countries. This may not fully reflect the demographic proportion of air passengers compared to those using

other modes of transport, especially in countries located in developing regions, such as Asia, the Pacific, Latin America or the Caribbean. To examine the links between socio-economic, anthropometric and regulatory weighting standards, further research is crucial.

In this study, questioning covered respondents from different countries. It is obvious that there is a large difference in passengers' weight depending on their region of origin, as indicated in Table 2.1 and the *Scatter Chart: Mean Passenger Weight* in Figure 2.3 :



**Figure 2.3 Scatter Chart: Mean Passenger Weight**

**Table 2.1 : Comparison of standard passenger weights used in aviation and average passenger weights in countries covered by research.**

	Country	average weight(kg)		standart passenger weight (kg)	
		male	female	male	female
1	Kazakhstan	72,82	66,12	88	70
2	Turkey	74,67	67,91	88	70
3	Germany	82,82	68,41	88	70
4	Italy	78,48	64,63	88	70
5	Albania	75,60	64,92	88	70
6	Israel	78,79	67,12	88	70
7	USA	85,40	72,06	88	70
8	Lebannon	77,69	66,49	88	70
9	Serbia	81,28	68,50	88	70
10	Bulgaria	79,88	67,09	88	70
11	Mongolia	66,85	60,81	88	70
12	UK	80,96	68,17	88	70
13	Ireland	82,40	67,42	88	70
14	Jordan	76,58	71,82	88	70
15	Russia	76,73	70,62	88	70
16	Egypt	74,71	71,08	88	70
17	Greece	81,26	69,72	88	70
18	Ukraine	79,62	69,60	88	70
19	Bosnia and Herzegovina	80,44	67,61	88	70
20	Azerbaijan	72,44	65,34	88	70
21	Armenia	71,87	66,07	88	70
22	Libya	76,01	71,32	88	70
23	Romania	74,92	65,65	88	70
24	Korea	67,04	56,43	88	70

**Note:** “Italics indicates that the standards are below the average weight.” (NCD Risk Factor Collaboration, 2016a), (NCD Risk Factor Collaboration, 2016b)

### 2.3 Aircraft Center of Gravity

There are several aerodynamic control surfaces that pilots use for maneuvering. These are the elevators, the rudder, and the ailerons. An aircraft begins to rotate around a point called the center of gravity (CG). The center of gravity is the average weight of the aircraft. However, it is very important to know how this happens. Actual weight distribution occurs throughout the aircraft; but it is important to know how exactly this distribution occurs. For complete maneuvering by an aircraft, it is enough to know the total weight at the location of the center of gravity.

The basic calculation for an engineer to determine the location of the center of gravity when designing an airplane is Newton’s equation:

$$w = m * g \tag{2.1}$$

A plane consists of many components, such as the wings; the fuselage; the engines; and the tail, together with payload and fuel. In this regard, engineers use this formula in the calculations, since each of the components has its own weight. In the formula,  $w$ =weight,  $m$ =mass, and  $g$ =the gravitational constant which is 9.8 meters/sec<sup>2</sup> in metric units.

To determine the CG, a conditional line is selected, after which the CG is determined relative to this conditional location. The total weight of the aircraft is the sum of all individual components. Since the center of gravity is the average load location, the weight of the entire aircraft ( $W$ ) multiplied by the location (CG) is equal to the sum of the weight ( $w$ ) of each component multiplied by the distance ( $d$ ) of the component from the conditional location:

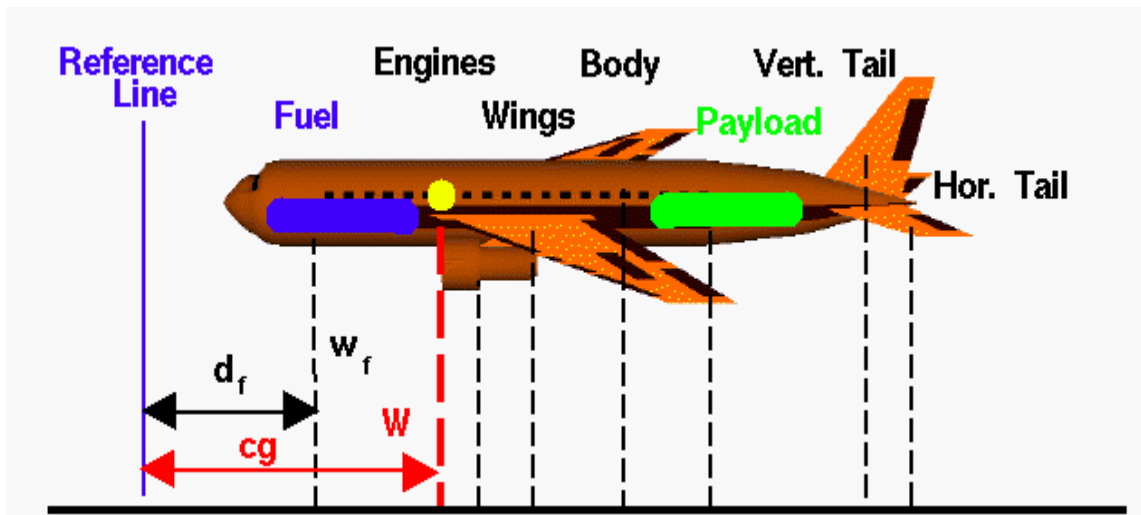
$$W \cdot cg = [w \cdot d](\text{fuselage}) + [w \cdot d](\text{wing}) + [w \cdot d](\text{engines}) + \dots \quad (2.2)$$

The center of gravity is the weighted average location of the components.

Applying this method, we find that if there are  $N$  numbers of individual components CG times the weight of the plane ( $W$ ) will ultimately equal the sum taken weight of component ( $i$ ) multiplied by the distance ( $d$ ) from the reference line ( $w \cdot d$ ), with index ( $i$ ) ranging from 1 to  $n$ . In mathematics, the Greek letter sigma is used to denote this complement:

$$W \cdot CG = \text{SUM}(\text{from } i = 1 \text{ to } i = n)[w \cdot d]i \quad (2.3)$$

The equation 2.3 shows that the center of gravity multiplied by the sum of the weight of ( $n$ ) parts is equal to the sum of the weight of the ( $n$ ) parts multiplied by their distance. This discrete equation works for ( $n$ ) individual parts. (NASA, 2015)



**Figure 2.4 Aircraft Basics**

### **2.3.1 Certification and Operational Issues**

Each year, there are a number of aircraft accidents related to weight and balance issues. Such accidents have occurred due to such reasons as incorrect loading of the aircraft and use of the wrong takeoff weight for performance calculations. Accuracy in data therefore reduces the risk of accidents/incidents related to weight and balance. However, due to the implementation of different DCS by airlines worldwide, the rate of accidents related to weight and balance dramatically decreased and data accuracy showed an improvement in the period from 1970 to 2004 (G.W.H. van Es.2007).

As the scope of this paper is to arrive at an understanding of the main problems of weight-related safety issues. Some background information about weight and balance calculations will therefore help towards a better understanding of this issue. A summary of some of the important issues relating to certification and flight operations is discussed next.

To determine the permissible limits of centers of gravity and weight, design criteria must comply with rules such as those specified in FAR 25 and EASA CS 25 (see, for example, FAR 25.27 and EASA CS 25.27). The criteria established in these rules determine the requirements for stability, controllability and strength in all permissible positions of the center of gravity and corresponding weights. The position of the aft center of gravity is determined by the requirements of stability; and the limit of the

forward center of gravity is determined by the control requirements. These requirements are discussed below in more detail.

One of the main conditions in determining the forward center of gravity is the controllability of the aircraft during landing. This means that the aircraft must be able to be trimmed to a high lift condition for expected landing speeds (including abuse of  $V_{ref-5}$  knots). Other cases associated with the flight control, which can affect the forward limit of the center of gravity, include avoiding maneuvering a quick rise in the angle of attack; the ability to quickly restore the angle of attack while lowering the nose; and controllable pitch at low speeds during unusual cases (e.g. failure). The above cases relate to airborne conditions. On the ground, the limit of the center of gravity is mainly determined by maximum pressure on the nose landing gear.

The most important factor in determining the limit of the aft center of gravity is static longitudinal stability. In order to maintain positive natural stability at the aft limit of the center of gravity, an aircraft must demonstrate pitch control of altitude at low speeds and high thrust (for example, go-around) and such control is possible even in unusual situations (failure cases, such as fuel caught in the trim tank). For good taxiing and full control during the take-off run, the aft center of gravity limit is determined by minimum loads on the nose landing gear; while to prevent the aircraft from capsizing, the entire maximum load should fall on a main landing gear. Even if an engine fails, control of the aircraft should remain.

All of the requirements that are discussed here determine the boundaries of the permissible center of gravity and weight during take-off, landing and in flight. An example of such an envelope is shown in Figure 1. This example was taken from the certified flight manual of Turkish Airlines (IATA AHM560, 2005).

During certification, a main task is to adjust the trimmer during take-off and certification of the so-called green zone. Thus, the trim setting is limited to take-off-abuse coverage areas. It should be shown that the aircraft retains control when taking off at the aft limit of the center of gravity and has a trimmer in the green zone with the nose-up. In addition, it should be possible to rotate the aircraft without significantly increasing the distance for take-off with the forward limit of the center of gravity and the trimmer in the green zone with the nose down.

Actual data from the center-of-gravity envelope does not always coincide with certified data. Due to the fact that at the moment there is no system for determining the actual weight of each passenger including their hand luggage before departure, the rules give standard values for the weight of passengers that are used for departure. Despite this, operational values remain unchanged and must be applied to the certified center of gravity. When determining the center of gravity, it is also necessary to take into account deviations from expected load distribution. In this regard, the actual limit of the center of gravity carries a more restrictive range than the aft and forward centers of gravity. With the free seating of passengers (as many low-cost airlines have), the crew must make corrective movements of passengers inside the cabin. So, for example, if in a half-filled airplane all passengers are sitting either in the front or in the back rows, the crew must move the passengers accordingly.

What are the consequences of exceeding the certified limits as defined by the envelope of the center of gravity? If the limits are exceeded, depending on the design of the aircraft, flight performance will only deteriorate. Suppose the center of gravity moves to the aft, the aircraft becomes less stable as the center of gravity approaches the neutral point 1). In the event that the center of gravity is behind the neutral point, the coordination and control necessary to maintain stable flight is lost, and the pilot may lose control. While static or moving on the ground, a center of gravity located outside the aft limit of the center of gravity in the aft can lead to a tail strike due to aircraft lifting (even at low speeds during take-off when power is supplied to the engines). The effect of exceeding the forward limit of the forward point of the center of gravity leads to a decrease in the lifting force of the aircraft.

Due to excessive stability, the elevator control, which is necessary for maneuvering the aircraft, is enhanced. In some cases, control of the elevator may not be sufficient to maneuver, such as a flare at the time of landing or go-around. The position of the center of gravity can be moved forward during take-off until it reaches a position where the aircraft is definitely stable; but it can no longer be turned without great difficulty, since the elevator has reached its maximum deflection. An improper center of gravity can, moreover, also exert strong pressure on the structure of the aircraft and thus can lead to destruction of the structure of the aircraft. However, exceeding the maximum weight of airworthiness as indicated in the manual does not always adversely affect flight performance. For example, if the maximum take-off weight is exceeded, the

landing gear may collapse. However, the chassis is designed with a large margin of error in terms of safety in order to withstand a greater load than normal landing with maximum landing weight. Under such conditions, it is possible to land the aircraft with a weight somewhat in excess of the maximum landing weight. Landings in excess of the maximum weight are often made during emergency or precautionary landings. Exceeding the maximum take-off mass affects the flight characteristics of the aircraft. The distance required to take off is lengthened and climb performance reduces. While the take-off mass does not greatly exceed the permissible limits, the aircraft can safely take off. However, any malfunction in the engine quickly reduces the limits for maximum take-off weight if the runway is short or there are obstacles that the aircraft must overcome.

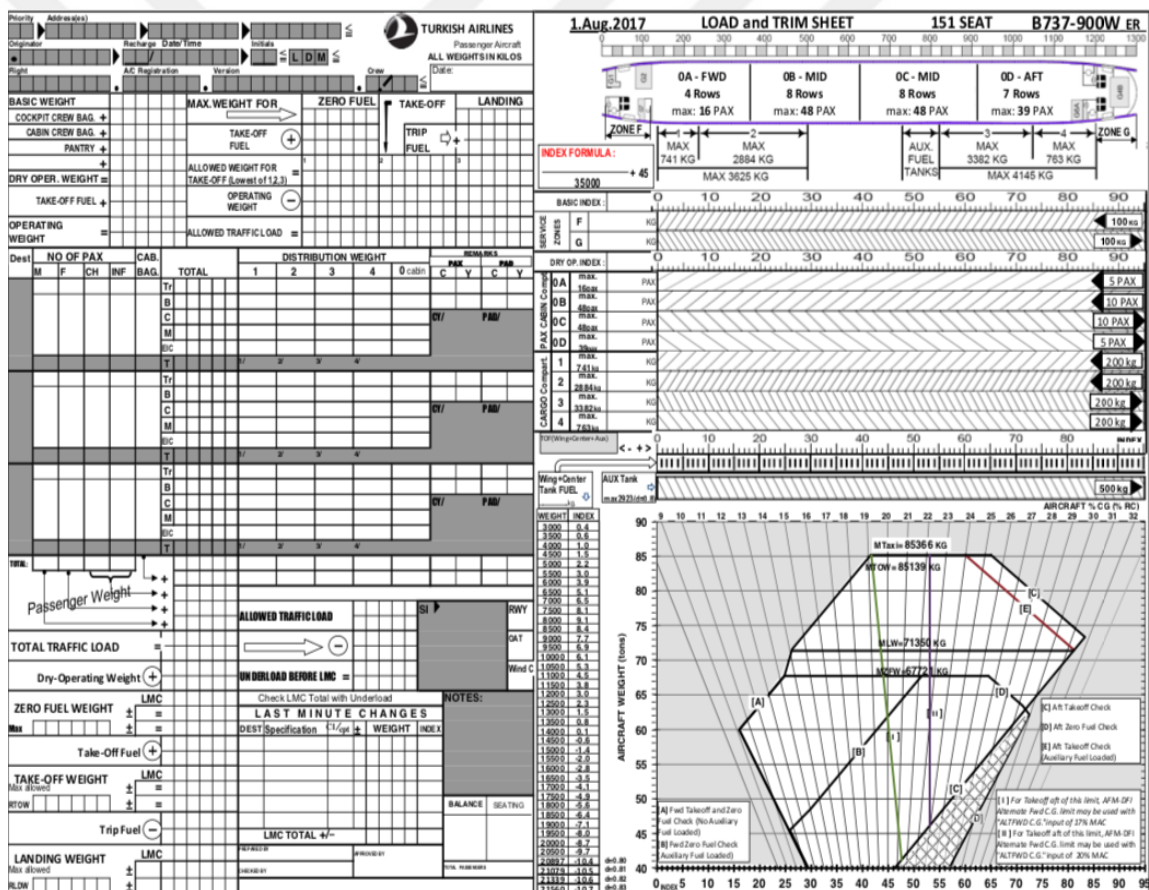


Figure 2.5 Example of load and trim sheet envelope (AHM 560, 2017)

## 2.4 Fuel Consumption

At the moment, fuel consumption in the ratio of 1 passenger per 100 kilometers varies from 3 to 4 liters. Thus, fuel is one of the largest items of expense for airlines,

amounting to about 30 percent of all costs. Effective management and reduction of jet-fuel consumption is therefore a vital factor for airlines (Laia and Pierre-Selim, 2018).

However, some new aircraft such as the Airbus Neo series significantly reduce fuel consumption and improve flight characteristics at the same time. For example, average fuel consumption per seat for medium-haul flights for the A321NeoLR is around 2.43 lt/100 km; and for short-haul flights it is 1.93 L/100 km per seat for the A319Neo.

The main task is how to measure the right amount of fuel and effectively reduce this amount without any harm to production. There are several industry-comparable “production” indicators by which fuel efficiency may be determined.

Traditionally, the aviation business consists of transporting passengers and cargo from point A to point B. Accordingly, a classic indicator will consist of the number of passengers carried multiplied by the distance.

**Revenue passenger kilometers (RPK) (or passenger kilometers performed PKP):**

The distance between VLC and TLS is about 485 km, and 6 passengers are carried.

The distance between TLS and NYC is about 6000 km, and 7 passengers are carried.

$$RPK = 6 \times 485 + 7 \times 6000 = 44910 \quad (2.4.1)$$

**Available seat-kilometer (ASK):**

The distance between VLC and TLS is about 485 km, and a number of available seats is 20. The distance between TLS and NYC is about 6000 km, and there are 20 available seats:

$$ASK = 20 \times 485 + 20 \times 6000 = 129700 \quad (2.4.2)$$

**Passenger Load Factor (PLF):**

$$PLF = RPK/ASK \quad (2.4.3)$$

$$PLF = \frac{44910}{129700} = 0,34 = 34\% \quad (2.4.4)$$

**Passenger ton-kilometers for an airline:**

If the passenger + baggage weight is unknown, the suggested value by ICAO is 0.1 ton per passenger + baggage

$$Passenger\ Ton - Kilometer = 6 \cdot 0.1 \cdot 485 + 7 \cdot 0.1 \cdot 6000 = 4491 \quad (2.4.5)$$

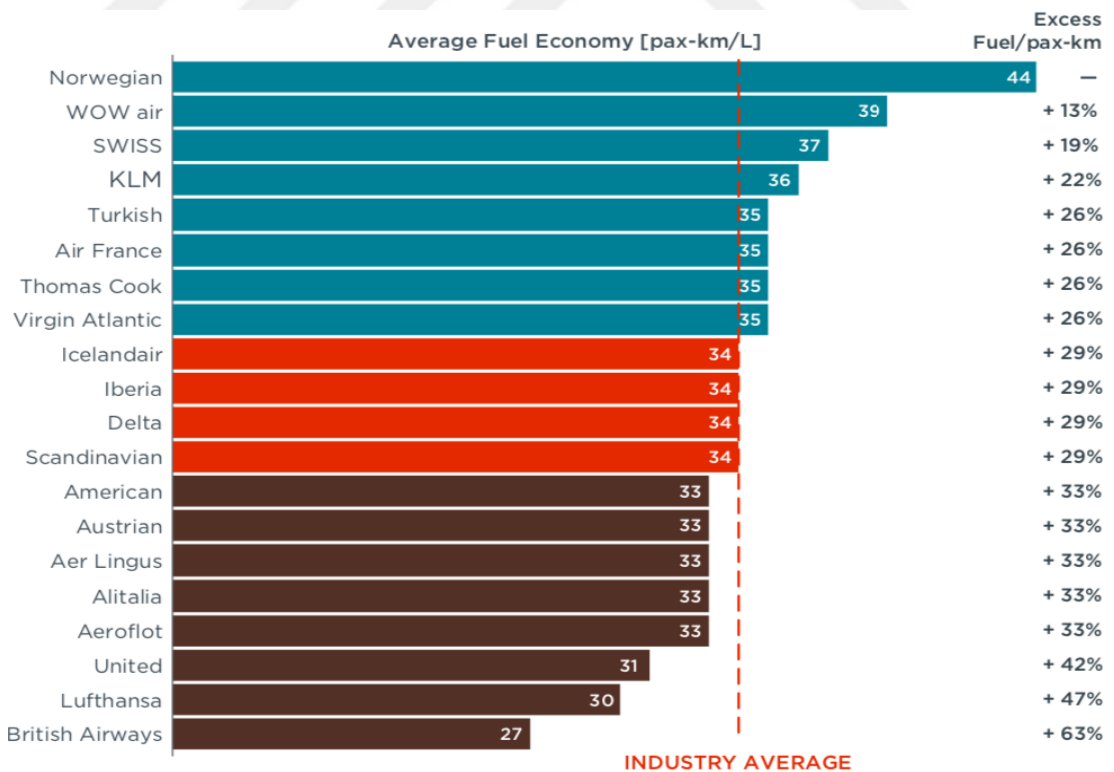
**Freight ton-kilometers for an airline:**

400 kg cargo from VLC to TLS, and 800 kg cargo from TLS to NYC

$$Freight\ ton - Kilometers = 0.4 \cdot 485 + 0.8 \cdot 6000 = 4994 \quad (2.4.6)$$

Fuel efficiency can be measured by comparing airline production with the amount of fuel burned. The graph below compares the performance of different airlines in terms of passengers per kilometers per liters.

**Table 2.2 : Fuel efficiency of 20 airlines on transatlantic passenger routes, 2017 (Brandon Graver, Ph.D., and Daniel Rutherford, Ph.D., 2018.)**



From the Table 2.2, it is clear that for long haul an average of 34-35 passengers per km per liter of fuel is burned. For example, Turkish Airlines has an average fuel

efficiency of 35 passengers per km (pax-km/L) (2.86L/100 PK), which is 21% higher than the industry average. British Airways, however, the least efficient, has a performance of 27 passengers per km and burned 37% more than Turkish Airlines and 63% more than the top airline in the list, Norwegian, which recorded 44 pax-km/L (2.27 L/100 PK). According to the Table 3, it can be assumed that the amount of fuel burned per passenger per 100 km is about 3.2L. However, in different environmental reports fuel efficiency is higher than airlines show in their sustainability reports, as is demonstrated in Table 2.3.

**Table 2.3 : Airline’s Environmental performance**

Airline	Airline reports	Environmental report
Lufthansa	3.85L/100PK	4.2L/100PK
Delta or Emirates	2.9L/100PK	4.3L/100PK

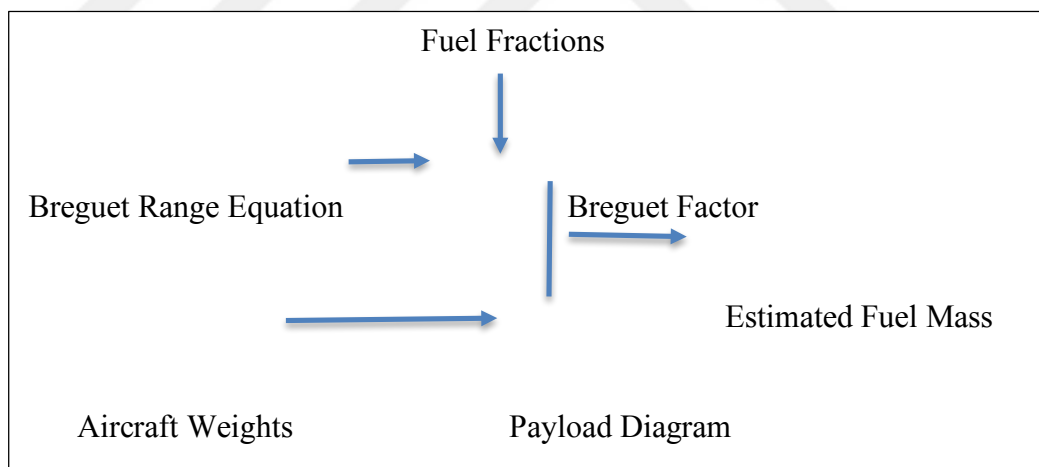
There is a Table of differences between different airlines business models in Table 2.3. From Table 2.4, it is clear that low-cost airlines have better results in terms of fuel consumption in liters per 100PK units. Due to the fact that low-cost airlines use different tools in terms of filling and savings, their indicators are therefore better and more efficient. Suppose, for example, an airline operates flights over a medium-haul range an a flight with a duration of two hours in a narrow-body aircraft with a seating capacity of 200 seats. When the load factor is equal to 80%, efficiency is about 3.5 liters per 100 PCs; but when using a load factor coefficient of 90%, this Figure will be 3.15 liters per 100 PK. However, does this mean that these indicators are the best in terms of efficiency? In order to measure fuel efficiency, the number of liters per km per passenger is not always suitable, since this value depends on the loading factor. However, other metrics such as fuel consumption per hour also exist.

**Table 2.4 : Fuel Consumption According To Airlines’ Business Model**

Airline business model	Litres/100 passenger kilometre
Low Cost	3.18
Charter	3.469
Regional	4.47
Flag carrier	3.405

### 2.4.1 Fuel Calculation

During the flight, many factors affect fuel consumption, such as: type of aircraft, payload, distance, cruise speed and much more. It is clear that the greater the distance, the greater the fuel consumption. However, how does the range affect constant fuel consumption and how will the fuel consumption change if the range and number of seats changes? It is therefore important to know that during long routes over very long distances, the payload (and therefore the number of passengers) should be reduced. In all of the cases mentioned, nonlinear behavior was found for a specific fuel consumption depending on the range. The only problem is that there is very limited information about aircraft in publicly available sources. There is information for a general understanding of how fuel consumption is calculated: the basis is the Breguet factor or so-called "Breguet Range Equation", which was developed by a French aviation pioneer, Louis Breguet (1880–1955). This equation calculates the rate of change in mass of an aircraft during a flight. The following steps are shown in Figure 2.6:



**Figure 2.6 Fuel calculation scheme (M.Burzlaff,2017)**

#### 1) Breguet Range Equation

To calculate the change in aircraft mass during a flight by flown distance, this equation is used:

$$R = \frac{V \cdot E}{c \cdot g} \ln \frac{m_1}{m_2} \quad (2.4.7)$$

### ***Breguet Factor for Horizontal Flight***

This calculation of the Breguet Factor can be valid only for horizontal flight.

$$B = \frac{R}{\ln \frac{m_1}{m_2}} \quad (2.4.8)$$

### **2) Fuel Fractions:**

This is the Fuel Fraction for the whole flight.

$$M_{ff} = M_{ff,Cr-Res-Loi, C} \cdot M_{ff,LTO} \quad (2.4.9)$$

### ***Breguet Factor for Entire Flight Equation:***

$$B = \frac{R}{\ln \left( M_{ff,LTO} \frac{m_1}{m_2} \right)} \quad (2.4.10)$$

### ***Breguet Factor- Based Range Equation:***

$$R = B \cdot \ln \frac{m_1}{m_2} \quad (2.4.11)$$

### ***Breguet Factor-Based Fuel Mass Equation:***

$$M_{fuel}(R) = m_2 \left( \frac{R}{e^B - 1} \right) \quad (2.4.12)$$

### **3) Aircraft Weights**

The weight of the aircraft consists of different classifications. The following describes the weights that are used in the calculation of fuel:

**Manufacturers Empty Weight (MEW)** = Aircraft structure components including basic equipment, engines and required systems.



Number 1 shows the maximum load at which transport is possible to point A with an increase in the amount of fuel. This so-called settlement point is reached when the maximum weight is reached, but it can still accommodate more fuel.

From this diagram, it follows that for an extended flight range a decrease in payload weight is required along with an increase in the amount of fuel. At point B, the fuel tanks are fully loaded, followed by a decrease in payload until the ferry limit is reached.

### ***Breguet Factor Calculations***

$$B = \frac{V \cdot E}{c \cdot g} \quad (2.4.13)$$

In practice, environmental conditions such as temperature or wind, which have a strong influence on fuel calculation, are ignored. The values used for a B737-type aircraft are considered as a general standard:

$$C = 0.025 \frac{g}{NS}; V = 236.6 \frac{m}{s}; E = 15; g = 9.81 \frac{m}{s^2} \quad (2.4.14)$$

$$B = \frac{236,6 \cdot 15}{0,025 \cdot 9,81} = 14470.948 \simeq 14471 \text{ km.}$$

$$B = \frac{236,6 \cdot 15}{0,025 \cdot 9,81} = 14470.948 \simeq 14471 \text{ km.} \quad (2.4.15)$$

### **2.4.2 Flight-Plan Fuel Calculation**

One of the main aspects of a flight is the development of a flight plan. The airline dispatch service is involved in flight-plan preparation. Based on available data such as flight time, weather conditions, route restrictions and alternative airports, the dispatcher, based on the payload, draws up a flight plan and calculates the required amount of jet fuel. Fuel calculation is carried out according to criteria such as trip fuel; contingency (3-5 %); alternative airport; final reserve; ETOPS /ADDNL; dispatch extra; taxi; APU; commander extra; required fuel on board (FOB); tinkering; and total ramp FOB.

In below Table 2.5 are descriptions for the items mentioned in Table 2.6:

**Table 2.5 : Dispatching fuel abbreviations**

<i>Abbreviation</i>	<i>Description</i>
<b>Trip Fuel</b>	The amount of fuel estimated to be used during the flight. Trip fuel includes take-off, Clb, Cr, Ldg.
<b>Contingency fuel</b>	The amount of fuel required to compensate for unforeseen obstacles. It can be the deviations that can occur during the operation such as weather conditions; extended taxi time; and cruising level.
<b>ALTN</b>	Fuel required to reach an alternative airport in case of diversion.
<b>Final Reserve</b>	Calculation of the amount of fuel estimated to be kept in reserve in case of diversion.
<b>ETOPS/ADDNL</b>	Additional fuel reserves required for an extended route.
<b>DISP.EXTRA</b>	The amount of extra fuel required.
<b>TAXI</b>	The amount of fuel required for taxiing from aircraft ramp area to the runway.
<b>APU</b>	The amount of fuel required to generate electricity in the aircraft during time on the ground.
<b>Commander Extra</b>	The amount of extra fuel as decided by the pilot-in-command.
<b>Required FOB</b>	The total fuel on board required for the flight.
<b>Tankering</b>	The amount of excess fuel required to reduce or eliminate refuelling at the destination. In case of a shortage of fuel or because of high-priced fuel, airlines practice tankering in order to reduce or eliminate refueling at destinations.
<b>Total Ramp FOB</b>	The total fuel required for operation.

The next table shows an example of the dispatch fuel calculations required during the flight:

**Table 2.6 : Dispatch Fuel Calculations in kg.**

<b>ERA LTFH</b>	<b>FUEL</b>	<b>TIME</b>
TRIP	11952	04:56
CONT %3	359	00:10
ALTN (LTAC)	1711	00:42
FINAL RESERVE	1006	00:30
ETOPS/ADDNL	0	00:00
DISP.EXTRA	539	00:15
TAXI	120	00:10
APU	105	01:00
COMNR.EXTRA	0	00:00
REQUIRED FOB	15792	06:33
TANKERING	0	00:00
TOTAL RAMP FOB	15792	06:33

## **2.5 Aircraft Design and Passenger Comfort**

The design of an aircraft provides for passenger capacity in limited fuselage conditions. Profit maximization is the main goal of airlines, while designers are working to develop more comfortable, spacious, and ergonomic seats for passengers. To increase profits, airlines are constantly developing new methods to increase the number of passengers on the plane, while creating minimal conditions of comfort for them. Despite the fact that trends in increasing parameters of people's bodies show growth, the ergonomic standards of seats in airplanes remain unchanged. As a result, more and more people suffer from discomfort during flights. And for this reason, passengers with large anthropometry sometimes have to suffer from "non-placement" on board. Unfortunately, at the moment there are no specific documents that regulate this problem. Experiencing high competition, many airlines apply changes to their passenger seating strategy. In addition, airlines solve problems to improve ergonomics and designs while maintaining maximum passenger capacity. There are several studies in this area that are summarized below.

Surveys have shown that the main reason for passenger dissatisfaction is aircraft seats. One of the first studies in this area was carried out by Richards and Jacobson (1975), who evaluated passenger comfort through two questionnaires. One questionnaire was distributed to passengers on the ground, and the second in flight. Overall, 32% of those questioned considered the aircraft seats to be uncomfortable. There was an obvious connection between the overall comfort of flight and the comfort of the seat. Their study showed that men reacted most sensitively to seat comfort, while for women this was not significant. But we must take into account the fact that of the sample only 2% of those questioned on the ground and 12% of those in flight were female.

Research in this area was also conducted by Vink et al. (2012), but with a more balanced sample of men and women. Across 10,032 surveys and 153 interviews there were a number of point of complaint that related to discomfort. Many of the complaints related to the ergonomics of the seats. Despite the fact that there were aspects of complaints about hygiene, legroom, and crew attention, personal space on the plane was criticized the most. The study recommended that seat ergonomics should be improved by increasing the width of the seats and increasing passengers' overall personal space.

A study conducted by Ahmadpur et al. (2014) also included a questionnaire to determine the relationship between passenger comfort and aircraft cabin characteristics. General physical comfort including personal space was one of the key criteria of this study where legroom space is a secondary factor. This study differed from the previous ones in that the interior designers of the aircraft were also interviewed to determine the level of comfort. As a result, passengers and designers' opinion were divided: passengers believed that personal space, autonomy, and privacy played the most important role; while designers believed that personal space is a secondary factor which cannot be avoided.

A survey to determine the invasion of personal space in aircraft was conducted by Lewis et al. (2017). Through questioning o passengers, the authors tried to establish the reaction of passengers to finding that their personal space has been violated; and the criteria for determining when passengers feel that their personal space has been violated. According to the results of the study, passengers noted that they experienced irritation, discomfort, and anger during physical disturbances, such as touching with

hands and feet, which were the main determining aspects of a violation of personal space.

There are also surveys carried out by Vredenburg, Zackowitz, and Vredenburg (2015) and Park, Park, and Kim (2014) which also measured passengers dissatisfaction level, and factors which led them to feel discomfort during the flight.

Despite the fact that passengers experience discomfort during the flight, there are fears that the width of the seat can also cause health problems for people. Vein thrombosis is one such condition, when a decrease in space can cause the development of this problem. In addition, due to the narrow space, the time of disembarkation and boarding of passengers increases, and in emergency cases this can become a serious problem. In this regard, the Federal Aviation Administration (FAA) was instructed to introduce seating standards in the cabin of passenger aircraft (Bromwich 2017).

According to a study conducted by Elizabeth L. Miller et al., (2019) a standard was developed by US military personnel in the 1980s and this ANSI/HFES 100-2007 standard provides for an armrest width of 460 mm for seats with a margin of 25 mm for clothing and movement. As the standard was developed almost 40 years ago, it is insufficient for modern passengers. Even seats designed according to the HFES standard will make it possible to comfortably accommodate only 77% of passengers, assuming that half the passengers are men and half women. The ANSUR II study of femoral width for seated women, accurate to the 95<sup>th</sup> percentile, gives a result of 456 mm (Gordon et al. 2014). Under these conditions, if the HFES standard is used with an armrest width of 480 mm when the aircraft is fully loaded, passenger seating will improve to 85%.

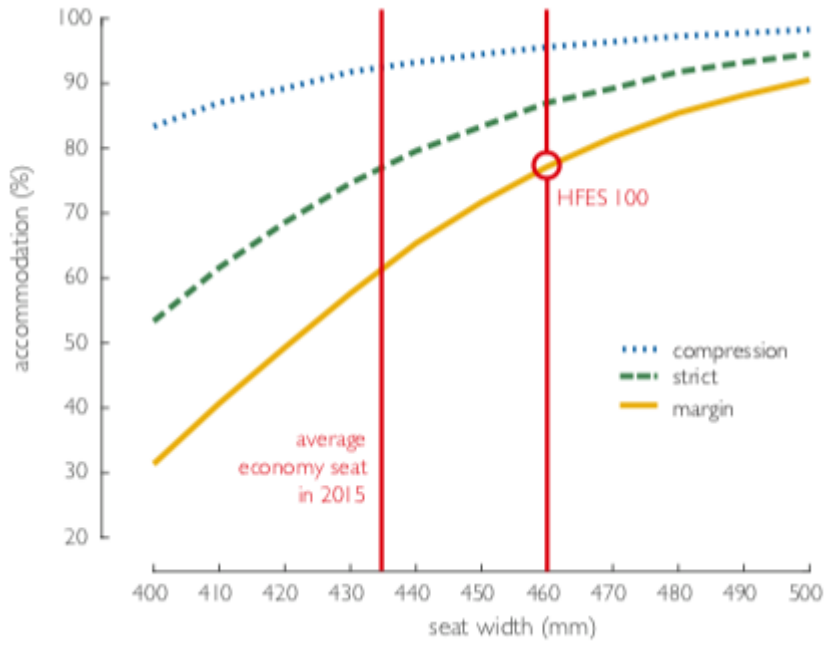
Moreover, there are several scenarios presented in a case study by Elizabeth L. Miller, et al., (2019), where researchers developed several models of passengers seating in the cabin. According to the results of the study, it is clear that the most efficient placement in the cabin is with fewer passengers and more seats. But the reality is that modern aircraft fly with a very large load, and, in this regard, the placement coefficient is highly dependent on this. The options are limited as regards optimizing passenger accommodation and modelling of optimal scenarios.

At the moment, due to the fact that airlines are all compensating for the narrowing of the width of the armrests with an increase in the number of seats, planes are becoming more and more cramped. The likelihood of the efficient accommodation of passengers is much reduced; and this differs drastically from the situation in the 1990s when aircraft loads were much lower and even with a smaller seat width load factors such as 67% could be achieved.

Even under the most optimistic scenarios and even if a passenger does not have a lot of clothing on, the level of effective accommodation is very low. Thus, when the aircraft is fully loaded, 1 in 5 passengers will still not be accommodated, even if clothing is compressed by 50 mm.

Due to the fact that anthropometric parameters have increased since the beginning of the 2000s, placement in an airplane is now problematic. However, even with the constant width of the seats and aircraft loading at the level of the 1990s, the effect of the increased width of the seats would be created due to the additional space.

The analysis cited in Elizabeth L. Miller's, et al., (2019) work is based on the assumption that passengers are seated unmoving in their seats. However this does not take into account personality factors such as a passenger moving closer to their neighbor, even if there is free space; or a passenger being uncomfortable sitting with a neighbor and moving somewhere else on the plane. Future models may also include anthropometric factors such as shoulder width, leg length, and non-anthropometric preferences such as foot disease, posture, etc. All of these behavioral or individual models can be embedded in the model for future research.



**Figure 2.8 “Accommodation as a function of seat width with load factor =1 and gender ratio =0.5. The HFES 100 recommendation for width between armrests (460mm) is noted” (Human Factors and Ergonomics Society 2007).**

## **CHAPTER III**

### **RESEARCH METHODOLOGY**

#### **3.1 Introduction**

In this section, the author of this study collected data from nine flights. The methodology used in the study based on an empirical, statistical, and analytical approach is the induction method. By comparing and using different techniques, the author tried to create a simulation of a new approach to the passenger check-in process. Since the main criterion for this study is safety, applying and analyzing the data will provide the possibility for simulation in the implementation of new approaches.

#### **3.2 Sampling**

Sampling is the process of obtaining small representative units from a larger population (Neuman, 2011). The criteria for data selection were based on anthropometric passenger data (see Appendix A). 20 questionnaires were collected for each flight. The main measurement was the weight of adult passengers alone, while the weight of children and infants was not taken into account and standard values were used. Since the presence of passengers was required to collect information, the study needed to be carried out in practical conditions. In order to obtain more realistic indicators, the choice of respondents was carried out by random choice. Moreover, due to ethical considerations, this survey was conducted by observation. No personal data was collected during the survey.

In conducting the questioning, the choice fell on international flights, as this provided the opportunity for a deeper and more diverse study. That is, in view of the fact that each country and region has its own range of anthropometric parameters, a larger spectrum is embraced when examining a diverse audience. It was decided that 20 questionnaires per flight were sufficient to collect information. After creating the

questions and unpacking the ready-made tables for several flights, the survey was carried out.

Before each flight, the researcher asked the airport staff members to determine their weight and the weight of other employees. After that, the personnel representatives who were most able to determine weight were selected to collect data by observation. The airport staff wrote down the data that was collected in the table; and after the end of each flight the researcher collected the questionnaires from the airport staff.

Due to the complexity of data collection, the questionnaire method is considered the most humane and most effective.

### 3.3 Data Collection

Several data collection methods were used. The first and the main method was carried out by direct questionnaire. The number of all respondents was 180 passengers. That is, over nine flights, 20 questionnaires were collected from each flight. Data from similar studies and publications over past periods was also used, as described in chapter 2. In addition, for better data processing, data were used from the open sources of companies' websites as well as the Departure Control System of Turkish Airlines Inc. For instance, weights used by the airline were required for the formation and comparison of the use of standard data and data from the study (Table 3.1).

**Table 3.1 : Passenger and Baggage Weights Standards Turkish Airlines Inc. (AHM560, 2019)**

	<b>Male</b>	<b>Female</b>	<b>All Adult</b>
<b>All flight except holiday charters</b>	88 kg	70 kg	84 kg
<b>Holiday charters</b>	83 kg	69 kg	76 kg
<b>Child (2 years to 12 years)</b>	35 kg	35 kg	35 kg
<b>Infant</b>	10 kg	10 kg	10 kg

### 3.4 Design of Questionnaire

In order to cover the full range of data, it was necessary to create a questionnaire on data based key points. The following are the points on the questionnaire listed in Appendix A:

**Flight Number** - This number determines the airline and flight route. In this case, flight number TK0355 is a regular flight operating from Nur Sultan Airport to Istanbul.

**Date** - It is very important to know when the study took place, since passengers' weight can vary from season to season. For instance, a passenger can weigh much more during the cold months than during the summer months because of the weight of their clothing. In this study, the average weight of passenger' clothing was 7 kg.

**Key Criteria** - The criteria by which research and data collection were carried out;

**Aircraft Type** - There are several varieties of types of aircraft; but in practice there are only two: wide-body and narrow-body. This parameter is crucial for the research. The CG parameters of narrow-body and wide-body aircraft are completely different, in addition to the fact that the flight characteristics of the different types of aircraft are different also. The CG and the influence of the load being carried on the CG is therefore different. For example, the narrow-body B737-800/900 and A320 and the B747 and A330 have different characteristics.

**Seat Number** – This is the place where the passenger is located. Due to the fact that the location of each passenger affects the center of gravity of the aircraft, this criterion is one of the key criteria.

**Nationality** - It is very important to know the nationality of the passenger, as the anthropometric parameters of people of different nationalities are always different. This is clearly visible in section 2.1.1.

**Category** – This is the gender of the respondent. Due to the fact that the anthropometric parameters of men and women are different, this criterion is one of the key factors.

The weight of passengers is probably the most important criterion and is the main reason why this study was conducted.

**Weight of Cabin Baggage** - Since the weight of hand luggage is not registered anywhere and only conventional numbers are used, it was very important in this regard to know what weight the passenger has in addition to his or own bodyweight.

### 3.5 Confidence-Level Test for Samples

The total number of respondents was 180, consisting of 107 males and 73 females. This meant that about 60 % of the overall sample were males and 40 % females. As far as statistical analysis is concerned, the data-descriptive method was used in order to ensure data validity.

**Table 3.2 : Samples Descriptive Statistics results**

<b>Descriptive Statistics</b>	<b>Male</b>	<b>Female</b>
Average	78.41121495	62.46575342
Stdev	10.74134427	10.37904164
Count	107	73
Confidence level 95%	2.058738801	2.421609585
Upper	80.46995375	64.88736301
Lower	76.35247615	60.04414384

**Table 3.3 : Descriptive statistics test results of average weight**

<b>Date</b>	<b>M</b>	<b>F</b>
19.12.2019	86.16	67.5
20.12.2019	85.66	71
21.12.2019	94.71	72.5
22.12.2019	93.07	65.28
23.12.2019	87.42	78.83
27.12.2019	95.83	76.42
29.12.2019	78.92	69.33
30.12.2019	88.69	68.71
31.12.2019	85.83	71.21
<b>Average</b>	88.47666667	71.19777778
<b>Stdev</b>	5.32473004	4.266567056
<b>Count</b>	9	9
<b>Confidence level 95%</b>	4.09294983	3.279573758
<b>Upper</b>	92.5696165	74.47735154
<b>Lower</b>	84.38371684	67.91820402

After the confidence level test, it is obvious that with 95 % confidence the true mean weight for male passengers is between 80.5 and 76.4 kg; and for female passengers the true mean is between 64.9 and 60.05 kg.

### **3.6 Data Analysis and ANOVA test**

In this study, data is processed for analysis using descriptive statistics. Several types of data were used: data obtained through questionnaires; data obtained through the company's systems; and data obtained through calculations. The data obtained through research is basic.

The data obtained through the company system and calculation are given in Table 3.6. The following example demonstrates how the data was calculated.

When loading the aircraft at 53% with the number of passengers equal to 81, consisting of 51 men, 26 women, 3 children, and one infant and taking into account the fact that there were 77 adults on board, the sample of respondents was 26%. This indicator maximally allows us to get closer to the real indicators and makes it possible to calculate the probability in the most accurate way. Indeed, it appears to be that the smaller the load factor the greater the likelihood of data accuracy. However, due to the changing load factor, the overall load indicator for all flights' indicators changes slightly. Thus, for nine flights, the total average load of the flights was  $0.7321777673 \approx 73\%$ , with the number of passengers equal to 1078. If we take into account the fact that the number of adults on the flights was 1032 and that the number of respondents was 180, the total percentage of the sample is  $0.1744186 \approx 17\%$ , which is significant to process for better accuracy.

After testing on the level of confidence through descriptive statistics, using standard values, deviations, and graphs, a general model for the implementation of this study was created. Data processing and analysis of the results was carried out by using programs such as IBM SPSS (version 22) and Microsoft Excel.

**Table 3.4 : Load factor for researched flights**

Date	Total seat	Seat occupied	Load factor
19.12.2019	151	81	0.54
20.12.2019	169	99	0.59
21.12.2019	151	96	0.64
22.12.2019	151	122	0.81
23.12.2019	169	111	0.66
27.12.2029	169	133	0.79
29.12.2019	169	164	0.97
30.12.2019	169	132	0.78
31.12.2019	169	140	0.83

**Table 3.5 : Mean passenger weight according to the research**

Date	Sample Mean in kg.		Cabin and Winter Factor Mean kg.		Result kg.	
	M	F	M	F	M	F
19.12.2019	75.83	57.5	86.16	67.5	86	68
20.12.2019	73.33	58	85.66	71	86	71
21.12.2019	85.71	72.5	94.71	72.5	95	73
22.12.2019	83.07	57.14	93.07	65.28	93	65
23.12.2019	79.28	70	87.42	78.83	87	79
27.12.2019	85	68.57	95.83	76.42	96	76
29.12.2019	70.71	61.66	78.92	69.33	79	69
30.12.2019	79.23	58.57	88.69	68.71	89	69
31.12.2019	76.66	62.14	85.83	71.21	86	71

(0.5↑, 0.4 ↓)

**Table 3.6 : Passenger figure**

Date	Men	Women	Child	Infant	Total
19.12.2019	51	26	3	1	81
20.12.2019	51	45	3	0	99
21.12.2019	65	27	3	1	96
22.12.2019	89	31	1	1	122
23.12.2019	72	36	2	1	111
27.12.2029	69	58	5	1	133
29.12.2019	96	62	6	0	164
30.12.2019	69	58	3	2	132
31.12.2019	72	55	10	3	140

According to the collected samples, the dependent parameters of the research are ethnicity, gender, age has an influence to the weight factor. The results of this relationship shown in ANOVA test analysis in Table 3.6.

**Table 3.7 : ANOVA Analysis**

		Sum of Squares	df	Mean Square	F	Sig.
<b>ETHNICITY</b>	<b>Between Groups</b>	9.055	5	1.811	8.834	.000
	<b>Within Groups</b>	35.673	174	.205		
	<b>Total</b>	44.728	179			
<b>GENDER</b>	<b>Between Groups</b>	16.946	5	3.389	22.296	.000
	<b>Within Groups</b>	26.449	174	.152		
	<b>Total</b>	43.394	179			
<b>AGE</b>	<b>Between Groups</b>	1650.592	5	330.118	2.618	.000
	<b>Within Groups</b>	21938.208	174	126.082		
	<b>Total</b>	23588.800	179			

Performed ANOVA analysis test has shown definite influence of the ethnicity to the weight with a high significance level. For gender parameter, the results are more accurate and presents higher significance level of the weight. However, age results

shown less accurate results but still significant and show as 0.26043 the level of significance.

It can be concluded, that weight highly depending on these three parameters and shows an obvious influence.



## CHAPTER IV

### COMPARISON AND DATA ANALYSIS

#### 4.1 Comparison of Data and Calculation of Passenger Weights

For a clear analysis of the likelihood in the study, it was necessary to clearly show what data should be compared. For this, standard weights used by the airline were used to calculate the payload of the aircraft as indicated in section 2.3.1. The following is a comparison of the total weight of passengers according to standard data and data according to the study.

*Flight number and date: TK0355, 19 December 2019.*

Flight details, passenger figures as shown: men - 51, women - 26, children – 3 and infants - 1. According to standard weight parameters, the payload is represented in Table 4.1.

**Table 4.1 : Real payload values**

<b>Payload total</b>	<b>Passengers weight</b>	<b>Baggage /cargo weight</b>
7831 kg.	6423 kg.	1408 kg.

**Table 4.2 : Projection with updated passenger weight for the same flight**

<b>Payload total</b>	<b>Passenger + winter clothing factor+ cabin baggage factor</b>	<b>Baggage/cargo weight</b>
7647 kg.	6269 kg.	1408 kg.

According to the questionnaire, the average passenger weight for the sampled men was 86 kg, for women - 67 kg. These values include a winter-clothing factor (+5 kg) and a cabin-baggage factor (+ 8 kg). The calculation was made from the average number from the sample, followed by multiplying by the number of passengers. At the beginning of the research the cabin weight did not take into consideration whether only

a “Yes” or “No” option had been given. In the case of “Yes”, the standard value for cabin-baggage weight (8 kg.) was included in the cabin-luggage factor. Only two flights had shown a cabin factor of +8 kg of cabin baggage, on 19.12.2019 and 20.12.2019. In further samples, the actual cabin-luggage weight was included; and so the research obtained more precise data over the next seven flights. As a result, the ghost weight for the 19.12.2019 flight was calculated as **154 kg**.

#### **4.2 Passenger Weight Value Comparison**

According to the standards used in aviation as mentioned in Chapter 2.1.1., the standard weight includes people's bodyweight, their clothing and cabin baggage. However, the same standard cannot be valid for all regions, which have not only different anthropometry, but also for regions with different seasonal factors and climatic diversity. For example, January is a winter month in the northern hemisphere; but for areas such as Australia, South Africa and South America it is a summer month. Clothing factors will therefore be different for these regions and this will in turn alter the values for passenger weight. It is important to use the right winter or summer clothing factor. In this study, the clothes factor was taken to be 5 kg. The pure weight of passengers, the weight of hand luggage and the factor of winter clothes were thus taken as the basis, since these values are the only weights that are not measurable and not fixed anywhere. In the Table 4.3 below, total values are presented and results of the differences for each flight are shown. “Ghost Weight” is the weight which was not actually present but is present and fixed in flight documents. “Overweight” is the weight that is not fixed in a flight document but is still present on the aircraft. It is the same as Ghost Weight but has the opposite effect.

**Table 4.3 : Comparison of Actual and Projected weights.**

Date	Standard	Projection	Ghost Weight	Overweight	%
19.12.2019	6423	6269	154		-0.02
20.12.2019	7743	7686	57		-0.01
21.12.2019	7725	8261		536	0.06
22.12.2019	10047	10368		290	0.03
23.12.2019	8936	9260		324	0.03
27.12.2019	10317	11275		900	0.08
29.12.2019	12998	12134	926		-0.07
30.12.2019	10257	10268		11	0.001
31.12.2019	10566	10532	89		-0.003

According to the calculations, almost every flight has noticeable discrepancies in values. However, there are flights where the discrepancy is not so significant. Many factors can contribute to this, such as age and a significant number of representatives of one region. As indicated in Chapter 2.1.1, due to anthropometric data varying between regions, the weight of people may show very different results. As a fact, this study presented these changes clearly. A more detailed analysis of the data will be carried out in the data-analysis section.

### **4.3 Effect on Centre of Gravity**

Ghost Weight and Overweight have an impact on the center of gravity and they may have negative effects on aircraft safety. This section will examine what effect Overweight or lack of Overweight has on the center of gravity of the aircraft. Each aircraft has its own individual flight characteristics. From the weight and location of the seats, the configuration changes accordingly, and the center of gravity shifts. As an example, variations of weight distribution and how it affects the CG will be presented in relation to a flight dated 12/19/2019. The Table shows the MAC values

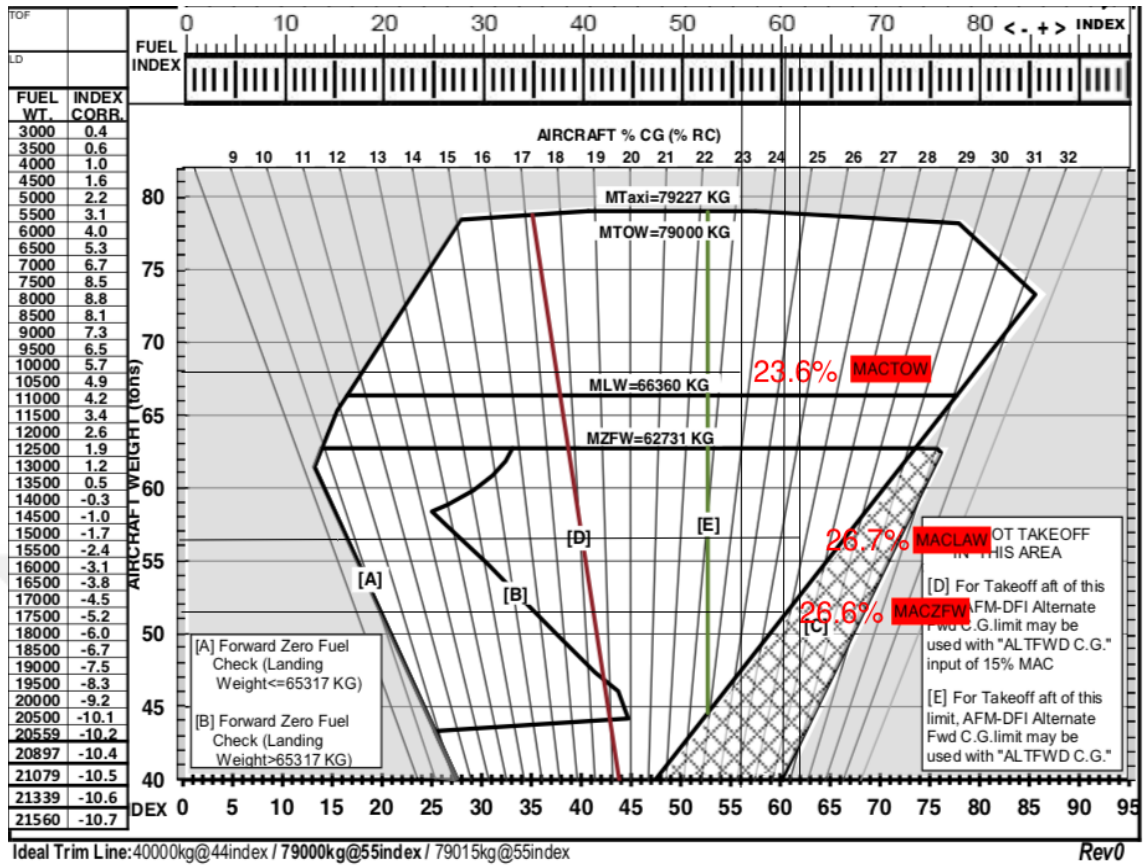
of the center of gravity at three levels (weight without fuel, with take-off weight, and weight during landing):

**Table 4.4 : Centre of gravity index**

MAC Value	Center of Gravity
MACZFW	26.6
MACTOW	23.6
MACLAW	26.7

These parameters should not pass the so-called security zone, or the green zone as indicated in Chapter 2 section 2.2.2. However, as it is shown in section 4.2 of the Table 4.3, the Ghost Weight is 154 kg. That is, it turns out that 154 kg of payload weight in an airplane is missing. Depending on the part of the aircraft where this weight is missing, the center of gravity will change. Suppose, based on the sample, the average weight of men is 86 kg, and the average weight of women is 68 kg. In this regard, in case of recalculation of all of the data, a shift will occur in the center of gravity. The Table below shows that if there is a weight shift in the OA zone by 154 kg, then the CG will shift accordingly. In Table 4.4, the normal distribution and MAC percentage are validated similarly. By multiplying 154 kg by 0.010623, the index will be 1.635942. Taking into consideration that the weight is Ghost Weight, the total weight will be lighter.

**Table 4.5 : Centre of Gravity MAC. AHM560 Turkish Airlines Inc.(2017)**



In this regard depending on the distribution of the weight, the index would be changed in a positive or negative direction. In this case the center of gravity will shift by +1.635942 divisions. In this case, all of the data on the MAC will also change. Thus, in changing by +1.6 the data is as presented in the table below:

**Table 4.6: CG index distribution AHM560 Turkish Airlines Inc. (2020)**

For TCJHK,L,M,N,O,P,R,S,T,U,V,Y,Z,JVA,B,C,D,E,F,G,H,I,J,K,L,M,N,O,P,R,S,T,U,V,Y, JZE,JZG,JZH				
	+/-	inch	+/-	per 1 kg
OA	-	371.805	-	0.010623
OB	-	71.995	-	0.002057
OC	+	286.3	+	0.008180

According to Table 4.4, the MAC of ZFW,TOW, and LAW is as shown in the table below:

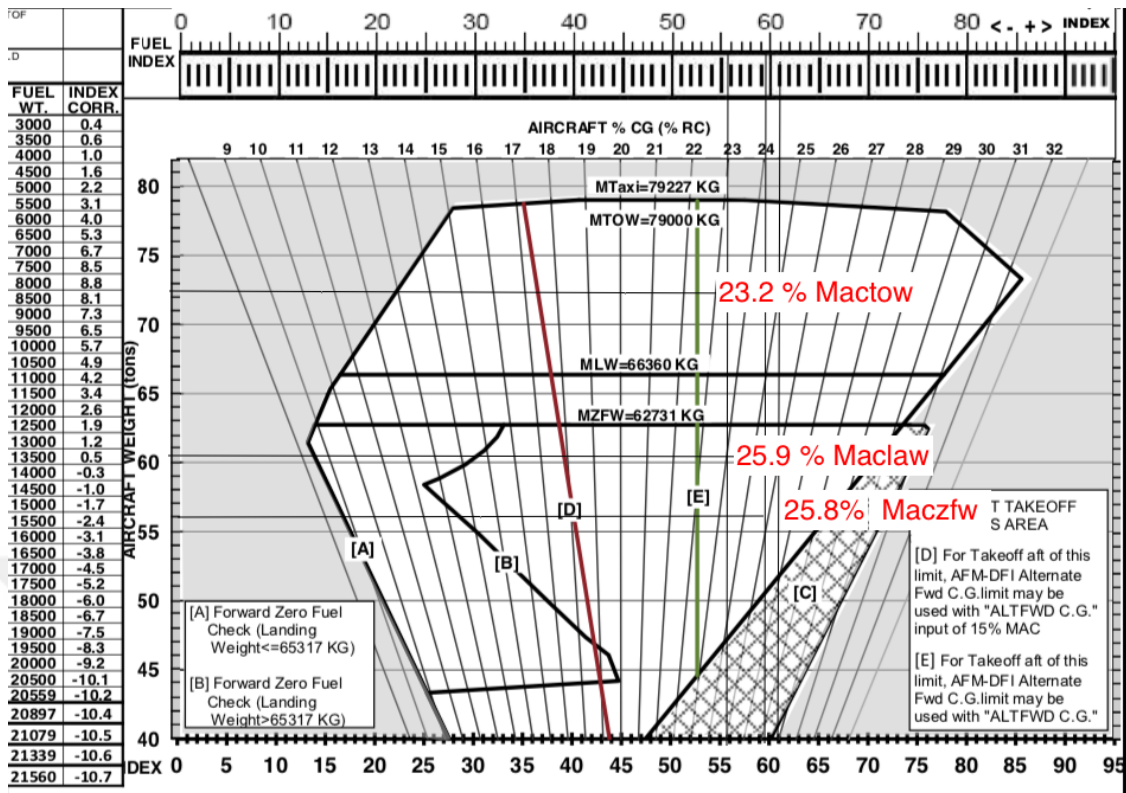
**Table 4.7 : Centre of gravity effect after recalculation**

	Old values	Updated index	New Values
MACZFW	26.6	+1.6	28.2
MACTOW	23.6	+1.6	25.2
MACLAW	26.7	+1.6	28.3

According to the table, after recalculation of indices MACZFW occurs in the critical zone; but MACTOW and MACLAW stay in the safe zone. An ideal CG value for safety and fuel efficiency is 22. Actually, this will not have a significant effect on flight safety since the values are not significant. The smallest effect on the center of gravity is the OB zone, since it is located at the very center of the aircraft. Nevertheless, there is a very serious risk if passengers weighing more than the standard move to the extreme zones of OB or OC. According to the data from the questionnaire, the distribution of passengers throughout the cabin is as follows: zone OB - 8 male and 3 female passengers; and zone OC 4 - male and 5 female passengers. In the OB zone there are the following passengers with: two men and one woman; and in the OC zone there are three men and one woman with excess standard weight values. This makes up 20% of the total number of respondents and about 30 kg of excess weight.

If the flight has a large overweight value, whether the weight is Ghost Weight or Overweight, CG changes dramatically. In the case of the flight on 22.12.2019, the load factor is 80 % and the overweight value is 290 kg more than the values calculated according to the standards. The average weight for a male passenger is 93 kg and for females it is 65 kg. Flight characteristics applied for this case are according to the individual characteristics of the B737-800 aircraft. The distribution of passengers was A12, B63, C47. First of all, the actual values and charts are evaluated, then the comparison and different scenarios of weight distribution are applied. The MAC chart and values are given as follows:

**Table 4.8 : Centre of Gravity MAC. AHM560 Turkish Airlines Inc. (2017)**



The sample passenger cabin distribution is as follows: cabin zone B - 8 male and 2 female passengers; and cabin zone C - 5 male and 5 female passengers. However, according to the documentation about 51 % (68 pax) were seated in cabin B, 39 % in cabin C and 10 % in cabin A. If the distribution of Overweight was carried out according to this data, it would mean that cabin A has 90 kg, cabin B has 459 kg, and cabin C - 351 kg. In the next table, the calculation and index-shifting performed according to the extra weight distribution is shown. As a result, according to the values below, the effect of + 1(-2+3=1) index would take place, so it is not significant and therefore not critical for this flight:

**Table 4.9 : Centre of gravity shifting index**

Cabin Zone	Index	Shifting Division
Zone A (90*0.95607)	0.95607	-1
Zone B (459*0.002057)	0.944163	-1
Zone C (351*0.008180)	2.87118	+3

#### 4.4 Effect on Fuel Consumption

As mentioned in Section 2.3, calculation of fuel consumption depends not only on the standard weight of the aircraft, crew, weather conditions, the direction of the wind, etc., but also on the weight of payload, which is the most important thing regardless of standard and unregulated (wind direction, route, waiting time and taxiing, etc.) factors. The greater the payload, the more fuel is necessary for the flight. Based on the data obtained in this research, as well as data from the airline, this study will try to show the calculated effect and how fuel consumption could be changed, as well as what environmental effects can be carried out in this regard. According to the data obtained from the airline, the estimation of fuel needed for the trip is given in Table 4.7.

In fact, as mentioned in section 2.3 in chapter II, there are many factors that influence fuel consumption. The flight dispatcher calculates the amount of fuel according to certain parameters; but the final decision is up to the crew pilot. The captain decides the final fuel figure according to the current situation and the conditions. Nevertheless, pilots' decisions cannot significantly vary from the calculated fuel in the flight plan.

**Table 4.10 : Estimated Fuel table**

<b>Date/Aircraft type</b>	<b>Estimation Trip fuel/Payload</b>	<b>Fixed in Documents Trip fuel/Payload</b>
19.12.2019/B737-800	12111 kg/8245 kg	12111 kg/7831 kg
20.12.2019/B737-900	13045 kg/9618 kg	13045 kg/9295 kg
21.12.2019/B737-800	11952 kg/9806 kg	11952 kg/9688 kg
22.12.2019/B737-800	12227 kg/12513 kg	12227 kg/12130 kg
23.12.2019/B737-900	13068 kg/10573 kg	13068 kg/11244 kg
27.12.2019/B737-900	12773 kg/13489 kg	12773 kg/11997 kg
29.12.2019/B737-900	13484 kg/16005 kg	13484 kg/14589 kg
30.12.2019/B737-900	13376 kg/12707 kg	13376 kg/12215 kg
31.12.2019/B737-900	12551 kg/13483 kg	12551 kg/12565 kg

A main parameter of fuel burned during the flight is trip fuel. There are some fuel amounts that are burned before flight such as those for taxi and APU. These amounts are generally stable values and they total 330 kg (this amount is valid only for a specific region, in this case Nur-Sultan Airport). However, there is an extra fuel limit which pilots may obtain during operation depending on their needs. The estimation of fuel burn for the trip is given in the table below. According to that data the average fuel needed for the trip (excluding 330 kg) in respect of burned kg of fuel per kg of payload is 1.114455515 kg, and total fuel is 1.143062349:

**Table 4.11 : Trip Fuel-Burn table**

<b>Aircraft Type</b>	<b>Trip fuel-burn kg/per kg payload</b>
737-800	1.468890237
737-800	1.218845605
737-800	0.9771437705
737-900	1.356311083
737-900	1.235978436
737-900	0.9469197124
737-900	0.8424867229
737-900	1.052648147
737-900	0.9308759178
<b>Mean</b>	<b>1.114455515</b>

Table 4.12 shows the result of the projected payload obtained from the research by multiplying estimated fuel needed for the trip:

**Table 4.12 : Projected Trip fuel burn table**

DATE	Projected payload	Projected Fuel needed for trip
19.12.2019	7677	11276.67035
20.12.2019	9238	12529.60179
21.12.2019	10224	12461.47746
22.12.2019	12420	12136.12563
23.12.2019	11568	14297.79854
27.12.2019	12897	12212.42353
29.12.2019	13663	11510.89609
30.12.2019	12226	12869.67624
31.12.2019	12476	11613.60795

Moreover, according to the results there is an obvious difference between flights with Ghost Weight and Overweight. The table below shows the results after combining all of the projected factors.

**Table 4.13 : Calculated projection of Ghost Weight and Overweight**

DATE	Projected Payload	Projected Fuel Estimation	Fuel Estimated in flight plan	GW Fuel Difference	OW Fuel Difference Factor
19.12.2019	7677	11276.67035	12111	834	
20.12.2019	9238	12529.60179	13045	515	
21.12.2019	10224	12461.47746	11952		510
22.12.2019	12420	12136.12563	12227		-91
23.12.2019	11568	14297.79854	13068		1230
27.12.2019	12897	12212.42353	12773		-561
29.12.2019	13663	11510.89609	13484	1973	
30.12.2019	12226	12869.67624	13376		-506
31.12.2019	12476	11613.60795	12551	937	

\*GW-Ghost Weight, OW-Overweight

An updated table with projected values shows that there is a significant difference in fuel estimation. Moreover, there is a significant fuel overestimation in the overweight fuel factor due to the standard and projected data difference for flights occurring on 27.12.2019 and 30.12.2019. Actually, an overestimation of the fuel can be seen in most flights. Only two flights, the one occurring on 21.12.2019, which had 510 kg of fuel, and the one occurring on 23.12.2019 with a fuel weight of 1230 kg., had an underestimated amount for fuel burned.

According to the results of the projection of figures with the updated weight, it is clear that fuel is excessively calculated for seven out of nine flights,. For example, the trip-fuel estimated by the dispatch for the flight on 19.12.2019 is 12111 kg; but the projection results show a different value of 11277 kg of jet fuel. It means that about 834 kg of jet fuel will be saved and CO<sub>2</sub> emission will also be less. Thus, it becomes possible to recalculate the payload with more accuracy.

#### **4.5 Effect on Passenger Comfort**

As it is mentioned in section 2.4 of Chapter II, as soon as airlines try to maximize revenue by increasing the number of seats in an aircraft, passengers' comfort level declines.

Further projection and calculations will be presented under different scenarios and it will be shown how this affects both passengers' comfort and flight safety.

The load for nine flights was presented in the Table 3.4 of Chapter III. It is obvious that after December 20, 2019 flight load significantly increased. Thus, very few seats were empty and so the ability to change seats in the cabin was significantly reduced. In the example of the flight on 19.12.2019, the load factor is about 54%. The total seat number is 151, of which 16 are business-class seats and 135 are economy. Taking into consideration that only one business class seat is occupied, the majority of passengers are seated in zones B and C.

According to the results of the questionnaire and the proportion of actual seating plans, the values are the same. 55% of respondents were seated in zone B (8 male and 3 female passengers), and 45% in zone C (4 male and 5 female passengers). In the actual

data, the distribution of the passengers is as follows: zone A - 1 passenger; zone B - 45 passengers; and zone C - 34 passengers. According to the table, zone A has 15 unoccupied seats; zone B 27; and zone C 29. The main thing is that there are enough unoccupied seats and, therefore, there is no need for passengers to change seats. There is a possibility that the middle seats are mostly unoccupied.

**Table 4.14 : Aircraft configuration AHM560 Turkish Airlines Inc (2016)**

Cabin Configuration(s) TC-JHK,...-JHZ,-JVA,...-JVO,...-VZ, TC-ZE-ZF,-ZG,-ZH	A / C TYPE B737-800	Carrier TK
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**8. PASSENGER CABIN**

**8.1 Passenger Seats**

**8.1.3.1. International Flights**

CLASS CODES Class 1 : C Class 2 : Y Class 3 :

Name of cabin section	NUMBER OF SEATS			Total per cabin section	Name of cabin section	NUMBER OF SEATS			Total per cabin section
	Class 1	Class 2	Class 3			Class 1	Class 2	Class 3	
CABIN CONFIGURATION 16C / 135Y					CABIN CONFIGURATION 151Y				
OA	16			16	OA	16			
OB		72		72	OB	72			
OC		63		63	OC	63			
Total per class	16	135			Total per class	151			

However, there is a risk of passengers with high anthropometric parameters moving from one zone to another. In this case, CG will change significantly, as projected in section 4.1. According to the questionnaire for the specific flight, there are 4 men and 1 woman with high anthropometric parameters. The men's seats are 14C, 11D, 7D, and 12D. Those seats are located where zone B has less effect on CG. A woman is seated in 22C, in zone C. In this regard, the flight occurring on 19.12.2019 is considered as safe and has more capacity for passenger comfort.

As it is mentioned in section 2.4. the larger the load factor, the less passenger comfort is provided during the flight. Examples of such flights are those occurring on December 27<sup>th</sup>, 29<sup>th</sup>, 30<sup>th</sup> and 31<sup>st</sup>, 2019. In the next table, the projection and the probability of problem areas and the number of passengers who will experience discomfort, obtained from the results of the questionnaires, is presented:

**Table 4.15 : Aircraft Configuration AHM560 Turkish Airlines Inc. (2019)**

**8.1.2. Passenger Seats (TC-JYL,JYM,JYN,JYO,JYP)**

CLASS CODES      Class 1 : C    Class 2 : Y    Class 3 :

Name of Cabin Section	NUMBER OF SEATS			Total per cabin section
	Class 1	Class 2	Class 3	
<b>CABIN CONFIGURATION 16C / 153Y</b>				
OA	16			16
OB		60		60
OC		60		60
OD		33		33
<b>Total per class</b>	<b>16</b>	<b>153</b>		

Name of Cabin Section	NUMBER OF SEATS			Total per cabin section
	Class 1	Class 2	Class 3	
<b>CABIN CONFIGURATION 169Y</b>				
OA		16		16
OB		60		60
OC		60		60
OD		33		33
<b>Total per class</b>		<b>169</b>		

According to the descriptive statistics test in section 3.4 of Chapter III, the upper overall data limit for males is 80 kg, and for females 70 kg. However, including the cabin-baggage limit and the winter-factor limit this value appears to be higher. For that reason, the upper anthropometry limit for males is considered to be more (“>”) than 90 kg. - “90>”; and for female passengers it is more than 70 kg (“70>”). The distribution of passengers with high anthropometric characteristics is given below in Table 4.16:

**Table 4.16 : Distribution of high anthropometry by zone**

DATE	GENDER	A	B	C	D
27.12.2019	M	1	1	1	
	F		2	2	
29.12.2019	M				
	F				2
30.12.2019	M		1	1	2
	F		2		
31.12.2019	M		1		
	F		2	1	1

According to Table 4.16, passengers’ seating and the zones loading factor, the probable number of passengers who will have seating problems is calculated. Table 4.17 shows the load factor inside the cabin by individual zone.

**Table 4.17 : Load Factor inside the cabin**

DATE	A	B	C	D
27.12.2019	8 pax-50%	49pax-81%	59pax-98%	16pax-48%
29.12.2019	12pax-75%	59pax-98%	60pax-100%	33pax-100%
30.12.2019	4 pax-25%	52pax-87%	55pax-92%	19pax-58%
31.12.2019	4pax-25%	53pax-88%	57pax-95%	23pax-70%

According to this table, it can be seen that on 27.12.2019 the busiest zones were zones B and C; and passengers with high parameters seated there were equally distributed as follows: three passengers in zone B; and three passengers in zone C. That makes up 30% of the overall sample. By multiplying the passengers in the sample and their distribution in the cabin by the zones load factor, the probable passenger numbers can be calculated. In this regard, the Table below shows the percentage of passengers in each zone who may have comfort problems:

**Table 4.18 : Percentage of high anthropometry passenger among zones**

Date	A	B	C	D
27.12.2019		15%	15%	
29.12.2019				10%
30.12.2019		15%	5%	10%
31.12.2019		15%	5%	5%

To be clear, zone A is out of evaluation as A zone is in the business-class cabin. As a result of simulated estimations for the flight occurring on 27.12.2019, 7 passengers in zone B and 8 passengers in zone C had accommodation problems. On the flight travelling on 29.12.2019, 6 passengers in zone C and 3 passengers in zone C were likely to have had accommodation problems. On 30.12.2019, 8 passengers in zone B, 3 in zone C 3, and 2 in zone D were likely to have had accommodation problems. However, the total load factor for zone D is 58%, so it is clear that there are unoccupied seats in that zone and there is therefore less chance of there being accommodation problems in zone D. On a flight occurring on 31.12.2019, zone A had 8 passengers, zone B had 3 passengers and zone C had 1 passenger with accommodation problems. As mentioned above, as the load factor becomes less the probability of passengers

experiencing accommodation problems also becomes less. Therefore, for the flight on 31.12.2019, 30% of seats, or 10 seats, were unoccupied, so the risk of accommodation problems for a single passenger is not significant.

#### 4.6 Analysis and Influence Factors

In this section, through analytical statistics, the results of surveys will be compared and analyzed. The reliability of the data and the factors which can influence the results of the data will be determined.

The hypothesis of reliability in the results of questionnaires will be considered. According to a Z-test analysis of the overall data, the male mean is 78.411 kg. and the female mean is 62.46 kg. However, the mean of male and female passengers can significantly change on each separate flight. There are several factors that can influence the weight of respondents, such their age and their region of origin. Statistical analysis is presented below on how age and region of origin influence weight:

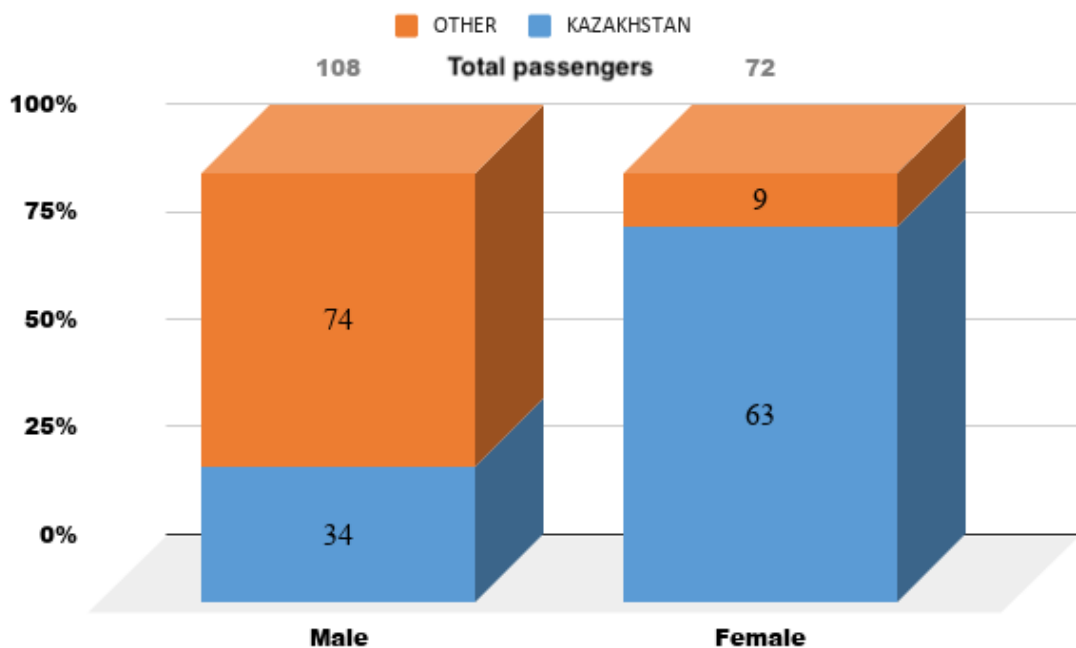
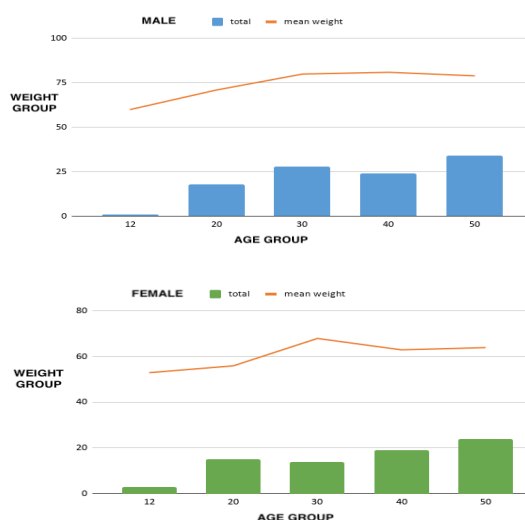


Figure 4.1 Chart of distribution of respondents in sample

Firstly, the graph shows that the number of men from other countries is greater than representatives of Kazakhstan; while among women there are more representatives of Kazakhstan.



**Figure 4.2 Trendline of the mean weight**

From the following trend graph, it can be seen that the weight of men over the age of 40 is slightly more than those in the other age groups - although there are many more representatives in the category of those 50 and over. The following table is a quantitative breakdown table:

**Table 4.19 : Quantitative Breakdown Table**

Age	Gender	Total	Mean weight
12	Male	1	60
20	Male	18	71
30	Male	28	80
40	Male	24	81
50	Male	34	79
12	Female	3	53
20	Female	15	56
30	Female	14	68
40	Female	19	63
50	Female	24	64

From all the graphs and tables given in this research, it can be concluded that the weight of men over 40 is a high anthropometric indicator. However, there is the fact

that in the category of those 50 and over, the number of respondents is bigger than in the other categories and there is a relatively small difference in weight. For women, these indicators are higher in the category of women over 30. The Table below shows the average weight of respondents, where it can be seen that the weight of representatives of men from other countries is much higher than that of representatives of Kazakhstan, while women have the opposite tendency. The difference in women's weight may have been influenced by the fact that there are more women from Kazakhstan in the sample than women from other countries.

**Table 4.20 : Average Weight**

<b>NATIONALITY</b>	<b>M</b>	<b>F</b>
KZ	74.89	62
OTHER	83.56	57.5

The data for each flight shows different values. Looking at each flight separately, it will become clear why the data is different. For example, since the deviations in weight are the highest for flights on December 27, 2019, and December 29, 2019, further analysis was carried out by comparing passengers' data:

**Table 4.21 : 27.12.2019 flight data**

27.12.2019	KZ	Other Nat.	overall
average male weight	80	95	85
average female weight	69	0	69
average age male	28	40	32
average age female	43	0	43

**Table 4.22 : 29.12.2019 flight data**

29.12.2019	KZ	Other Nat.	overall
average male	69	80	71
average female	62		62
average age male	32	35	33
average age female	34		34

By comparing these data, it became clear that the flight on 12.27.2019 has clear excesses in both weight and age. Thus, for men, the category of high indicators falls in the range from 30 to 40 years; while for women, the same effect is seen in the age range 40 and above. However, for women the average weight for this flight is much higher than the average female weight given in Table 2.1 Chapter II. But since the number of women in the category “50 years and older” is much larger than men, this fact can be considered significant.

Regarding the flight on December 29<sup>th</sup>, 2019, it is clear that although the average age of respondents in the category is over 30 and the quantitative advantage is on the side of respondents from Kazakhstan, it is obvious that the average weight for men on this flight is much less than the overall average. In this regard, it is obvious that Ghost Weight is higher than on other flights.

Looking at the data in this section, it can therefore be concluded that for a flight where most of the passengers are from one region the data will always be different from flights where there is a uniform distribution of passengers from different regions. This is because the anthropometric data will always be different. In this regard, it is obvious that, for flight safety, standards should be applied depending on the region.

## **CHAPTER V**

### **CONCLUSIONS AND RECOMMENDATIONS**

#### **5.1 Conclusion**

The main objective of this study is to determine the effect of passenger weight on flight safety. The study shows that the weight of passengers may not only affect the uneven distribution of the center of gravity but also has an impact on fuel consumption. In this regard, it is safe to say that the introduction of new standards for passenger registration can to some extent significantly reduce the risks associated with flight safety. In addition, the determination of a more accurate weight helps reduce the burning of jet fuel which in turns reduces CO<sub>2</sub> emissions and increases environmental performance.

The study used the decimal method for determining weight - that is, the weight of passengers was visually determined and, accordingly, assigned to one or another group. Of course, errors and deviations are possible; but the impact of such on the research as a whole is considered to be non-significant.

As explained in Section 2.1, the anthropometry of people from different regions can vary significantly. The results of the study clearly show that respondents from Western countries are very different in anthropometry from those from Kazakhstan. That is, the weight of these respondents far exceeds the weight of Kazakhstani citizens. In this regard, the application of the method by dividing passengers into groups looks much more efficient. Moreover, the results for calculating the center of gravity, calculating fuel and determining the place for disembarkation of passengers will improve performance in many ways.

#### **5.2 Recommendation**

This study used the method of distributing passengers by weight category. In practice, this method can work very effectively since it does not entail a significant financial impact for airlines. Setting up registration systems and changing flight characteristics

and instructions does not take much time. In addition, a weight option in both the ticket-booking system and online registration can be introduced. This option can also be implemented in the passenger-loyalty database and so, when buying tickets as a part of airline's loyalty program, weight data will already be reflected in the registration system. In the future, along with personal data, it will be possible to link biometric and anthropometric data for passengers. For a more accurate determination of passenger weights, placing scales in front of the check-in counter and in front of the counter in the boarding area for passengers with online check-in can generally eliminate errors in scales in the future. However, this measure entails a bigger financial investment both on the part of airlines and airports, since the installation process and the configuration of systems may take longer. Even though minimization of fuel costs is crucial for modern airlines due to high competition, this measure is considered effective in the medium term. During the first months of the introduction of updated standards, airlines will already be able to save more on jet fuel, since consumption will already be calculated based on actual figures. Reducing emissions by calculating payloads precisely will greatly increase environmental performance.

As the study shows, the zones located in the middle of the fuselage have the least impact on the center of gravity of the aircraft. Therefore, as soon as passengers' weights have been measured, it is recommended that airlines offer passengers with high anthropometry indicators seats with the least impact on a shift in the center of gravity of the aircraft. As it is shown in one of the examples in this study, zone B is the zone with the lowest index of influence on the center of gravity. When allocating these seats, airlines can allow an expansion to the armrest part of the seats by charging passengers a fee for those who want more comfortable seats. An example of how this approach can take place can be seen in relation to Turkish Airlines flights, as those flights that use the B737-800 aircraft with a transitional configuration can apply a method of expanding the armrest parts so that an economy-class seat can be transformed into a business-class seat. Based on this principle, it is possible to install such seats in the middle zone of the aircraft to accommodate heavier passengers.

Finally, the characteristics of anthropometry due to ethnicity have a significant influence on passengers' weight; and thus the standard-weight approach taken in aviation should be revised.

### **5.3 Study Limitation**

First of all, this study was limited to a single aircraft type and airline. Due to data availability, limitations of other aircraft types and airline data, the study was carried out based on the B737 aircraft and with Turkish Airlines. Because of the different flight characteristics and the different standards of the various aircraft types that different airlines use, other airlines may show different results. However, the general principle of the implementation of such methods is still valid for any aircraft type and airline.

In addition, questioning in this study was carried out purely in line with ethical rules. Direct weighing of passengers or asking direct questions about passengers' weight were therefore excluded. Due to the fact that the questionnaire was conducted by an approximate determination of each passenger's weight, a possible occurrence of error and deviations in the determination of weight can happen. But the main objective of this study was to demonstrate clearly how passengers' weight can have an impact on certain parameters, as well as to determine the factors that anthropometry of passengers has effects on in terms of flight safety, environmental performance, and passenger comfort.

In fact, due to the fact that relatively little information is available relating to the anthropometric data of people by age in different regions, the author mostly used the data obtained during the study. Moreover, an important factor that needs to be considered is that a large percentage of passengers go through online check-in or the self-check-in process. The fact that passengers directly proceed to the boarding area with electronically printed boarding passes made it more difficult to determine passengers' weight and the weight of their hand luggage taken as a whole. Based on the information provided, it may be concluded that the deviations and the degree of errors in the study may affect the results for the above reasons.

### **5.4 Directions for Future Research**

It appears that not very much research has been done in this direction and, thus, a future detailed analysis on the influence of various factors on the weight of passengers would be very helpful. It is also recommended that a number of studies should be carried out to examine the environmental performance of aircraft and passengers' comfort. For

airlines, especially low-budget ones, an important factor is rapid turnaround, and further research in this area can lead to higher performance and a better financial position for such airlines. Other research areas might include ideas on how to seat passengers effectively within limited boarding time. In addition to that, further research should be conducted in order to solve the problem of accommodating a passenger with abnormal anthropometric parameters when they have a ticket in their hands and when they are boarding an aircraft which has a large number of seats but of small width. Are there regulations in this area? Does the airline have the right to refuse a passenger because he cannot fit into a seat? Medical research in this direction can also determine what consequences limited seats can impose.

This work provides the basis for future extended research. Using data provided in this study can be helpful in finding solutions not only in aviation but also in many different industries.

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# APPENDIXES

## APPENDIX A : QUESTIONNAIRE

FLIGHT NUMBER: <b>TK0355</b>			
DATE: <b>27.12.2019</b>			
AIRCRAFT TYPE: <b>B737-800</b>	(underline <b>NARROWBODY</b> or WIDEBODY)		
PASSENGER SEAT NUMBER: <b>20F</b>			
1. NATIONALITY: <b>KAZ</b>			
2. CATEGORY OF THE PASSENGER			
Man	Woman <input checked="" type="checkbox"/>		
3. AGE GROUPING FOR ADULT PASSENGERS			
MAN in a year	WOMAN in a year		
12 >	12 >		
20 >	20 >		
30 >	30 >		
40 >	<b>40 &gt;</b>		
50 >	50 >		
3. PASSENGER WEIGHT			
MAN in kg.	WOMAN in kg		
60 >	50 >		
70 >	<b>60 &gt;</b>		
80 >	70 >		
90 >	80 >		
100 >	90 >		
4. CABIN BAGGAGE (8 kg. in 1 piece) <b>4 Kg</b>			
actual weight in kg			
	ACTUAL WEIGHT		
	<table border="1"><tr><td></td><td></td></tr></table>		

## APPENDIX B : DATA

FLIGHT NUMBER	DATE	A/C TYPE	NATIONALITY	SEAT	GENDER	AGE	WEIGHT	CABIN BAG
TK355	12/19/2019	B737-800	AZE	14C	M	40>	90>	YES
TK355	12/19/2019	B737-800	KAZ	08A	F	50>	60>	NO
TK355	12/19/2019	B737-800	ARM	8B	M	50>	70>	NO
TK355	12/19/2019	B737-800	ALB	20E	M	50>	90>	NO
TK355	12/19/2019	B737-800	KAZ	7F	F	50>	60>	NO
TK355	12/19/2019	B737-800	TUR	11D	M	40>	80>	NO
TK355	12/19/2019	B737-800	KAZ	18F	M	50>	80>	YES
TK355	12/19/2019	B737-800	ITA	12A	M	30>	70>	YES
TK355	12/19/2019	B737-800	JOR	15A	M	30>	70>	NO
TK355	12/19/2019	B737-800	KAZ	22C	F	30>	90>	YES
TK355	12/19/2019	B737-800	USA	7D	M	50>	80>	YES
TK355	12/19/2019	B737-800	KAZ	24E	F	30>	50>	YES
TK355	12/19/2019	B737-800	KAZ	7A	F	40>	50>	NO
TK355	12/19/2019	B737-800	DEU	22A	M	20>	70>	YES
TK355	12/19/2019	B737-800	DEU	22B	F	40>	50>	YES
TK355	12/19/2019	B737-800	KAZ	23A	F	20>	50>	YES
TK355	12/19/2019	B737-800	TUR	10C	M	20>	60>	YES
TK355	12/19/2019	B737-800	RKS	12D	M	30>	80>	YES
TK355	12/19/2019	B737-800	KAZ	21C	F	20>	50>	NO
TK355	12/19/2019	B737-800	KAZ	19E	M	30>	70>	YES

FLIGHT NUMBER	DATE	A/C TYPE	NATIONALITY	SEAT	GENDER	AGE	WEIGHT	CABIN BAG
TK355	12/20/2019	B737-900	KAZ	6C	F	40>	60>	YES
TK355	12/20/2019	B737-900	KAZ	20F	F	20>	60>	YES
TK355	12/20/2019	B737-900	LBN	10F	M	30>	60>	YES
TK355	12/20/2019	B737-900	DEU	18E	M	50>	80>	YES
TK355	12/20/2019	B737-900	ISR	13C	M	50>	80>	YES
TK355	12/20/2019	B737-900	ISR	13A	M	40>	80>	YES
TK355	12/20/2019	B737-900	ISR	22D	F	40>	60>	YES
TK355	12/20/2019	B737-900	ISR	1E	M	40>	70>	YES
TK355	12/20/2019	B737-900	TUR	14D	M	50>	80>	YES
TK355	12/20/2019	B737-900	KAZ	20A	M	30>	70>	YES

TK355	12/20/2019	B737-900	KAZ	20B	F	30>	50>	YES
TK355	12/20/2019	B737-900	KAZ	14A	F	30>	60>	YES
TK355	12/20/2019	B737-900	KAZ	7B	M	20>	70>	NO
TK355	12/20/2019	B737-900	KAZ	7A	M	20>	70>	NO
TK355	12/20/2019	B737-900	BGR	23A	M	50>	70>	YES
TK355	12/20/2019	B737-900	ITA	6D	M	50>	90>	YES
TK355	12/20/2019	B737-900	BGR	20D	M	50>	70>	YES
TK355	12/20/2019	B737-900	ITA	6F	M	50>	70>	YES
TK355	12/20/2019	B737-900	LBN	19A	M	20>	60>	YES
TK355	12/20/2019	B737-900	ISR	3A	M	40>	80>	YES

FLIGHT NUMBER	DATE	A/C TYPE	NATIONALITY	SEAT	GENDER	AGE	WEIGHT	CABIN BAG
TK355	12/21/2019	B737-800	KAZ	9D	F	20>	50>	4
TK355	12/21/2019	B737-800	ALB	13B	M	30>	80>	0
TK355	12/21/2019	B737-800	TUR	12D	M	50>	90>	5
TK355	12/21/2019	B737-800	BIH	11F	M	30>	80>	0
TK355	12/21/2019	B737-800	TUR	11C	M	30>	90>	5
TK355	12/21/2019	B737-800	TUR	11D	M	30>	100>	6
TK355	12/21/2019	B737-800	KAZ	9F	F	40>	60>	4
TK355	12/21/2019	B737-800	KAZ	24A	F	30>	70>	3
TK355	12/21/2019	B737-800	USA	15D	M	30>	100>	8
TK355	12/21/2019	B737-800	UKR	8A	M	30>	90>	4
TK355	12/21/2019	B737-800	KAZ	16D	F	20>	60>	8
TK355	12/21/2019	B737-800	ITA	8D	M	50>	80>	8
TK355	12/21/2019	B737-800	IRL	10D	M	50>	80>	7
TK355	12/21/2019	B737-800	BEN	16C	M	40>	80>	8
TK355	12/21/2019	B737-800	DEU	2F	M	40>	90>	0
TK355	12/21/2019	B737-800	TUR	17A	F	20>	70>	3
TK355	12/21/2019	B737-800	USA	2B	M	50>	70>	4
TK355	12/21/2019	B737-800	DEU	13D	M	50>	80>	0
TK355	12/21/2019	B737-800	KAZ	15B	F	30>	70>	3
TK355	12/21/2019	B737-800	KAZ	24E	M	30>	90>	6

FLIGHT NUMBER	DATE	A/C TYPE	NATIONALITY	SEAT	GENDER	AGE	WEIGHT	CABIN BAG
TK355	12/22/2019	B737-800	ALB	21E	M	40>	90>	5

TK355	12/22/2019	B737-800	KAZ	20A	F	20>	60>	3
TK355	12/22/2019	B737-800	DEU	15C	F	30>	60>	5
TK355	12/22/2019	B737-800	DEU	14F	M	50>	90>	6
TK355	12/22/2019	B737-800	DEU	14E	F	40>	70>	6
TK355	12/22/2019	B737-800	KAZ	16D	M	50>	70>	5
TK355	12/22/2019	B737-800	USA	10C	M	50>	90>	3
TK355	12/22/2019	B737-800	LBN	18C	M	30>	80>	6
TK355	12/22/2019	B737-800	ITA	11D	M	30>	80>	6
TK355	12/22/2019	B737-800	BGR	24C	M	50>	100>	5
TK355	12/22/2019	B737-800	ITA	11A	M	50>	80>	8
TK355	12/22/2019	B737-800	DEU	15D	M	20>	70>	5
TK355	12/22/2019	B737-800	KAZ	24D	F	50>	50>	0
TK355	12/22/2019	B737-800	KAZ	17F	F	20>	50>	3
TK355	12/22/2019	B737-800	KAZ	17E	F	20>	50>	5
TK355	12/22/2019	B737-800	KAZ	24F	F	50>	60>	0
TK355	12/22/2019	B737-800	BGR	26A	M	40>	90>	0
TK355	12/22/2019	B737-800	GRC	5A	M	50>	80>	8
TK355	12/22/2019	B737-800	JOR	5C	M	30>	80>	8
TK355	12/22/2019	B737-800	BGR	24A	M	30>	80>	5

FLIGHT NUMBER	DATE	A/C TYPE	NATIONALITY	SEAT	GENDER	AGE	WEIGHT	CABIN BAG
TK355	12/23/2019	B737-900	MNG	18B	M	30>	70>	0
TK355	12/23/2019	B737-900	MNG	18A	M	30>	70>	0
TK355	12/23/2019	B737-900	MNG	18C	M	30>	80>	0
TK355	12/23/2019	B737-900	ALB	19A	M	50>	70>	2
TK355	12/23/2019	B737-900	ALB	19B	M	50>	80>	5
TK355	12/23/2019	B737-900	ALB	19C	M	20>	70>	5
TK355	12/23/2019	B737-900	KAZ	6D	F	40>	60>	5
TK355	12/23/2019	B737-900	KAZ	20A	M	20>	60>	3
TK355	12/23/2019	B737-900	KAZ	8A	F	40>	70>	5
TK355	12/23/2019	B737-900	TUR	18F	F	40>	80>	3
TK355	12/23/2019	B737-900	ITA	7E	M	40>	90>	4
TK355	12/23/2019	B737-900	KAZ	7A	F	50>	60>	6
TK355	12/23/2019	B737-900	TUR	9B	M	40>	70>	5
TK355	12/23/2019	B737-900	TUR	9A	F	50>	70>	4
TK355	12/23/2019	B737-900	TUR	14A	M	30>	90>	3
TK355	12/23/2019	B737-900	KAZ	22F	F	50>	80>	0

TK355	12/23/2019	B737-900	TUR	13B	M	30>	80>	5
TK355	12/23/2019	B737-900	ROU	27C	M	30>	100>	8
TK355	12/23/2019	B737-900	DEU	8C	M	40>	90>	8
TK355	12/23/2019	B737-900	KAZ	19D	M	40>	90>	0

FLIGHT NUMBER	DATE	A/C TYPE	NATIONALITY	SEAT	GENDER	AGE	WEIGHT	CABIN BAG
TK355	12/27/2019	B737-900	KAZ	20F	F	40>	60>	4
TK355	12/27/2019	B737-900	KAZ	6D	F	50>	60>	2
TK355	12/27/2019	B737-900	KAZ	6E	F	50>	70>	2
TK355	12/27/2019	B737-900	KAZ	11F	F	40>	60>	3
TK355	12/27/2019	B737-900	KAZ	11E	F	50>	60>	4
TK355	12/27/2019	B737-900	KAZ	11D	F	50>	80>	3
TK355	12/27/2019	B737-900	KAZ	5B	F	40>	60>	4
TK355	12/27/2019	B737-900	TUR	02E	M	40>	100>	8
TK355	12/27/2019	B737-900	KAZ	3E	F	20>	60>	0
TK355	12/27/2019	B737-900	KAZ	20B	F	30>	80>	3
TK355	12/27/2019	B737-900	KAZ	22E	F	50>	80>	4
TK355	12/27/2019	B737-900	KAZ	2B	F	40>	80>	3
TK355	12/27/2019	B737-900	KAZ	23E	M	20>	70>	5
TK355	12/27/2019	B737-900	ISR	14A	M	40>	90>	8
TK355	12/27/2019	B737-900	KAZ	24D	M	40>	90>	8
TK355	12/27/2019	B737-900	KAZ	23F	F	50>	80>	3
TK355	12/27/2019	B737-900	KAZ	23D	F	40>	70>	0
TK355	12/27/2019	B737-900	KAZ	26D	M	20>	80>	3
TK355	12/27/2019	B737-900	KAZ	8F	F	50>	60>	3
TK355	12/27/2019	B737-900	KAZ	8E	M	30>	80>	3

FLIGHT NUMBER	DATE	A/C TYPE	NATIONALITY	SEAT	GENDER	AGE	WEIGHT	CABIN BAG
TK355	12/29/2019	B737-900	KAZ	14B	M	12>	60>	2
TK355	12/29/2019	B737-900	KAZ	15A	F	50>	60>	5
TK355	12/29/2019	B737-900	KAZ	15C	F	40>	60>	3
TK355	12/29/2019	B737-900	KAZ	14C	M	40>	80>	3
TK355	12/29/2019	B737-900	KAZ	25A	F	40>	70>	3
TK355	12/29/2019	B737-900	TUR	3F	M	50>	80>	8
TK355	12/29/2019	B737-900	KAZ	9A	M	50>	80>	8
TK355	12/29/2019	B737-900	KAZ	14F	M	20>	60>	1

TK355	12/29/2019	B737-900	KAZ	14E	M	20>	60>	1
TK355	12/29/2019	B737-900	KAZ	17A	M	30>	80>	2
TK355	12/29/2019	B737-900	KAZ	13D	M	30>	70>	2
TK355	12/29/2019	B737-900	KAZ	14A	F	30>	60>	0
TK355	12/29/2019	B737-900	KAZ	30F	F	30>	70>	2
TK355	12/29/2019	B737-900	KAZ	30E	M	30>	70>	3
TK355	12/29/2019	B737-900	KAZ	5E	M	50>	60>	1
TK355	12/29/2019	B737-900	KAZ	7A	M	20>	70>	5
TK355	12/29/2019	B737-900	EGY	27A	M	20>	80>	5
TK355	12/29/2019	B737-900	KAZ	5A	M	40>	70>	0
TK355	12/29/2019	B737-900	KAZ	5D	M	50>	70>	4
TK355	12/29/2019	B737-900	KAZ	5C	F	12>	50>	3

FLIGHT NUMBER	DATE	A/C TYPE	NATIONALITY	SEAT	GENDER	AGE	WEIGHT	CABIN BAG
TK355	12/30/2019	B737-900	KAZ	23A	M	40>	60>	7
TK355	12/30/2019	B737-900	RUS	16A	M	50>	60>	6
TK355	12/30/2019	B737-900	KAZ	10A	F	50>	80>	2
TK355	12/30/2019	B737-900	KAZ	23F	F	20>	50>	4
TK355	12/30/2019	B737-900	GBR	14F	M	50>	80>	8
TK355	12/30/2019	B737-900	RKS	24C	M	50>	90>	0
TK355	12/30/2019	B737-900	KAZ	21E	M	20>	80>	4
TK355	12/30/2019	B737-900	KAZ	26F	M	20>	90>	4
TK355	12/30/2019	B737-900	KAZ	26D	M	20>	90>	8
TK355	12/30/2019	B737-900	KAZ	26E	M	20>	80>	2
TK355	12/30/2019	B737-900	DEU	15B	F	40>	50>	2
TK355	12/30/2019	B737-900	TUR	7C	M	50>	80>	4
TK355	12/30/2019	B737-900	KOR	27A	M	40>	80>	4
TK355	12/30/2019	B737-900	DEU	25A	M	40>	80>	4
TK355	12/30/2019	B737-900	GBR	17C	F	30>	50>	8
TK355	12/30/2019	B737-900	GBR	8D	M	40>	60>	2
TK355	12/30/2019	B737-900	KAZ	9E	F	20>	50>	4
TK355	12/30/2019	B737-900	KAZ	10C	F	50>	70>	8
TK355	12/30/2019	B737-900	IRL	8F	M	30>	100>	5
TK355	12/30/2019	B737-900	KAZ	7A	F	30>	60>	8

FLIGHT NUMBER	DATE	A/C TYPE	NATIONALITY	SEAT	GENDER	AGE	WEIGHT	CABIN BAG
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TK355	12/31/2019	B737-900	KAZ	16F	F	50>	60>	5
TK355	12/31/2019	B737-900	KAZ	23B	F	12>	60>	3
TK355	12/31/2019	B737-900	KAZ	23D	M	40>	60>	2
TK355	12/31/2019	B737-900	KAZ	23F	F	50>	50>	2
TK355	12/31/2019	B737-900	KAZ	24E	M	40>	70>	5
TK355	12/31/2019	B737-900	KAZ	18D	F	50>	70>	0
TK355	12/31/2019	B737-900	KAZ	25A	F	50>	70>	8
TK355	12/31/2019	B737-900	KAZ	13B	F	20>	50>	0
TK355	12/31/2019	B737-900	KAZ	13C	M	30>	70>	0
TK355	12/31/2019	B737-900	KAZ	12D	F	30>	90>	3
TK355	12/31/2019	B737-900	KAZ	10A	F	40>	60>	5
TK355	12/31/2019	B737-900	DEU	11F	F	40>	70>	8
TK355	12/31/2019	B737-900	KAZ	9F	F	20>	60>	4
TK355	12/31/2019	B737-900	USA	6C	M	50>	100>	5
TK355	12/31/2019	B737-900	KAZ	6A	F	50>	60>	3
TK355	12/31/2019	B737-900	KAZ	6B	F	50>	50>	0
TK355	12/31/2019	B737-900	KAZ	28B	M	40>	80>	5
TK355	12/31/2019	B737-900	KAZ	6D	F	20>	60>	8
TK355	12/31/2019	B737-900	KAZ	6E	F	20>	60>	8
TK355	12/31/2019	B737-900	TUR	14D	M	40>	80>	8

# CURRICULUM VITAE

Name and Surname: Ardak Kartayev

## Education:

1999-2004                      Tourism and Hotel Management, Anadolu University,  
Eskişehir/Turkey.

2018-2020    MSc.Air Transport Management, Ibn Haldun University, Turkey.

## Work Experience:

2006- current    Turkish Airlines Inc.

