ISTANBUL TECHNICAL UNIVERSITY ★ FACULTY OF AERONAUTICS AND ASTRONAUTICS

ECONOMISATION OF AIRPORTS AND AIRCRAFT MAINTENANCE

GRADUATION PROJECT

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Department of Aeronautical Engineering

Thesis Advisor: Prof.Dr Cemil KURTCEBE

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Rupesh Shrestha, student of ITU Faculty of Aeronautics and Astronautics student ID 110160901, successfully defended the **graduation** entitled "Economization of Airport and Aircraft Maintenance.", which he/she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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Date of Submission: 13 July 2020

Date of Defense: 22 July 2020

TO MY FAMILY

Acknowledgments

I would like to thank all those that made this work possible. This thesis would not have been possible without valuable advice and guidance of my advisor, Cemil KURTCEBE.
I sincerely thank Öğuz KARABULUT, for providing me important information regarding the Aircraft maintenance process and also my family for giving me support in my Undergraduate career.

Julu,2020 Rupesh SHRESTHA

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ABBREVIATIONS

FAA : Federal Aviation Administration

ICAO : International Civil Aviation Organization

ICT : Information and Communication Technology

AI : Artificial intelligence

IT :Information Technology

CBP : Customs and Border Protection

IATA :International Air Transport Association

ACI :Airport council international

AITSC :Airport Information Technology Standing Committee

DHMI :Turkish State Airport Authority

ATC :Airport Traffic Controller

SOP :Standard Operation Procedure

VFR :Visual Flight Rules

TIA :Tribhuvan international Airport

EASA :European Aviation Safety Agency

ATA :Air Transport Association

SMS :Safety Management System

MEL : Minimum Equipment List

AD : Airworthiness Directives

NAA : National Aviation Authority

EO : Engineering Order

MRO : Maintenance Review order

DMC : Direct Maintenance Cost

MRB : Maintenance Review Board

ISC : Industry Steering Committee

MWG : Maintenance Working Group

MSG : Maintenance System Group

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ECONOMISATION OF AIRPORT AND AIRCRAFT MAINTENANCE

SUMMARY

Air Transport has been a revolution in the modern world which changed the shape of the transportation industry. The Aircraft and airport industry have billions of dollars invested and even a small share of portion contributes of millions of dollars. Since its multibillion-dollar business, It is important to make it run in an efficient way. Airport are the places for hub for the air transportation industry. Its not just a building for planes to land or fly but it is more than that. There are many staffs working on airport and aircraft maintenance industry which shape up the aviation sector. This thesis emphasizes on the way and method that are used in the modern world to make the airport and aircraft maintenance sector efficient and economical.

The role of It in the modern world is incomparable. The IT sector has taken the world out in storm as the use of IT sectors are found in almost every sector. Modern airports and aircraft maintenance can also make use of IT sectors to connect with the passengers and make the airport journey much more efficient. Usually, it takes lot of time at Airport since the passengers has to go through many sections but with the introduction of the IT at airport, It has been proved as a game changer to save the time and to be more efficient. From the check in section till the time of boarding, the use of IT has made it easier for us to get connected. Also, the used of IT in Maintenance department has also been very useful. The introduction of IT has made the engineers easy to track down the defaults of the aircraft which would take a lot of time with human process.

Secondly, Ground handling services in the Airport department also plays a important role in making the airport run efficiently. The ground handling department prevents the delay of the airport and passengers can check in easily. The turnaround time take by the airport is also important in making the airport efficient.

I have also conducted the survey about the customer experience of the airports in Istanbul airport and Tribhuvan airport. Although both are very different airport, I would like to see the

reaction of the participants who have used the both airports. With the survey , I would learn about the problem that the passengers were facing at the airports and also try to find the way to solve it.

The recent pandemic situation in the world has also caused very negative impact on the airport industry. I have also included the majors taken by the airport after the covid 19 infection has taken place.

Finally, I have also described about the aircraft maintenance department and also included some process to minimize the cost of that department. The role of It has also changed in many sections in Maintenance department where the introduction of Robot and sensors have made the human capacity beyond the imagination. Since the Aviation sector is a multibillion-dollar industry, even a small amount of efficiency can save thousands of dollars. The cost of maintenance, the outsource and insource of the MRO department plays a very important role in cost saving in the Aircraft Maintenance industry

1. INTRODUCTION OF AIRPORT

Airport (Air Terminal, Aerodrome, Airfield) is one of the Important infrastructures where Airplanes Take off and Land which include all the services and Facilities needed for Airplanes, passengers and Cargo.

1.1 History of Airport

Hounslow Heath Aerodrome is the first Airport established in 1919 where first International commercial flight was held. The Airport included "Apron" which allowed heavy aircraft to land as well as paved way for Night flying. In 1922, after the closure of Hounslow heath Aerodrome , worlds first commercial permanent Airport was established at Flughafen Devau in East Prussia.[1]

1.2 Parts of Airport

I.Runway

Runway is a road designed especially for landing and takeoff operations of aircrafts. Runway should not be of any disturbance. Special signs are made on the runway to differentiate it from the normal roadways. Also, after sunset, specially provided lightings are helping the aircrafts for safe landing. Many factors are considered for design of runway. The direction of runway should be in the direction of wind. The number of runways for an airport is decided upon the traffic. it is necessary to provide another runway, If there is 30 movements per hour. bitumen or concrete are used to make the Runway. Bitumen (black viscous mixture of hydrocarbons obtained naturally or as a residue from petroleum distillation) is economic but concrete runways maintenance cost is cheap compared to bituman. The wideness of runway is decided on the aircrafts using that runway. The length of runway is decided from

different factors which includes elevation of land, location of the place, weather or temperature of the place etc.

II.Apron

Apron is a place which is used as parking place for aircrafts. It is also used for loading and unloading goods from the aircraft. Apron is normally located in front of terminal building or side of the hangar so that the passengers will have easiness to pass through the terminal building. The number of aircraft coming in the airport is the key factor to decide the size or area that needs to be located for apron and also the design of it.

III.Terminal building

All the administrative facilities of the airport take place in the Terminal building. In this building, arrival and departure checking's of passengers happens. Waiting lounge, cafes etc. are provided for the passengers. Passengers can directly enter the plane from terminal buildings through sky bridge, walkways etc. The passengers are also directly transferred to the terminal building through the sky bride or walkways from the airplanes.

IV.Control Tower

Like the name, The control tower represents the place where aircrafts are being controlled on the land or in the air. Radars and information are used and carried through radio as the Air. The controller from the control tower observes all the aircrafts with in that zone and communicates pilots about their airport traffic, visibility, speed of the wind, runway details, Arrival and landing route etc. based on which the pilot decides and attempts safe landing. Thus, we can say that Control tower is like the brain of the Aircraft.

V.Hanger

Hanger is a place where aircraft are repaired and their services are carried out. Taxiway connects the hanger with runway . An aircraft it can be moved to hanger easily when they need repair or any services.

VI. Parking

It provides parking facilities for Airport staffs and located outside of Terminal buildings.

1.3 Classification of Airport

Airports have many classifications, depending on their work, size, and owners. The normal classi fication is civil and military, international and domestic, etc. The most commonly accepted class ifications by the FAA (Federal Aviation Administration), ICAO (International Civil Aviation Organi zation), UK, and Canada are shown in the illustration. [2]

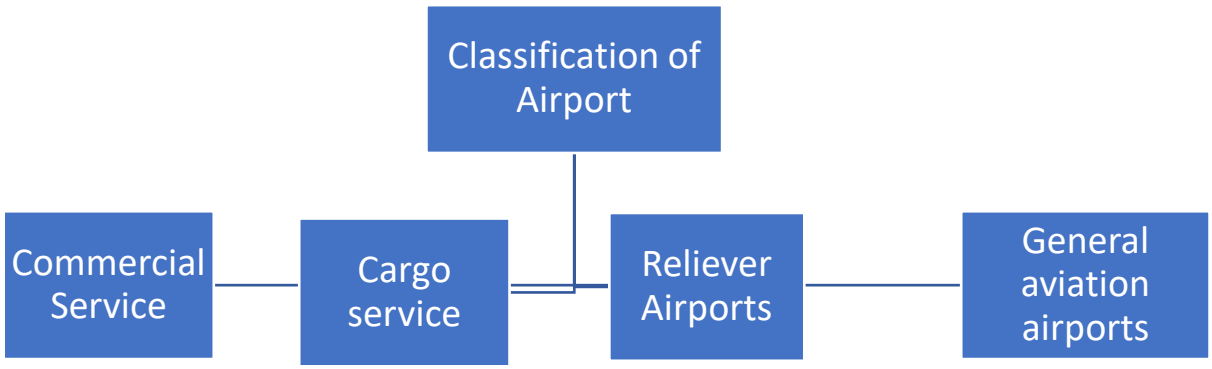

Figure:1.1 Classification of Airports

AS different elements like the terminal area, Airside, landside, Air space area makes a Airport system, They are often viewed differently or are seen in the different section defining their function separately. But the fact is that all this system is tied or depends on each other to work properly. It's like a chain where if one fails, every other thing fails along with it. All this component work together in which the good or bad performance in one system affects others.

The Us Airport Networking system consist of three categories which are Local interested Airport, National integrated airport and Military airport. National integrated Airport are sub classified as Primary Airport, Commercial service airport, Reliever airport and public airport. Reliever airport are those airports which are operated when primary and commercial service airport reached its maximum capacity. Commercial Service Airports are publicly owned airports which host at least 2,500 passenger each year and also receives the same number of passengers. General Aviation Airports are public used airports without any scheduled flight as commercial service and have very less passengers. There are generally training based airplanes or private jets in the general aviation airports. [3]

1.4 IMPORTANCE OF AIRPORT ON ECONOMY

Different country in this world have different features on International airports. Although they have different features, there are standard set of rules defined by the aviation standards to define International airport. It is compulsory to include tax points(customs), security checkpoints and international terminal building in these airports. International airport also has many other features like Duty free shopping center, Waiting lounge, Airlines office, room for children's, Prayer rooms and tourist information centers. Airports are more than places when you can start to travel, or carry some duty-free shopping; they are among the largest investments a nation or a city make. Goods or cargo and people are the two things airport moves. Airports are directly proportionate to the economic development that focuses on moving one thing to another, business around the airports and industry that is dependent on the airport. In today's economy, the ability to move one brain to one place to another to generate and share the knowledge is much more valuable than actual. [4]

Airports offer increased accessibility, which in turn fuels the tourism sector. With an increase in the number of visitors and airport users, more money flows into the local economy.

Airports helps in increase economic activity and drive employment opportunity to many people raising the standard of living in the area. As a result, airport provides a driving force to the GDP of the local region impacting in a positive way to the national Economy. The major impacts of airport are

1.Aiports helps to increase the business of the country and the local region

2.Airports helps to boost he Tourism of the country rising the GDP of the country

3.Helps in organize International Trade

4. Increase Jobs and oppurtunities.

2. ROLE OF INFORMATION TECHNOLOGY AT AIRPORT

In the Modern world, Technology has made so much drastic advances that many things are possible that used to be impossible in the past. Communication is usually a key aspect when it comes to traveling in air. Technology is proving the best tool and techniques between the airport official and consumers to make the airport efficient. The use of Information Technology in the Modern airport has completely transformed the economic behavior and has been major time saver. Aviation and Airports are the major backbone of any country's economy connecting people from places to places. People chose it because it's one of the shortest and easiest means to transport. Airports and Airlines are the engines of any economic aircraft to drive them to growth and development.

Although it sounds very interesting and easy, It is equally sensitive and important. Everything has to be in precise and everything should go as planned. Information technology can help the airplane and airport staff to handle their job more efficiently whereas passengers can also access the required information. Today every airport, airline and the air traffic control systems are based on intelligent transport system i.e. the information and communication technology (ICT). As IT is important in our daily activity in airport, it can also lead to information mismanagement and the abuse of the information can lead to serious security threat to passengers, crew members and other aviation industry.

People are increasing the trust on air transport every year and its increasing. In 2019 alone 4.5 billion passengers safely took their air journey 61.2 million metric tons of goods were delivered as air cargo. [5] This information tends to prove that how global economy is reliant on-air transportation. This is also one reason where we have to keep the air transportation safe and the introduction of information technology has provided a keep help to making it secure.

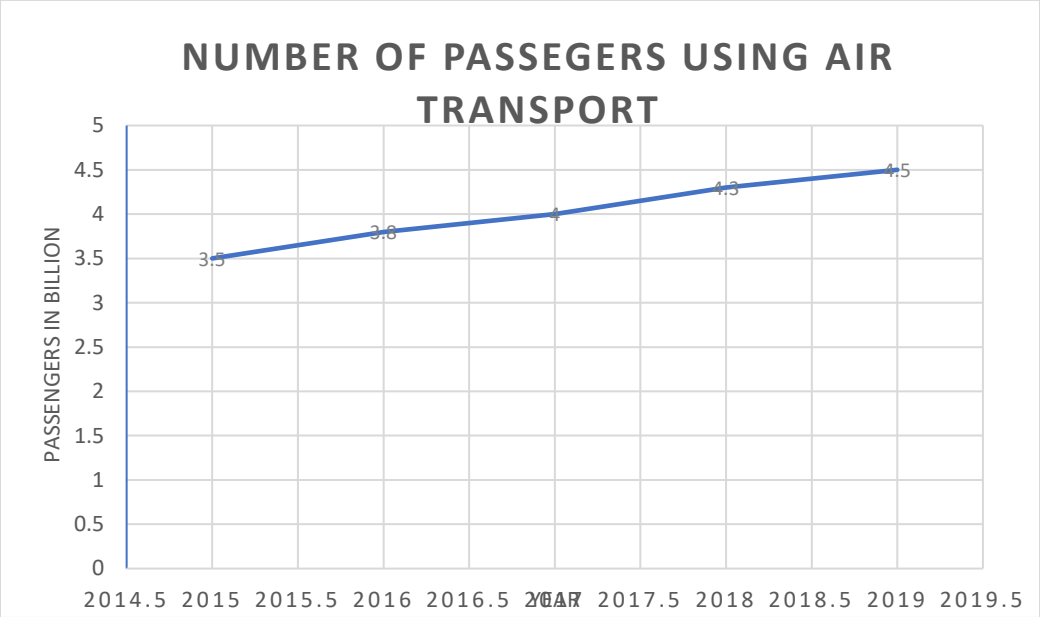

Figure 2.1 : Number of Passengers using Air Transport

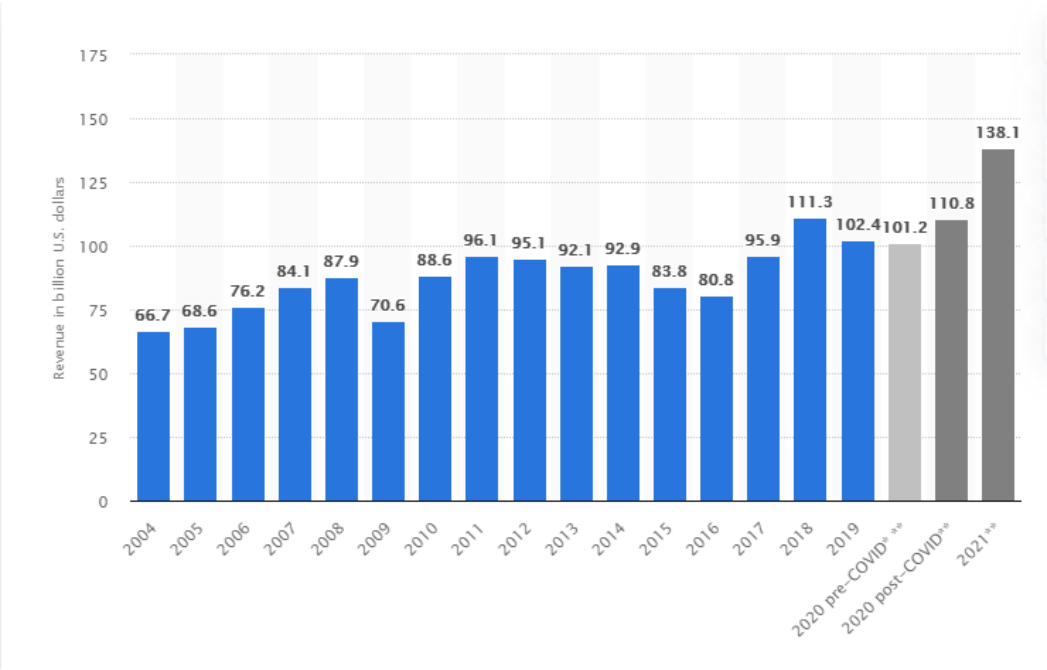

Figure 2.2 : Revenue of Air transport in year from 2004-2021

The number of Passengers and revenue generated has only been increasing in recent time and will continue to increase in near future as the Air transport business has been booming gradualy.

Role of Information Technology in Aviation Industry (Air travel) has been closely linked with (ICT)information and communication technologies . People tend to use it and the technology keeps on evolving as many bugs keep on developing day by day. The modern consumer is more familiar with IT technologies; he has access to information which makes him more sophisticated and demand worth, requiring more specialized and fast-forward services.

Airports today are investing heavily into technology than ever before, and they will continue to increase in future because as the technology advances, they need to renew it regularly. information technology (IT) departments have become the cornerstone of the airport business where every department is integrated with the information system to make the passengers and airlines workers work easy.

2.1 ICT(Information and communication technology)

ICT(Information and communication technology) which is also known as information technology but mainly focuses on the role of unified communication ,the combination of communication (telephone lines and wireless phones), computers , the necessary software that it needs, storage, visual system for the security and air traffic controller and all the other information to get and receive data.

ICT which is also now used to refer to the convergence of Audio- Visual and telephone networks with computer networks with the help of cabling or link system. In other simple term, we can define ICT as the combination of hardware software and the people that are working together at airport to exchange the useful information and communication services. [6]

Companies and people communicating in the airport can contact and coordinate each other where ever they are. ICT is so advantageous that it can provide a very powerful strategic and tactical tool in the highly competitive market by reducing cost and at the same time maximizing efficiency. In the modern world, ICT developments have revolutionized the entire aviation and business world.

2.2 INFORMATION TECHNOLOGY AT AIRPORT

As the Air traffic has increased in the modern world, challenged for security, flow of people and baggage's in in the aircraft has been a challenging task. To make it more efficiency, Airports are investing heavily on the information technology to make the system more efficient and faster. New technologies are developed every day in modern time to make our human life easier. Several new technologies like facial recognition, tracking of the baggage, connection of the flight, intelligence check in etc. are key factors to make the modern airport smart.

In the year September 2008, ACI World Airport Information Technology Standing Committee (AITSC) was established by the ACI World Governing Board. The Committee's mission is to develop industry policy guidelines and positions on issues affecting Information Technology (IT), Airport Automation, Telecommunications infrastructure and related passenger and cargo services at airports, in order to support operational and business processes in and around airports. [7]

The latest development in information technology, policy related to the technology and the impact it can have in the airport are discussed and examined under the AITSC. Also, the benefits that the airport can have from the latest development are discussed in the committee. They also actively work to transfer information within the airport community regarding the IT related issues. Any new policy and guideline changes are communicated to the personnel of the airport through this committee.

2.2.1 Artificial Intelligence

All the airport technology system collects the data's and are analyzed with the software to predict the air traffic and the slow down of air traffic with the help of Artificial intelligence. This software can lead to predict the traffic patterns and also helps us to define the future predictions easily.

The increase of the air passengers are the main factors for the increase of the airport facilities. The airlines and airport should keep up the pace and must be able to handle the growing demand along with the increase in the capacity of passenger. The use of Artificial intelligence, Machine learning and other software development are the key answer to solve this problem.

A digital twin is a method which can be used to monitor and model about how the passengers interreact with each other and also the surrounding around them. Airports are using this technology in dynamic tinting glass, indoor mapping, energy optimization and advanced asset management. Also, all the airport spaces, like parking lot, terminal building, land side, airside are using similarly embedded technology to create digital twin for smart utilization and greater efficiency. [8]

Artificial technology are not only growing in Aviation sector but also in every other field of technologies. In this modern digital world, AI is playing a very significant role in making the life easier and efficient.

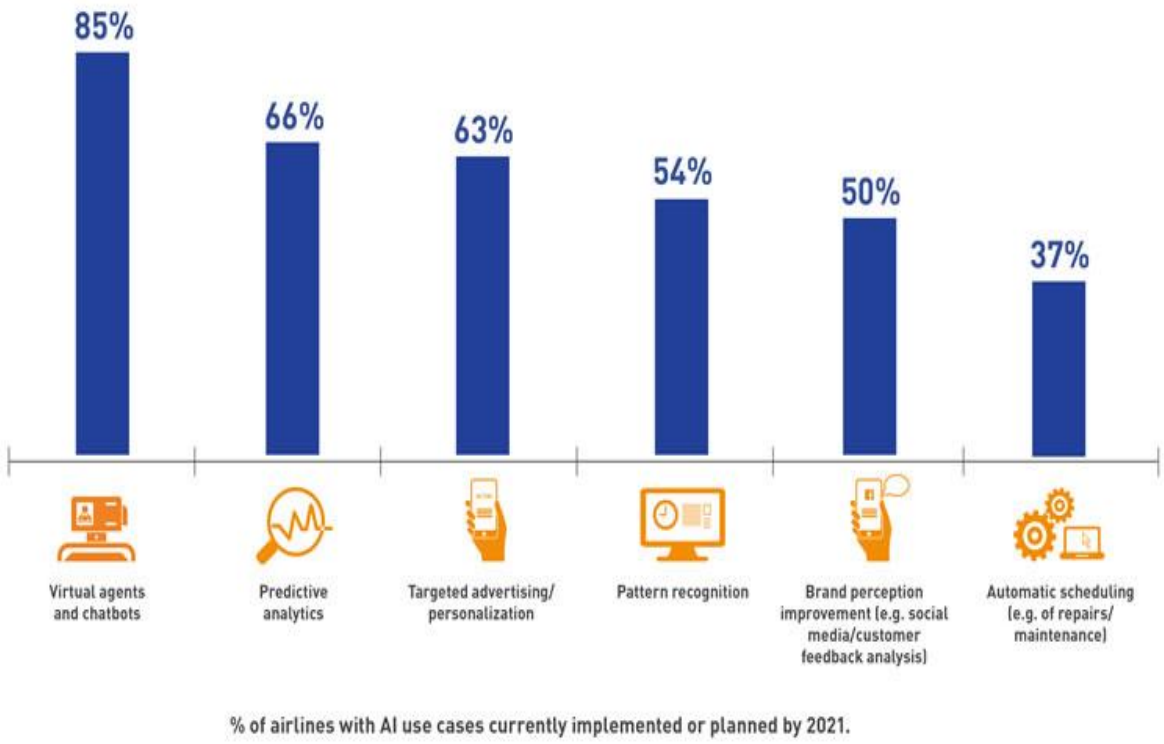

Figure 2.3: Percent of Airlines with AI use cases Currently implemented or planned by 2021

Virtual agents and chatbots is the most used AI function with almost 85 % of users using it at the present time followed by Predictive analytics and targeted advertising which accounts for 66% and 63 percent respectively. Automatic scheduling is the least used service of AI which accounts for only 37 % at the moment with pattern recognition and brand perception at around 50 percent each. [9]

2.2.2 Face recognition

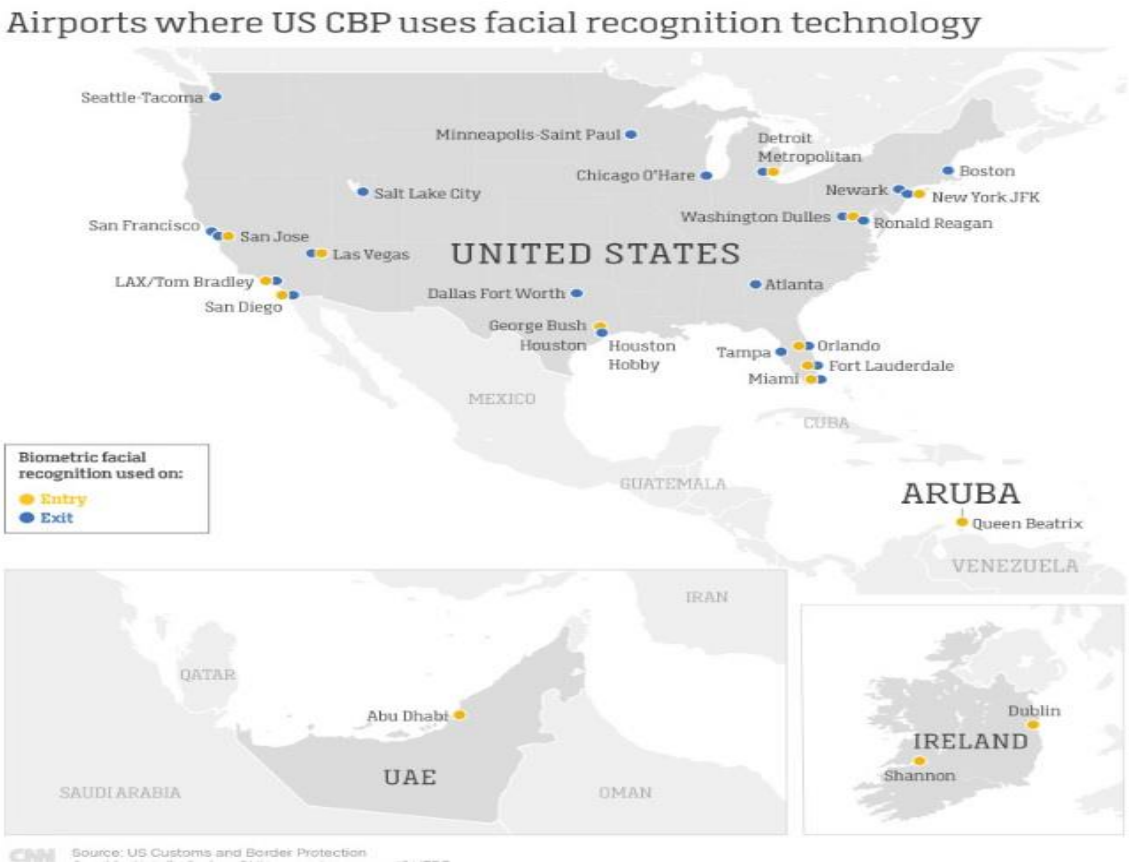

Figure 2.4 : Airports where Face Recognition technology is implemented

Going to the Airport security screening processing is a very daunting task for passengers and we all are aware of it. Long ques in the airport and the time-consuming process is very annoying for many passengers. The use of Artificial intelligence in the airport can optimize the process and makes it easier for the passengers. Ai will definitely change our travel experience in the future journey when we can spend on some other activities rather than waiting on a long que. On the figure above shows the airport where the facial recognition has been used in US, Ireland and UAE.

The facial recognition technology is a new technology established at the airport. In the current time, The law enforcement government works along with the airport to recognize the passengers using the face recognition technology. The database is collected by the U.S customs and border protection (CBP) in United states . The process of facial recognition is accurate with around 99% of accuracy. The CBP first conducted the trial at the airport across the united states to find out the accuracy of the system. Kiosk is a physical structure that provides the information or shows us the direction and also provides us services. In the airport, The kiosk scans your face which gets analyses and converted into the digital signature which is send to the database for matching. It is then analyzed and approved if it matches or denied if it doesn't matches. The information is then sent back to kiosk to show the result to the passenger. [10]

Figure 2.5 : How does Face Recognition work at Airport

Our faces are made up of 80 distinguish features as many people have different unique features to represent them self. All the 80 distinguish features have their own different unique code to represent it. The Artificial intelligence technology translates our facial feature on the kiosk and matches that unique features among the 80 distinguish features and creates a unique code. This code are the digital signatures or facial signatures which will be used when we are on the airport in front of kiosk for facial matching. In the Airports where facial recognition are used , for example in United states the CBP matches our facial signature to the passport photos for both the international and U.S citizens. [10]

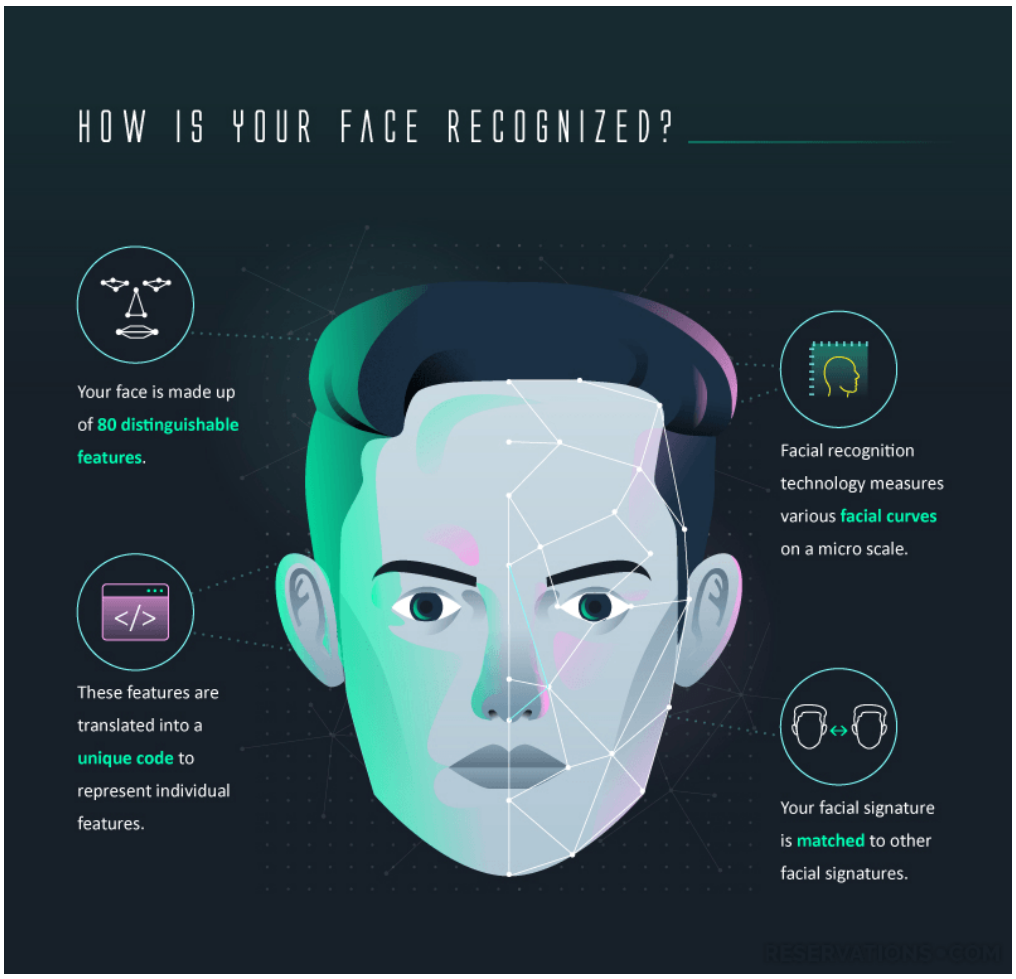

Figure 2.6 : Face recognition Pattern

Table 2.1 : Pros and Cons of Facial Recognition

PROS	CONS
Saves Time at Airport	Trust 3rd party Data provider
If you lose your identification, you can still board your flight	Privacy issue
Improves Security and can also prevent time	Not 100 percent accurate, racial disparities
Future of smart airport	

The facial recognition technologies are intended to be established in the major airport in the united states and around the world by the year 2021.With 99 percent of the accuracy it takes very short time with less than 2 seconds to show the result on the screen. During a survey in the year 2019. There are many advantages of using the facial recognition foremost, its saves the valuable time and makes the airport work faster. On the other hand, there has been a significant rise of privacy issue as people don't want their information taken by the government office for which they are afraid that they can misuse it in future. Another advantage of facial recognition is that, it improves security and it's the future of smart airport. Also since it is 99 percent accurate, there is still one percent chance that it can be wrong. There are many faces which matches together so there can be faults sometimes while executing the facial information.

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A survey was conducted on May of 2019 in USA in which people were asked, Did they approve the Facial recognition technology by US government?

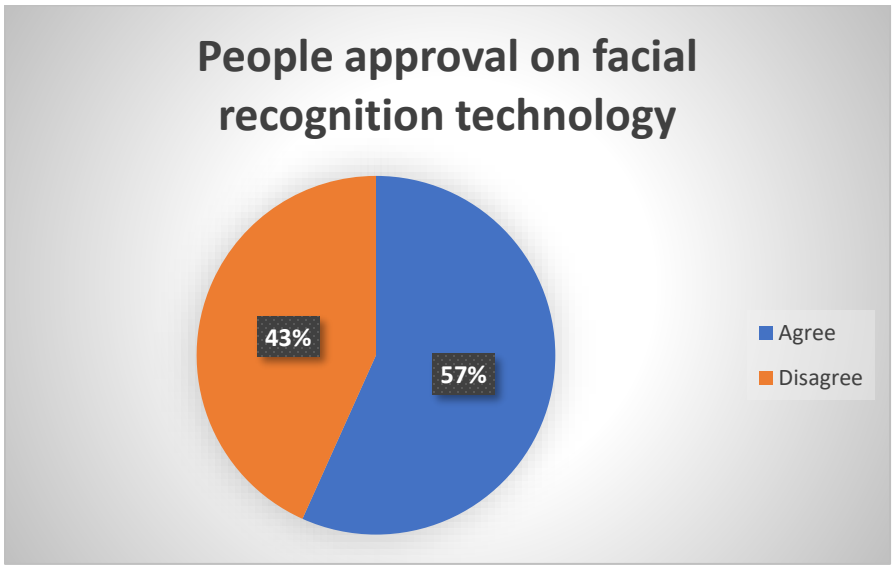


Figure 2.7 : Pie chart on People approval on facial Recognition

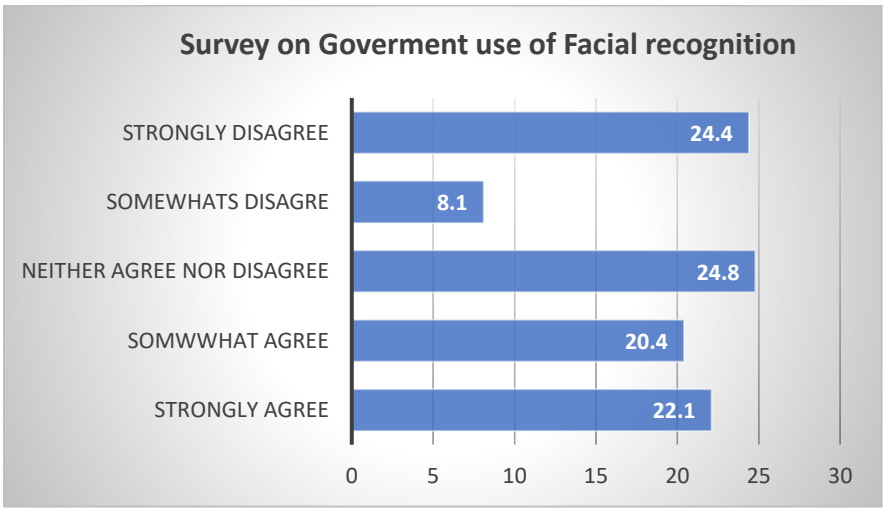


Figure 2.8 : Survey on Government use on Facial Recognition

More than half of the participants agreed on the facial recognition where as 43 percent did not agree on the facial recognition and showed privacy issue as their major disagreement [12]

2.3 AIRPORT SHOPPING

We all know that the number of travelers has increased in the recent years and also the amount of shopping that they do . As the number of passengers have increased in the significant rate, the amount of shopping done by the passenger have not increased at that rate tho. In the past 5 years, the airport shopping business has showed a decline in figure . Airport, airlines and shops need to work together and bring unique solution to cope up with this slow down.

Although some of the airlines and airports have launched a joint venture to increase the sales and increase their sales performance there has not been significant progress in the market. The latest example of this joint ventures is the Kuala lampur international airport located at Malaysia, Which has started to integrate with big data platform to provide the important information to the passengers and the airport staffs about the product so that the passengers and airport business staff can learn about the product in the better way . The passengers can see the product online on their mobile phone as the airport staff can bring the product to them before boarding. The same process can be seen in with the Singapore airlines and duty-free operator, where they have worked together to transfer the menu and the catalog online to start the ecommerce experience at the airport.

Companies need to do more than this, if they have to increase their sales . Also the information technologies can be used in the proper way so that the companies can provide useful information and pursue customers to buy their products at the airport. [12]

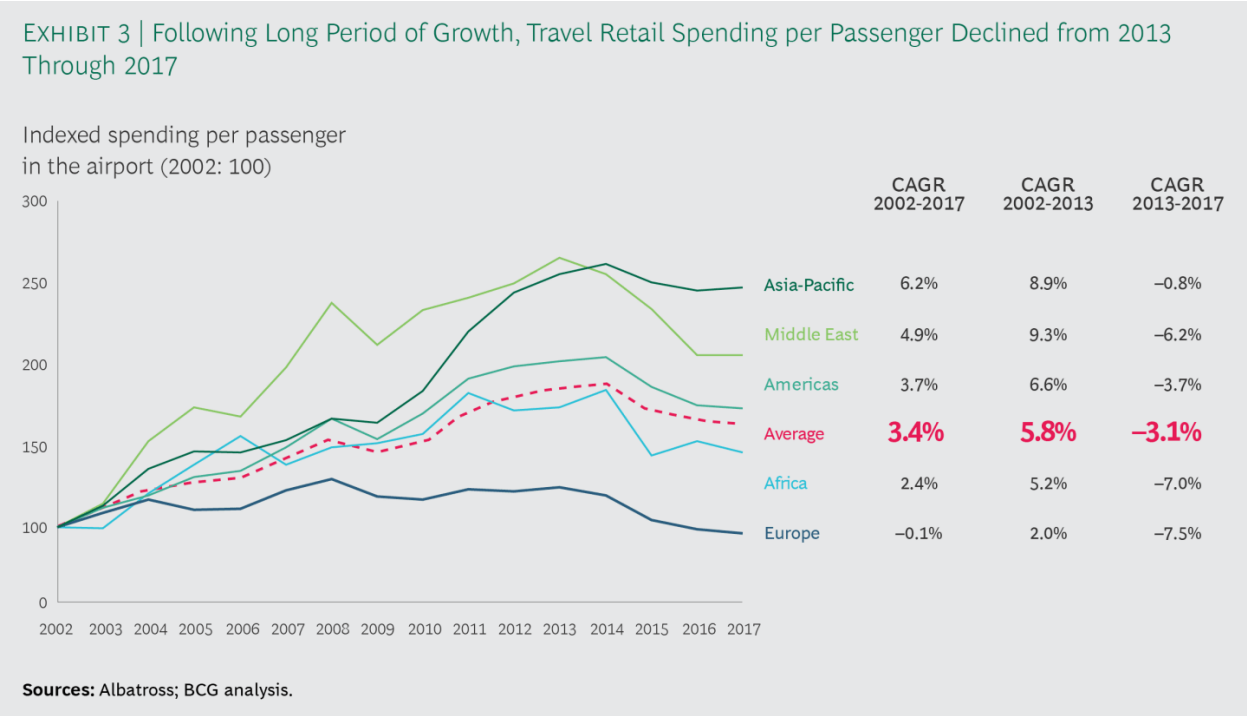


Figure 2.9 : Travel Retail Spending per passenger from 2013-2017

AS we can see the trend of spending per passenger in the airport has decreased gradually from the year 2013-2014 where the customers in Europe seems to be spending the least whereas the customers in the Asia-pacific region tends to be spending the most among all the regions. The main reason behind it can be the prices as, Asia pacific airport market provides the customers in the cheap rate compared to the other regions. The compound annual growth rates seems to be decreasing in all the regions where the average tends to be around -3.1 % . Also the market in Europe and Africa tends to the lowest with -7.5 % and 7% respectively.

Higher consumption per passenger determines higher level of customer satisfaction resulting in higher earnings for the airport operator. The survey also shows that the more customer waits in the airlines, the more it is likely to spend time in shopping. In other words, we can conclude that to make the satisfaction level of customer Hight, investment on the commercial facilities should also be taken into consideration.Commercial facilities have a strong link with IT, which is already put to use in various areas. Much of the technology is used to make profits. We can use to make the commercial product digitalize by displaying it on the digital screen which can make the passenger more interested towards the product. Like in the techniques used by the virtual store while we do online shopping, IT can help list the similar product that the passengers are buying according to the budget of the passenger. We can also say that IT provides many choices for the passengers to buy the product and to increase the customer satisfaction.[12]

Figure 2.10 : Connection of Airport, Airlines, Brands and Duty Free

Airports can use the help of digital directional signboard, billboards, helpful tips on the board and reminders, or helpful and informative kiosk with on demand and interactive services. Especially, in big airports where, buses, walking lift, and other forms of vehicles are needed to transport customers from one place to another, these kinds of facilities can be very useful to help in people finding their way. One of the important examples was Hamburg airport adopted a informative digital system where they included personalized directions, the directions of shops and restaurants and other important shops. This kind of installation helped in better user experience and increased the sales of the airport stores. [13]

In the recent years, the number of smartphones has also increased rapidly. Due to the help of search on their smartphone, they can find their way out in the airport and prevents them from getting lost in the airport. Passenger tend to use their smartphone which they are waiting at the airport. For this reason, it should be possible to provide services that suits both passengers and airport to provide with the right information., Displaying information to people leaves them with a memory of the content. For this reason, the displayed information should be designed to attract people into airport stores or generate profit, as with coupons for airport food and beverage outlets, information on where they can be used, or discount services according to the purchasing amount. Moreover, in terms of generating eagerness to buy, coupons can be expected to have a greater impact on ordinary passengers than on business passengers.

2.4 INFORMATION TECHNOLOGY AT AIRLINES

Airlines have for many years looked to technology to deliver greater operational efficiency. Now digital has ushered in opportunities for creating and delivering customer experiences that can build loyalty.

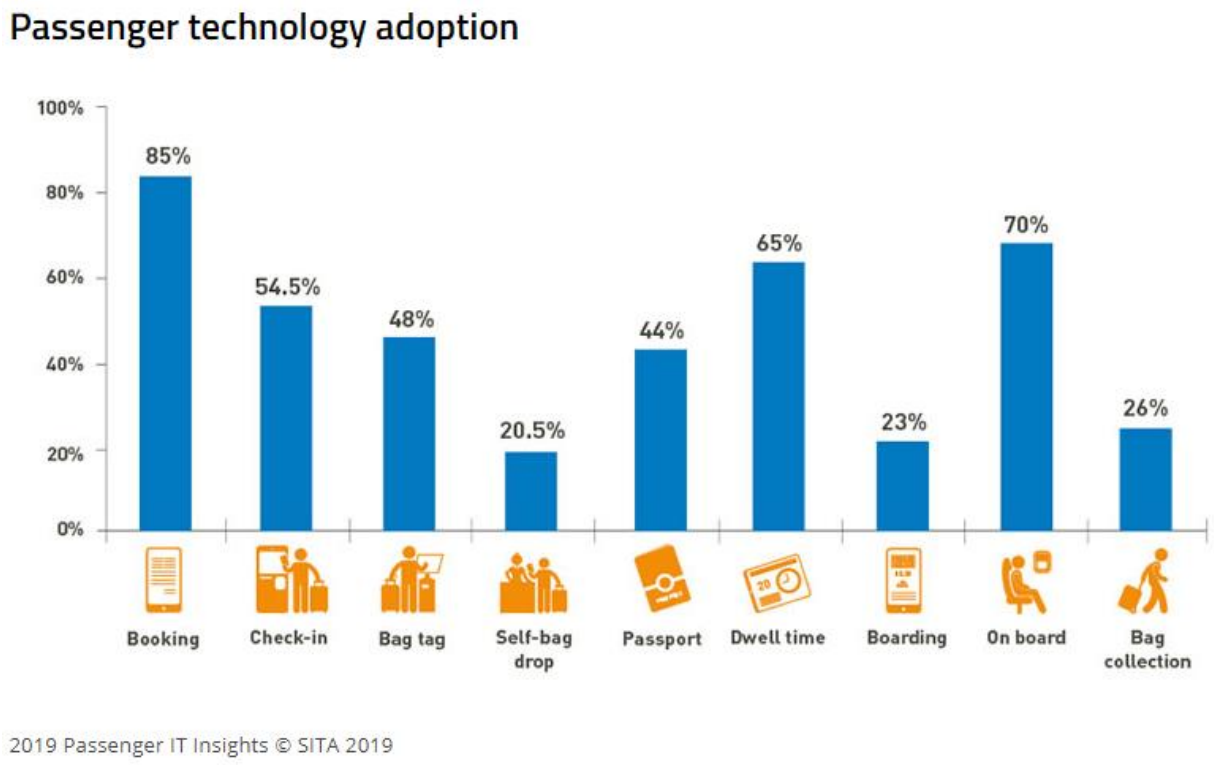


Figure 2.11 : Passenger adaptation on New Technology

2.4.1 Check-ins

As their name implies, check-in terminals are kiosk terminals where passenger's complete check-in procedures with the help of the kiosk service. Counter operations are managed digitally so that passengers can carry out the procedures in their own -time with the guidance provided on their Kiosk service screen. Many airports around the world are already introducing

kiosk terminals for self-check-ins. As an airport operator, therefore, its objective is to integrate this into the common-use. Replacing the terminals installed by individual airlines with common-use terminals will enable passengers to complete their check-in procedures at any terminal. This will eliminate the need for passengers to line up at counters, and enhance convenience by removing restrictions on their choice of transaction terminal. It will also enable passengers to use the time wisely.

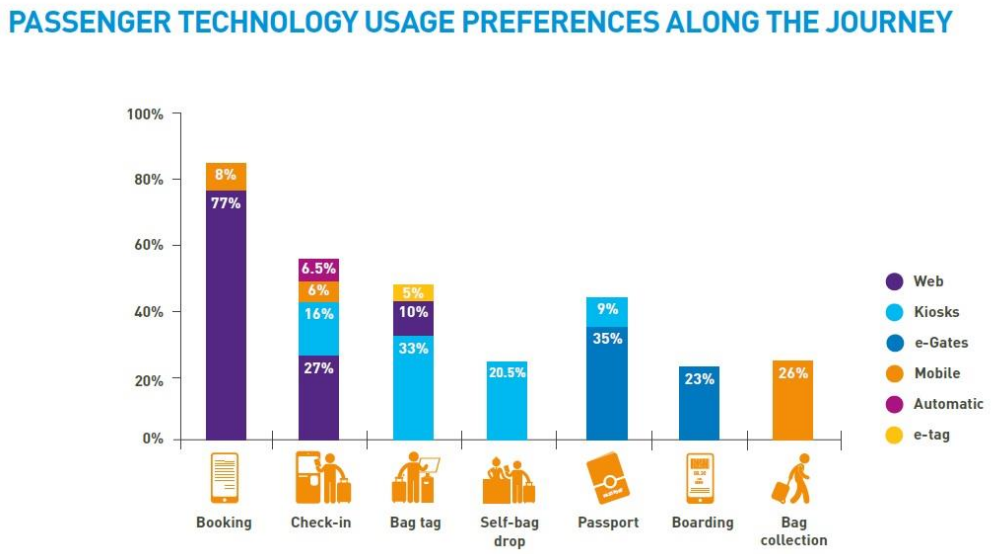


Figure 2.12 : Passenger Technology usage preference along the journey

Some of the airports terminals have already started to use the document checking function like passport checking and visa check in functions to make the check in faster. We can also see the system incorporating in the airport of turkey especially in airports in Istanbul. There is special kiosk for check in where we can check in with our passports. Another main advantage of this function is that the airlines can manage the check in facilities with less staffs. Also, the limited airport space provided to the airlines can be used efficiently. This can hugely help in airlines operators in reducing their cost of the operation. In this way, the airlines can also increase their profits by using the latest technology as the check in will benefit both the airlines and save customers valuable time.

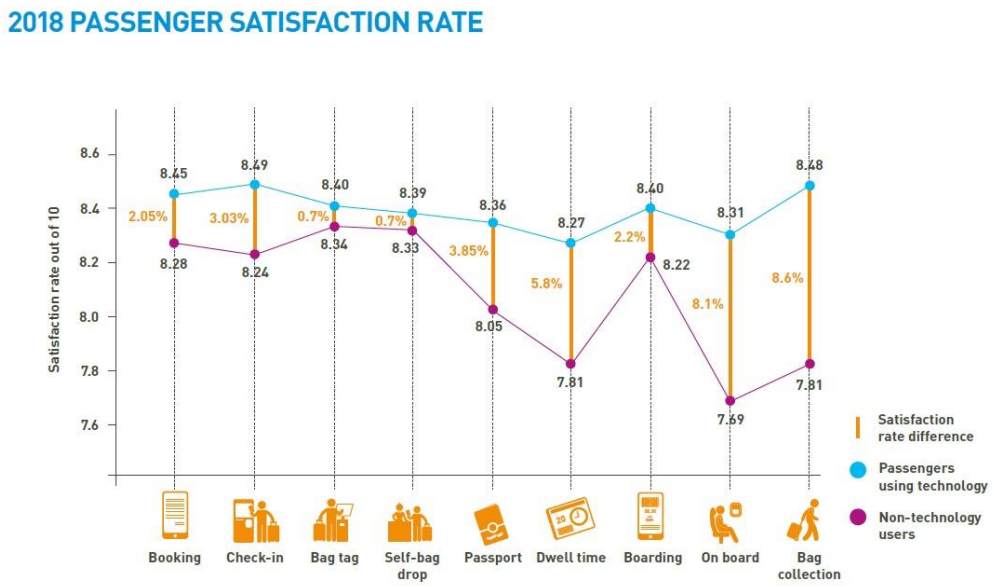


Figure 2.13 : 2018 Passenger Satisfaction Rate

2.4.2 Bag drops

Passengers can check in their baggage themselves by using the self-bag drop facilities. The main function of this self-bag drop facilities is to transport the bagged which are tagged in the conveyer belt to the airplane loading place. There are special scanners that read the tag which are installed in the conveyer belt. According to the data, the baggage are taken from the baggage center to their respective flight. The kiosk on the airport are especially arranged to weight in the amount of the baggage and also prevent the nonstandard baggage or over weight baggage. This function was conducted by the airline staff in the past which is not being conducted by the passengers theme self. The technologies remains the same, only the user is different at the moment.

The major benefit from this self-bag drop facility is to save the valuable time of the passengers which they can use for other purposes. Also, the long que is being avoided. Also the necessity of carrying heavy baggage with our self have been eliminated due to the introduction of this

facility. Some of the people also consider the hospitality given to them and value hospitality very importantly. One of the examples is the people of japan who strongly value the services given to them at the airlines. Since the airlines staff gets less engaged in this service, they feel like they have been left out and their satisfaction level may be well on the decline due to the less interaction by the airline's staffs to them [14]

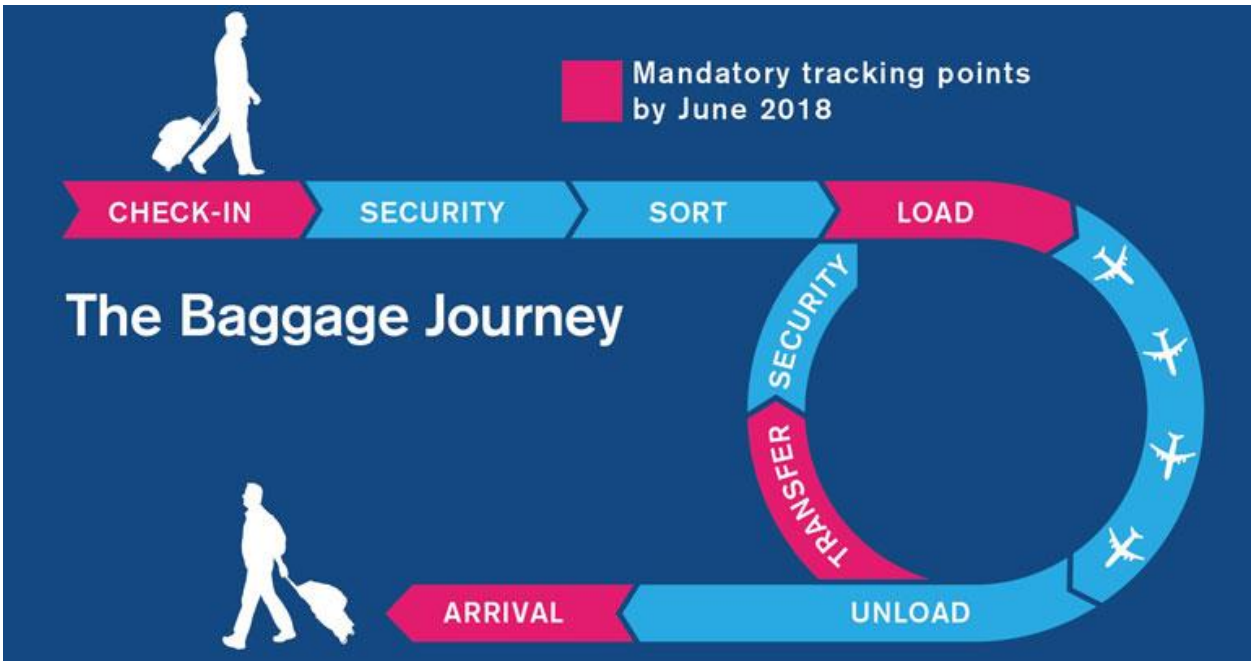


Figure 2.14: Journey from check in to arrival

2.4.3 Boarding

Self-boarding are the gate which are opened when we show our boarding pass on the ticket section. The gate opens and we pass out to the next section. There are bar code readers on the boarding gate in which we will show our tickets or the scanner on out mobile phone which will

scan our bar codes and the gate gets opened. It is also possible for the machine to read our passport information enabling the the machine to read both the personal and ticket information. Since the machine reads our personal data, powerful measure is taken to keep the data safe. This kind of facilities reduces time significantly on the boarding gates. The self-boarding service is not as efficient as the self-check in and baggage service but it is certainly reduces the human error occurred during the manned boarding gate services. The major limitation of this services are not many countries have adopted to the biometric passports so this kind of services are limited to the particular country or region.

3. GROUND HANDLING OPTIMIZATION

3.1 Introduction to Ground handling

Airport ground handling operations is defined by the services that are provided by the airport personals to an aircraft between the time of its arrival, and departure for next flight also being described as 'terminal operations' or 'airside operations'. In the world of airport, the words "ground handling" is connected to the services provided and to facilitate aircraft flight or aircraft ground repositioning, preparation for the takeoff or landing. Services and facilities such as passenger arrival/departure, baggage handling services, Security services, cargo services are all operated by the terminal operation services. All the ramp services, on ramp aircraft services, onboard services are included in the airside operation of the airport.

It is expected that the market size of global ground handling market to reach USD 189.09 billion by the year 2022, by the report published on Grand view research. The increase in the global ground handling services can be directly linked with the increase in the number of passengers in the global air transport services. [15]

In the current Ground handling market, North America dominates as there are huge inflow of air transport in the north America as many passengers use air transport in the region. The

busiest airport in the region includes Atlanta and los Angeles international airports which is also one of the busiest airports in the world.

The European aircraft ground handling services are led by European giants like Germany, France and Great Britain. The are showing significant growth in the recent time. Also highly crowded region in Asia pacific shows a significant growth during the time frame which is subjected to capture 25 percent of the global service by the year 2025 [15]. Large population country like India and china are contributing very significantly as these countries are gradually improving their Ground handling activities. Also other countries in this region are taking benefit from their high population as they are increasing their air passengers and also the ground handling services.

The introduction of sensors, tow-less vehicles, Improved baggage management services are the major results of the technological improvement done in the ground handling services to provide a better service in the airport. As the services in the airport gets better, the customer or passenger have high satisfaction rate which results in increase in sales and air activity in the airport.

3.2 TYPE OF GROUND HANDLING OPERATION

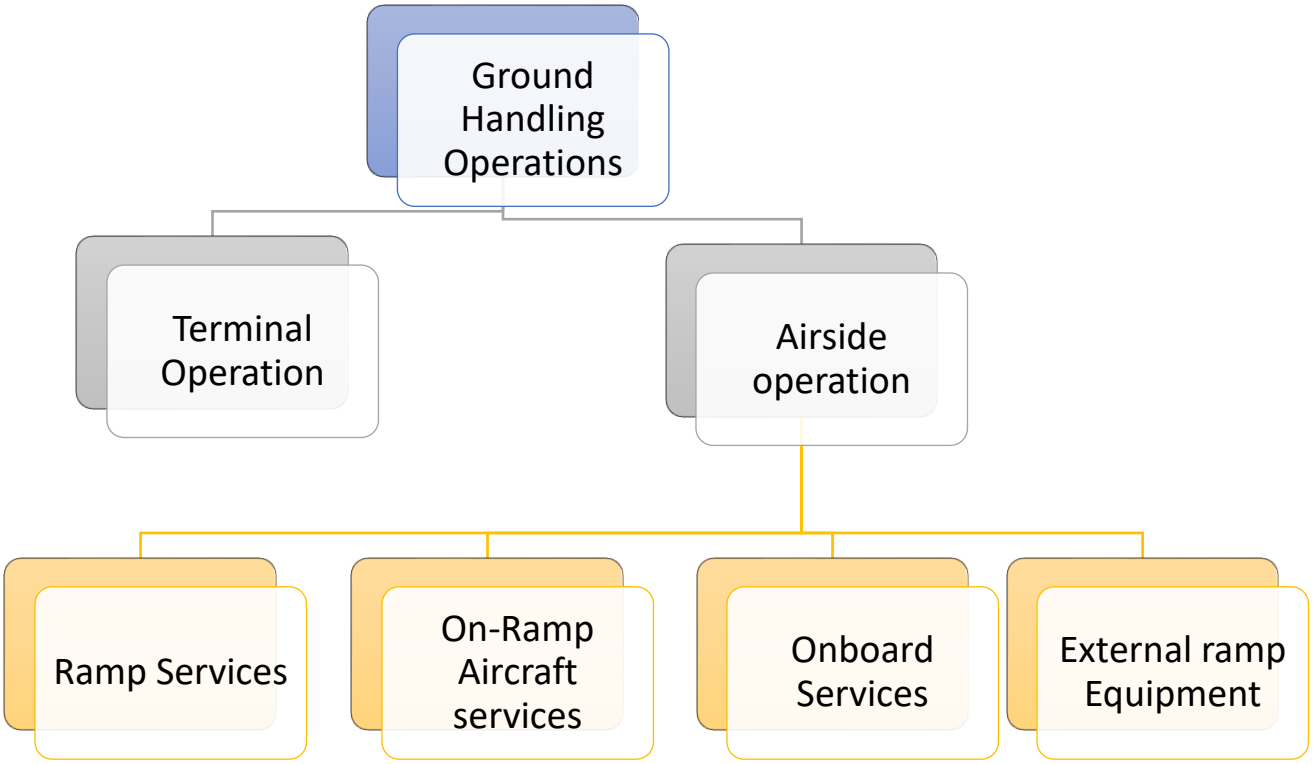


Figure 3.1 : Ground handling Operation Chart

Table 3.1 : Fucntion of Airside Ground handling operation

Ramp Services	include processes such as supervision, marshaling, start-up, moving/towing aircraft, and implementation of safety measures.
On-ramp Aircraft services	include routine and non-routine maintenance, refueling, checking of wheels, deicing, servicing of toilet, supply of potable water, and cleaning of windows and nacelle.
Onboard services	catering services, in-flight entertainment, cleaning, and other minor servicing of cabin fittings and seating configuration

External Ramp Equipment	include passenger steps, cargo loaders, mail and equipment loading, and crew steps on all freight aircraft.

3.3 OPTIMIZATION

The ground handling services are usually served by the airport personnel or the airlines itself . But recently a private company are given the responsibility. The airlines can give the contract of ground handling to the third party or the ground handling service of other airlines if they cannot conduct the job efficiently.

The Aircraft Ground handling services faces a tough competition around the aviation market as the number of aircraft and passengers are increasing, the responsibility to do the job efficiently and at fast rate has been the priority of every airlines. Every airport and airlines are trying to make their turn around time less and also to decrease the handling cost.

Many specialized equipment is needed for efficient ground handling jobs and some of the jobs need to be right on time or require quick services, For instance, When the aircraft lands, the ground handling staffs need to perform the task faster to allow the passenger pass to the terminal.

Aircraft Turnaround time refers to the time when the aircraft lands and departs from the airport. During this time, many things needs to be done for instance, filling up the fuel, loading and unloading the cargo, cleaning the aircraft etc. If the ground handling services can do their job efficiently, they can save the time and the aircraft can fly right on time.

4.AIRPORTS IN TURKEY

4.1 HISTORYOF AIRPORT IN TURKEY

Airport History

The first aerodrome in Istanbul was opened in Yesilkoy in 1912 for military purposes. In consequence of International Civil Aviation Convention undersigned in Chicago in 1944, it was decided to found an international airport in Istanbul/Yesilkoy. A contract was signed with Westinghouse Electric International Company and the IG White Engineering Corporation for the construction of this airport in 1947. Construction began in 1949 and completed in 1953 and the airport put into service on August 1, 1953 dedicated as Yesilkoy Airport.

The aerodrome consisted of Runway 06/24, taxiways, 10,000 square meters modern passenger terminal, maintenance hangars, radio receiver-transmitter equipment and a secondary power source in accordance with that period`s technology.

As Runway 06/24 became insufficient with the development of international civil aviation, a new runway was decided to be constructed. The constuction of Runway 18/36, which is 45 meters wide by 3,000 meters long, was started in 1968 and was completed in 1972.

In 1971, a new master plan was put into effect for Yesilkoy Airport. The plan consisted of 4 terminal buildings each of which has a capacity of 5 million passengers per year and complementary besides the Runways 06/24 and 18/36. The project by Architect Hayati TABANLIOĞLU included Turkish Airlines Hangar Facilities, Cargo Terminal Facilities, Air Traffic Control Tower and Technical Block, Lighting System, Electric Distribution System, reconstruction of Runway 06/24, Aircraft Fuel Facilities and other related facilities. The International Terminal included in the project under consideration was opened on October 29, 1983. In 1985, with the modern appearance it was re-dedicated as Atatürk Airport. [16]

4.2 CURRENT AIRPORT SITUATION IN TURKEY

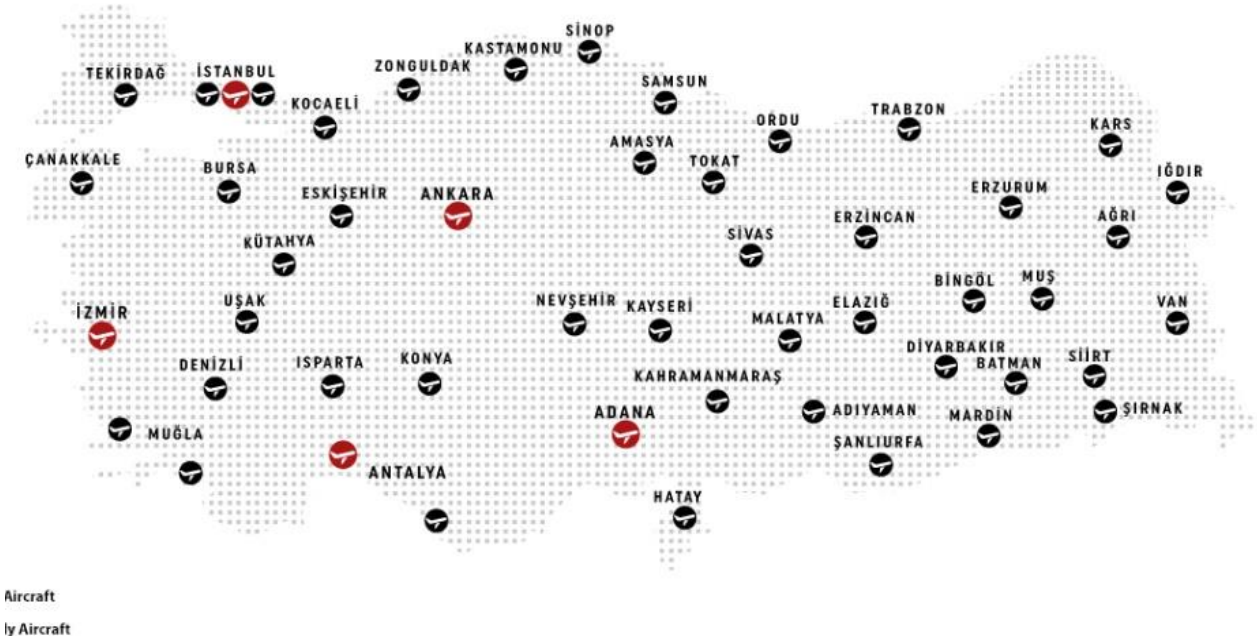


Figure 4.1 : Airports in Turkey

Turkish airports are equally spread out in every region of the country from Tekirdag to igdir.

There are currently 58 airports in Turkey included domestic and international airport in which 36 are operated as international airport and 22 are operated as domestic airport. [17] The major Airlines of Turkey are Turkish airlines, Pegasus, Onur air , Atlas jet etc. Turkish airlines is the leading airlines in the world going to 315 destination and 126 countries all around the world [18]

4.3 PASSENGER INFLOW IN TURKEY

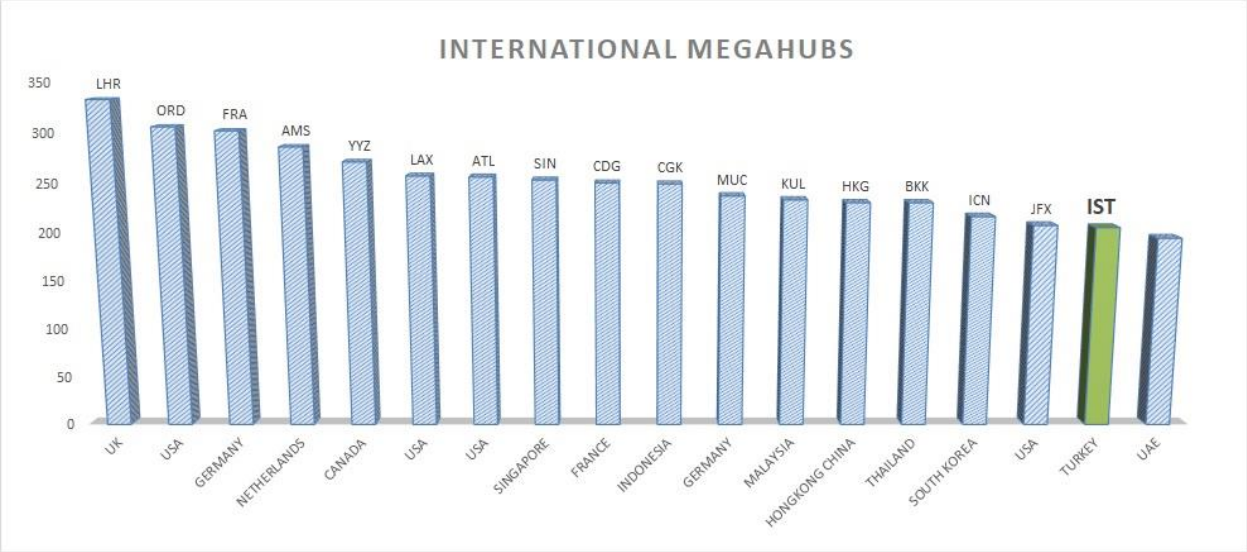


Figure 4.2 : Bar Graph of international Megahubs

‘ Turkish State Airports Authority (DHMI) announced AIRCRAFT statistics for Turkey in the year 2019 in which total of 209,092,548 passengers are handled by airports in Turkey in 2019.Transportation and Infrastructure Minister Cahit Turhan quoted “ that on the month of December 2019, the total number of aircraft landing and taking off were 62 thousand 442 in domestic and 43 thousand 890 in international flights.” The total aircraft traffic reported as 144 thousand 724. In 2019, domestic passenger number is recorded as 100,140,814 while international passenger number is recorded as 108,692,517. The number of take-offs and landings at Istanbul Airport in December 2019 announced as 8,215 for domestic, and 26,421 for international and a grand total of 34,636. ‘ [19]. Turkeys Istanbul airport ranked in the 17 position on the list of highest number passengers hosted by the airport.

5.NEPAL AIRPORT

5.1 AVIATION IN NEPAL

Nepal is a landlocked country between two Asian giants India and China. Its total area is 1,47,181 square kilometers. It can be called as the roof of the world as the highest peak Mount Everest (Sagarmatha). Currently, the only international airport and hub of all the air services in the country is Tribhuvan international airport (est in 1950). The two regional domestic airport of Nepal are now being upgraded to International Airport (Pokhara International Airport and Gautam buddha International Airport) respectively. The other international airport named Nijgadh International Airport is on the final phase of Planning as of the date today.

Figure 5.1 : International Airport of Nepal

5.2 CHALLENGES IN LUKLA AIRPORT

Lukla Airport is located in Solukhumbu District of the Eastern Development Region. Although these are remote domestic airfields, their importance to current and future economic development and tourism cannot be overstated. The airport in Lukla is often cited as the most dangerous on the planet. While there have been crashes, the airport is as safe as many major airports around the world.

The runway is short only about 1,700 feet which is built on the mountainside with a slope of about 12 making one end about 200 ft higher. Planes land headed uphill so the uphill slope helps in the brake of the aircraft which creates the illusion of distance for pilots. Clouds often creates problem as they seem to come and go suddenly and the visibility of the region is also very low which lead in to the accident in the year 2008.Pilot just have one chance to land in the area and don't have the option to return and land again.

As per the International Civil Aviation Organization (ICAO) Annex 2 Rules of the Air, under visual flight rules (VFR), a flight shall not take off or land at an aerodrome when the cloud ceiling is less than 450 meters or when the ground visibility is less than 5 km. "If these two critical requirements are not met, the airport should be closed,". VFR is a set of regulations under which a pilot operates an aircraft in weather conditions normally clear enough to allow the pilot to see where the aircraft is going.

after the Yeti Airlines Flight 103 crash in 2008, standard operating procedure (SOP) was developed specially for Lukla Airport .The airport has four sets of conditions.

1. the air traffic controller (ATC) should be able to see the second ridge of the South West or beyond. If this condition is met, it could be assumed that the ground visibility is more than 5 km.

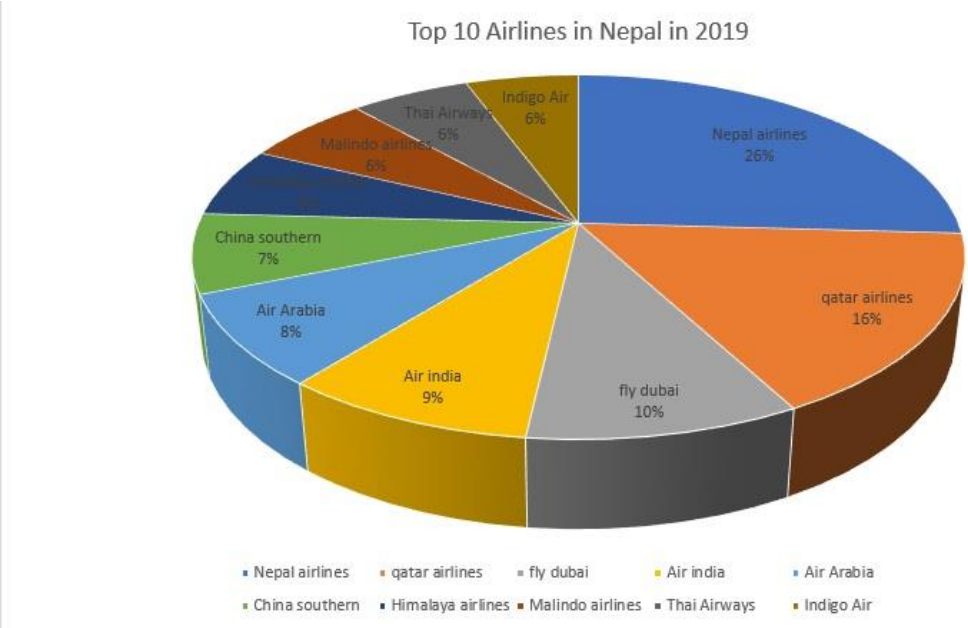
2. the ATC should be able to see a 3,000-metre hill dubbed ‘105’ from the tower. The ATC can declare the cloud ceiling to be favorable if this condition is met.

3. the wind speed should be less than 10 knots, equal to 5 meters per second, for aircraft to be permitted to land.

4 , the airport should be closed even if the rainfall intensity is light.

6.SURVEY ON CUSTOMER EXPERIENCE

Tribhuvan airport is the only International Airport in Nepal which host around 2 million passengers annually. Nepal airlines is the national carrier of the country which host highest number of passengers in the airport at around 735,835 followed by Qatar airlines and fly Dubai airlines .Since most of the passenger of Nepal or Nepalis citizens work as a migrant worker in the golf country .



Airlines	Passengers
Nepal airlines	735835
qatar airlines	462039
fly dubai	274688
Air india	255058
Air Arabia	228929
China southern	200003
Himalaya airlines	176392
Malindo airlines	179011
Thai Airways	169823
Indigo Air	160617

Figure 6.1 : Top 10 Arilines of Nepal in 2019

6.1 LIMITATION TO THE SURVEY

The survey had many questions regarding the services provided by the terminal building to the passenger arriving to the airport. The survey was conducted among the passengers that had used the airport in the past. Many of the participants were the foreign workers in the abroad. Nepal has one International airport at the moment so it is necessary to make the airport efficient and reliable to use. The entrance of the Terminal building, Going to find the flight details and doing check in , ID checkup and security , waiting lounge and way to boarding are the main aspects of any airport services.

About 100 participants joined in the survey of Customer experience in Istanbul airport and In Tribuwan airport where the questions were mainly focused on the terminal building services

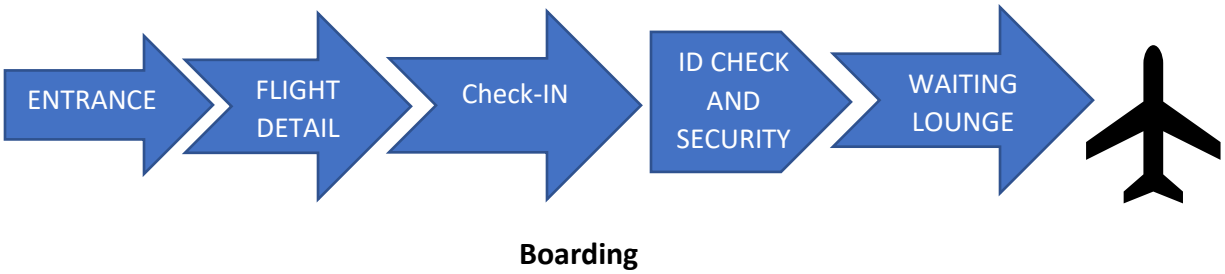


Figure 6.2: Journey to the airport

Comparision of Istanbul Airport to Tribhuwan Airport

What is your age? (Yaşınız kaç?) *

- 18-25
- 25-40
- 40-50
- 50 above

How did you buy your Ticket?(Bileti nasıl kestiniz?) *

- From The internet by yourself (internetten)
- From the Travel Agency (Seyahat Acentasından)
- At the Airport Itself (Havalımanında)

Customer Experience At Tribhuwan International Airport

Hello, My name is Rupesh Shrestha. I am at my final year studying Aeronautical Engineer at Istanbul technical University.I am doing my final thesis on "Economization of Airports and Aircraft Maintenance". The short survey is about the ways to improve the Airport condition of Tribhuwan international airport by analyzing the customer experience of the passengers. Thank you 🙏🙏🙏🙏🙏

*Required

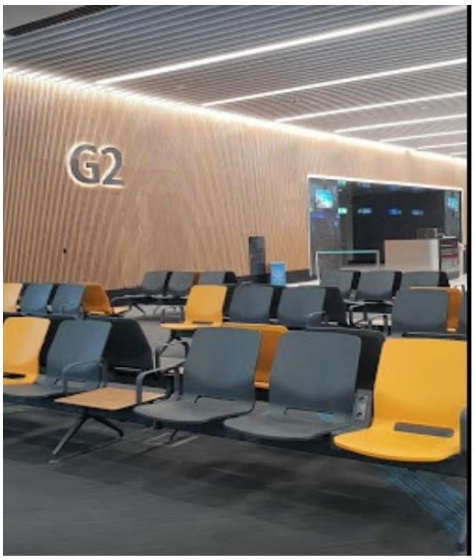
What is your age? *

- 18-25
- 25-40
- 40-50
- 50 above

How did you buy your Ticket? *

- From The internet by yourself
- From the Travel Agency
- At the Airport Itself

How long did you have wait before your sheduled flight at the Airport? (Uçuştan önce ne kadar beklediniz?) *

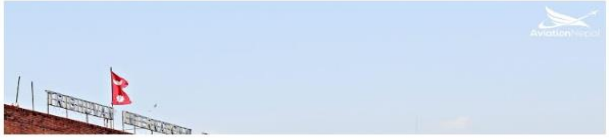


- 10-30 dakika
- 30-60 dakika
- 1 saat- 2 saat
- More than 2 hours (2 saattan fazla)
- It was right on Time(uçus zamaninda gerceklesti)

How long did you have wait before your sheduled flight at the Airport? *

- 10-30 minutes
- 30-60 Minutes
- 1 hour- 2 hour
- More than 2 hours
- It was right on Time

Please rate the Services of Tribhuwan international Airport? *



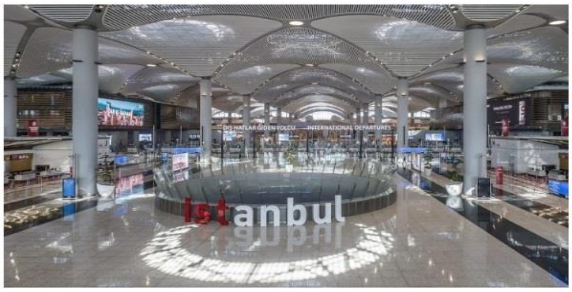
Please rate the Services of Istanbul Airport?(Istanbul Havalımanı'nın Hizmetlerini değerlendirin? *

	Highly Satisfied(çok memnumum) 😊😊	Highly Dissatisfied (hiç memnum degilim) 😒😒😒😒	Average (Orta seviyede)😎😎	Somehow Satisfied (yani fena değil) 🤔🤔🤔🤔🤔
Baggage Handling Services(Bagaj Taşıma Hizmetleri)				
Immigration and Visa Services				
Airlines services (Havayolların Hizmetleri)				
Airport Taksi Services (Havalımanı taksi hizmetler)				

Please rate the Services of Tribhuwan international Airport? *

	Highly Satisfied 😊😊😊	Highly Dissatisfied 😒😒😒😒	Average 😎😎	Somehow Satisfied 🤔🤔🤔🤔🤔
Baggage Handling Services				
Immigration and Visa Services				
Airlines services				
Airport Taxi Services				

Please rate the Terminal building of the Airport?



	Highly Satisfied 😊😊😊	Highly Dissatisfied 😒😒😒	Average 😎😎	Somehow Satisfied 🤔🤔🤔
Cleanliness (temizlik)	○	○	○	○
Comfort and Facilities (Konfor ve Tesisler)	○	○	○	○
Direction SignBoards to show way (Yol ve yön tabelaları)	○	○	○	○
Safety and Security(Emniyet ve güvenlik)	○	○	○	○
Staffs or Personal at Terminal building (Personelin davranış ve hizmetleri)	○	○	○	○

Please rate the Terminal building of the Airport

	Highly Satisfied 😊😊😊	Highly Dissatisfied 😒😒😒	Average 😎😎	Somehow Satisfied 🤔🤔🤔
Cleanliness	○	○	○	○
Comfort and Facilities	○	○	○	○
Direction SignBoards to show way	○	○	○	○
Safety and Security	○	○	○	○
Staffs or Personal at Terminal building	○	○	○	○

How do you rate the overall Facility of the Airport? Out of 5star.(Havaalanı'nın genel tesisini ve hizmetleri nasıl değerlendiriyorsunuz? 5 üzerinden *

- ○ One Star(Bir yıldız) ⭐
- ○ Two Star (iki yıldız) ⭐⭐
- ○ Three star (üç yıldız) ⭐⭐⭐
- ○ Four Star (dört yıldız) ⭐⭐⭐⭐
- ○ Five star (beş yıldız) ⭐⭐⭐⭐⭐

What are the wrost problem you have faced at Istanbul International Airport? (İstanbul Uluslararası Havalimanı'nında karşılaştığınız en kötü sorun nedir?)

Your answer

What did you Like about Istanbul Airport?(İstanbul Havalimani'nın neyi beğendiniz?)

Your answer

Please write your Name ?

Your answer

Thank you very much for your Participation

Submit

How do you rate the overall Facility of the Airport? Out of 5star *

- ○ One Star ⭐
- ○ Two Star ⭐⭐
- ○ Three star ⭐⭐⭐
- ○ Four Star ⭐⭐⭐⭐
- ○ Five star ⭐⭐⭐⭐⭐

What are the wrost problem you have faced at Tribhuwan International Airport?

Your answer

What did you Like about The Tribhuwan International Airport?

Your answer

Please write your Name ?

Your answer

Thank you very much for your Participation

Submit

Result of the Survery

6.2 AGE GROUP

On the survey, more than 62 percent of the participants are from the age group 25-40 which is normal as most of this age group are working abroad. It is followed by the age group 18-25 as around 27 percent. The least percentage of the people are from the age group 40-50 which comprises around 10 percent of the total participants.

On the Other hand, The 86 percent of participants are from the age group 18-25 as the fact that most of the participants are University students.

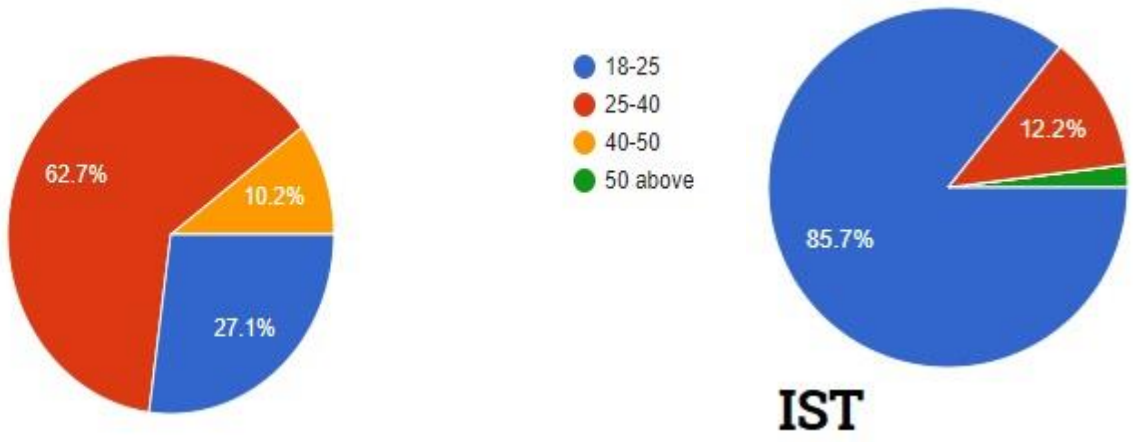


Figure 6.3: Pie chart on Age group of Participants in Tribhuvan Airport and Istanbul airport

6.3 BOOKING

From the survey, we can conclude that more than 66 percent of the participants relies on 3rd party for their ticket where as only 34 percent of the participants cut their tickets by themselves. On the modern world, People take their tickets themselves from the website or on the airlines website but still there are many people who relies on the 3rd party to cut the ticket. Many of the Nepalese are still lacking information about online business or online business of air tickets. They are also not familiar to the bank transaction which results them to rely on other people to do their transaction. Bank transactions are common in Istanbul, Which results in many people taking their ticket themself from the internet. We can save some amount by this as the travel agency do charge some amount for this service.

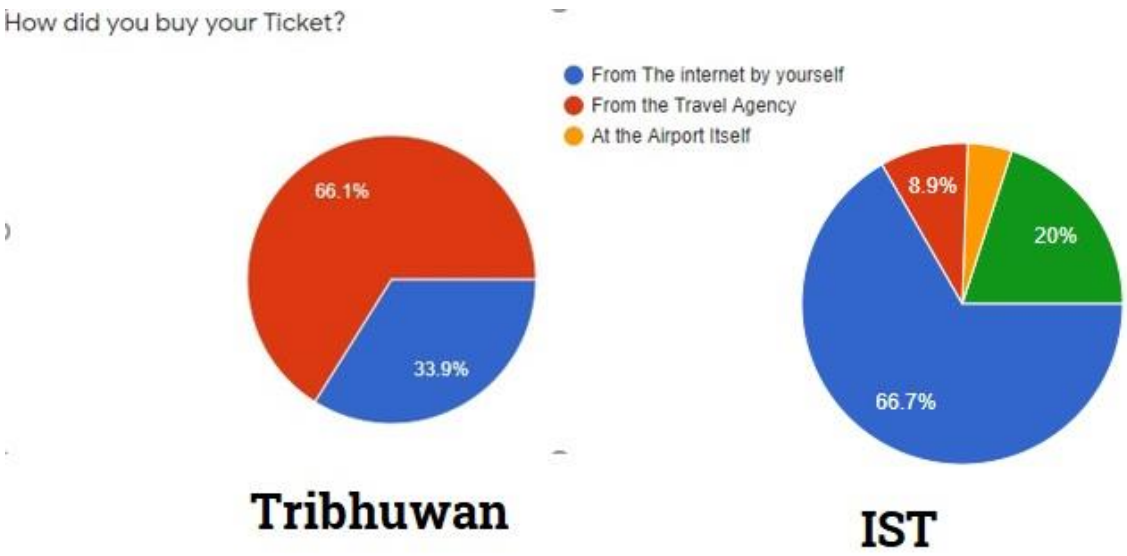


Figure 6.4 : Pie chart on booking statistics of Participants in Tribhuvan Airport and Istanbul airport

6.4 WAITING TIME AT AIRPORT BEFORE FLIGHT

Figure 6.5 : Pie chart waiting time before flight of Participants in Tribhuvan Airport and Istanbul airport

The numbers were not that differentiateent compared with the amount of waiting time for the scheduled flight. Around 18 percent of the participants had to wait around 10-30 minutes while just 3 percent of the participants had to wait around 10-30 minutes. The majority of the participants had to wait for around 1-2 hours before the flight in Tribhuvan international Airport where as 34 percent of participants had to wait for the same time.

Comparatively, Flights on Istanbul Airport is more efficient and were more on time compared to the flights in Tribhuvan airport. Considering the facility that the Istanbul airport provides to the airlines, it was obvious that Istanbul Airport would provide the better service to the airlines. On the other hand, the weather of Istanbul airport is much more suitable compared to that of Tribhuvan airport.

6.5 SERVICES AT THE AIRPORT

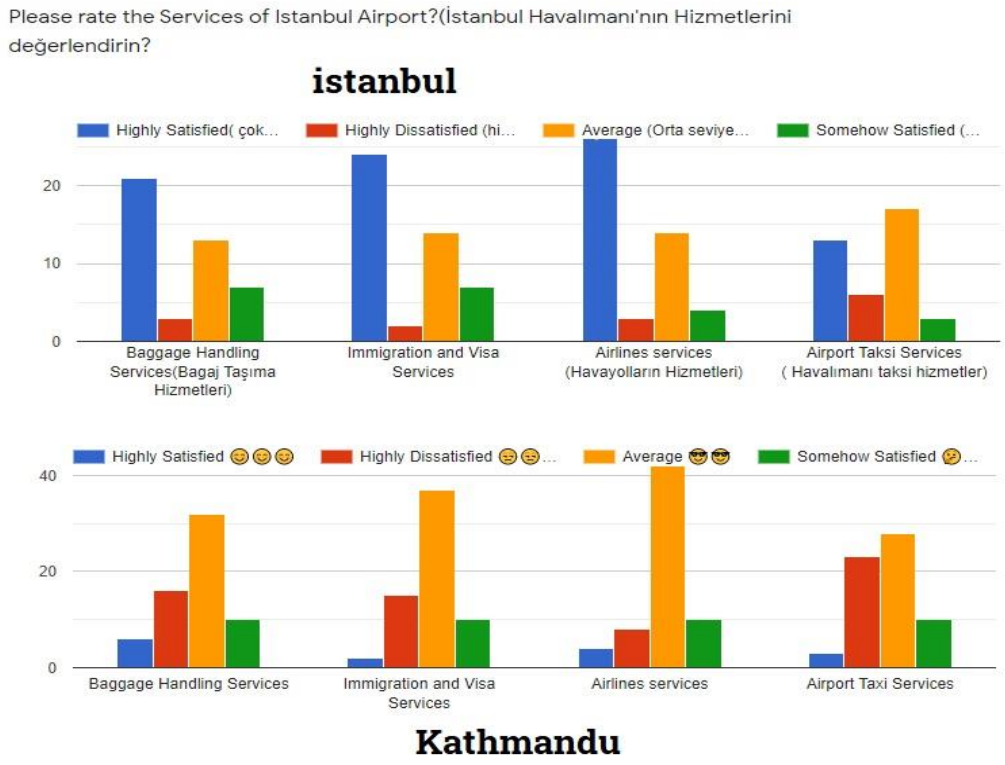


Figure 6.6 : Bar graph on services of in Tribhuvan Airport and Istanbul airport

The services provided on the airport were judged ın this question which clearly indicates that the participants are more satisfied on Istanbul Airport compared to the Tribhuvan airport. More than half of the participants were highly satisfied with the services on Istanbul airport where as more than half of participants find the services average on the Tribhuvan Airport. This was clear indication that Istanbul airport provided better facilities to their customers with modern facilities compared to the services in Kathmandu.

Tribhuvan Airport should particularly improve its services on every section especially on baggage handling, immigration and visa services and the airline services. On the other hand, the participants on Istanbul airport had found the airport taxi services to be average which the

airport needs to work on. The taxi services of Istanbul and the Istanbul airport should work together to solve this problem.

6.6 SERVICES AT THE TERMINAL

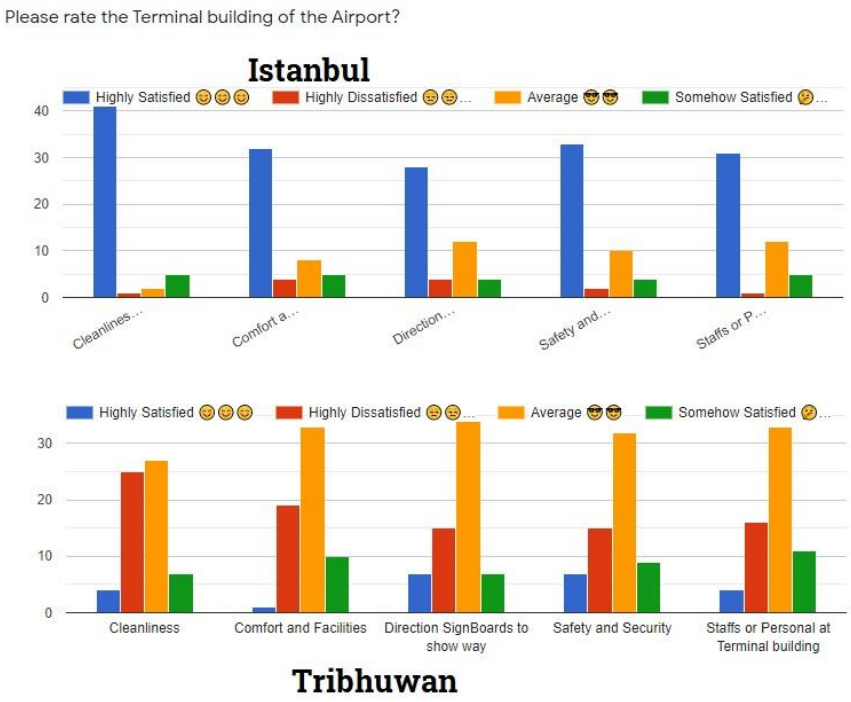


Figure 6.7 : Bar graph on Termianl building of in Tribhuvan Airport and Istanbul airport

Like the services, the facilities provide at the Istanbul airport were also highly satisfactory compared to the Tribhuvan airport, more than 90 percent of the participants were highly satisfied with the cleanliness, comfort and other facilities provided by the Istanbul airport. On the other hand, Tribhuvan airport has to develop in many sectors especially cleanliness .

Taking advantage of the lockdown, TIA management has improved the facilities of both domestic and international terminals to help maintain social distancing and hygiene at the

airport. construction of parking bay and construction of new departure boarding gates have been completed so far.

6.7 RATING

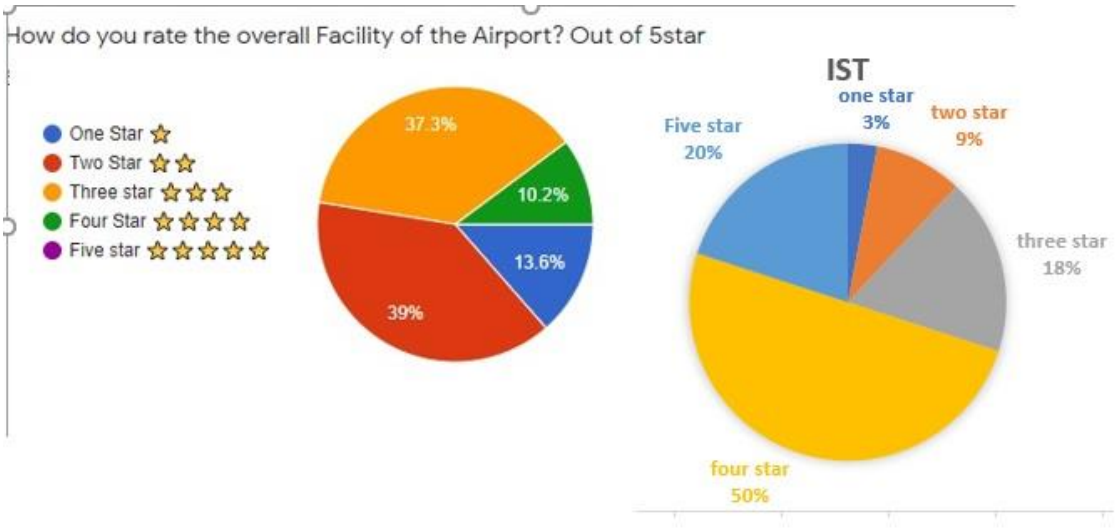


Figure 6.8 : Pie chart on overall Rating of in Tribhuvan Airport and Istanbul airpor

With all the facilities and services, 50 percent of the participants voted for four star for Istanbul airport whereas 39 percent of participants voted only two star for Tribhuvan airport. This is clear indication as Tribhuvan airport needs to invest a lot in providing better services to Its passengers. Around 38 percent of participants gave three star to Tribhuvan airport where as around 70 percent of participants have three and four star which is a very good rating for any airport.

6.8 MAJOR PROBLEMS FACED AT THE AIRPORT

Flight Delay as the Main Problem

The major problem at Tribhuvan International airport is the delay of flight. Only 1.7 % of the participants had their flight right on time which is a very low rate compared to the other airports of the world. Many participants around 38 percent waited 1-2 hour before their scheduled flights whereas around 28 percent of participant waited more than 2 hours and around 1 hours respectively. Weather, one-way approach, tourist season and technology are the major factors responsible for flight delay at Tribhuvan International Airport (TIA).

Baggage problems

Figure 6.9 : Improvement on TIA airport During lockdown

7.COVID 19 AND FUTURE OF AIRPORT

7.1 IMPACTS OF CORONAVIRUS AT AVIATION

The covid-19 pandemic has come at the great cost to world economies but the one of the biggest casualties is the aviation industry. Most international borders are closed, fleets of aero planes grounded, Millions of passengers sitting at home and billions lost in revenue. The Airline and airport industry is facing an unprecedented crisis. The center for aviation predicts that most of the airlines in the world will soon be bankrupt even if the countries ease their lockdown. In short, the Aviation industry is facing its darkest time in their aviation career. Some airlines are beginning to fly as countries begin to open the borders. South African airways has been run by administration. In Asia Cathay pacific received a 5-billion-dollar bailout from government after suffering huge first quarter of Emirates, Etihad and Qatar airlines announced of job loss and pay cut by 50%.

The latest estimates indicate that the possible COVID-19 impact on world scheduled passenger traffic would be overall reduction ranging from 42% to 52% of seats offered by airlines and overall reduction of 2,344 to 2,978 million passengers. Approx. USD 308 to 391 billion potential loss of gross operating revenues of airlines. [21]

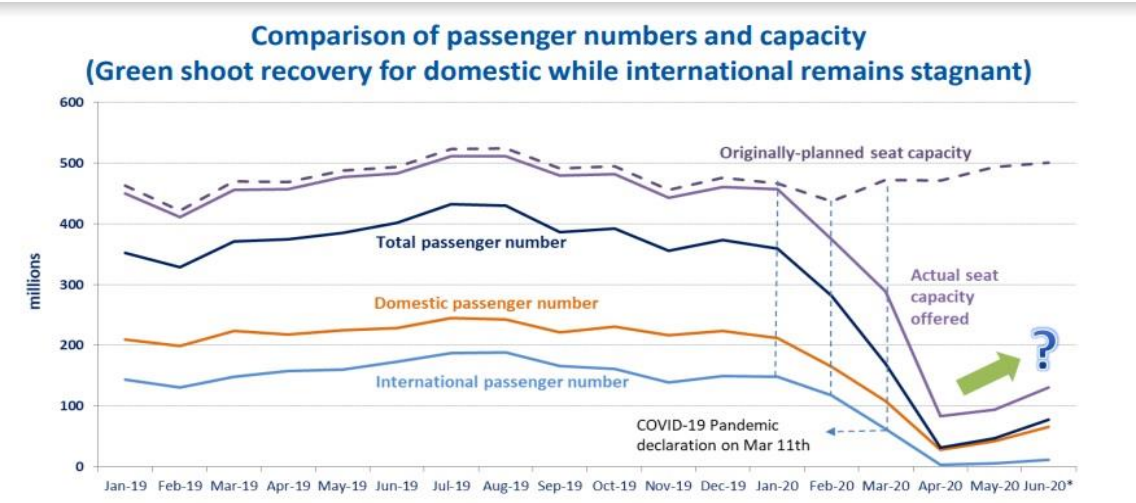


Figure 7.1 : Comparision of Passenger number and Passenger Capacity

International passenger traffic for 2020 shows that overall reduction ranging from 55% to 67% of seats offered by airlines and overall reduction of 1,194 to 1,457 million passengers. There is an Approx. USD 207 to 256 billion potential loss of gross operating revenues of airlines. Domestic passenger traffic for 2020 shows overall reduction ranging from 32% to 42% of seats offered by airlines and overall reduction of 1,150 to 1,524 million passengers . There is an Approx. USD 101 to 135 billion potential loss of gross operating revenues of airlines. [21]

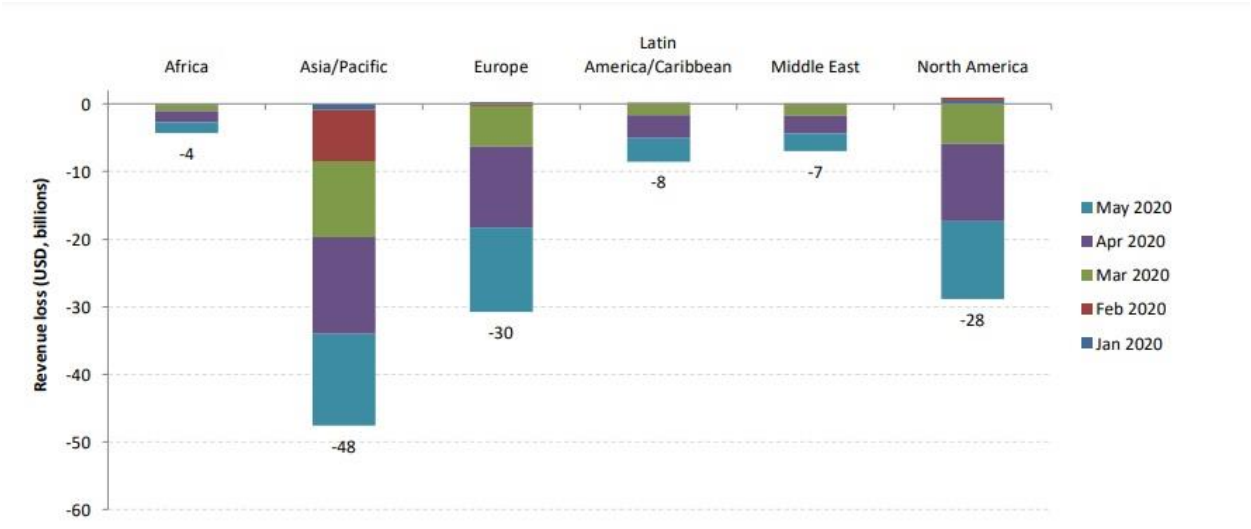


Figure 7.2 : Revenue Generated by Airlines in the year 2020

Approximately USD 126 billion passenger revenue loss from Jan to May 2020 where Asia/pacific and Europe are the major victims of the pandemic. The month of May is the seriously hit month for all the continents as the revenue lost is the highest, Also in the month of may , we have seen the closure of borders by many countries[21].

7.1 MEASURE TAKEN AT THE AIRPORT

Wearing mask has been a compulsory task in the terminal and on the board for the passengers. the passengers which doesn't not wear any mask are denied entry to the airport and the boarding sections to protect the public health. Only the airlines passengers are allowed to enter in the terminal while other members who do one have flight are not allowed to enter in the terminal building. Security checkup have specially been arranged so that they can pass through a thermal camera screening at the entrance of the terminal to measure their temperature. Anyone who has abnormal temperature are guided towards the health section area of the hospital. All baggage's passes through X-rays which is sanitized with UV (ultraviolet) light. Passengers using an e-passport can sanitize the contact surfaces of their passport using the UV (ultraviolet) e-passport system. Hand sanitizers are available in all areas open to passengers from the moment they enter the terminal building. The moving walkways in the terminal are cleaned regularly with a UV (ultraviolet) system. The terminal building is cleaned by UV (ultraviolet) autonomous robotic cleaners. vending machines with Personal protective equipment are available inside the terminal. Different Informative billboards, sign and stickers have been placed at various points inside the terminal to make passengers aware of keeping social distance. [22]

7.3 MEASURES TAKEN DURING BOARDING AND DEBOARDING

Private health insurance should be taken by the passengers before their flight which will cover any health risks during traveling. The floors of passenger buses operated by ground handling services are marked with social distancing tape for safe passenger transport from the aircraft to the terminal and vice versa. Passengers can maintain social distance from other passengers and ensure safe access to their airplane by paying attention to this tape. Passenger buses operated by ground handling services are disinfected after every use. If the foreign passengers while coming to Istanbul are tested positive , they are immediately taken to hospital by the turkeish health officials from the airport. [22]

8. AIRCRAFT MAINTENANCE

8.1 INTRODUCTION

"Maintenance is the action necessary to sustain or restore the integrity and performance of the airplane" [Hessburg, 2001]. Maintenance is one of the important parts of the Airplane to have safe and reliable flight. Maintenance programs are evolved and developed for each new type of aircraft based on previous experience with similar materials, engines, components, or structures

The objectives of an effective maintenance program are as follows (Edwards, 1994):

- Ensure, through maintenance activity, that the inherent safety and reliability imparted to an aircraft by its design are sustained.
- Provide opportunities to restore levels of safety and reliability when deterioration occurs.
- Obtain information for design modification when inherent reliability is not adequate.
- Accomplish the above at the lowest possible cost.

Aircraft maintenance is actions that can restore an item to a serviceable condition, and consist of servicing, repair, modification, overhaul, inspection and determination of condition. The common goal of maintenance is to provide a fully serviceable aircraft when it is required by an airline at minimum cost. High reliability is the most essential point in maintenance which cannot be compared with high cost. Although cost is the important parameter, we cannot take risk in aircraft maintenance because it is very delicate matter. If the system in aircraft is not maintained properly, It will sooner or later create problems in doing its functions with loss of safety and availability, also moreover it will lead to several loss like economical, structural and the most important loss of human lives. Aircraft maintenance activities form an essential part of airworthiness. Direct maintenance cost refers the labor and material costs directly associated in performing maintenance.

8.2 EASA(European Aviation Safety Agency)

The European Aviation Safety Agency is the centerpiece of the European Union's strategy for aviation safety. Its mission is to promote the highest common standards of safety and environmental protection in civil aviation. The Agency develops common safety and environmental rules at the European level. It monitors the implementation of standards through inspections in the Member States and provides the necessary technical expertise, training and research. The Agency works hand in hand with the national authorities which continue to carry out many operational tasks, such as certification of individual aircraft or licensing of pilots.

The main tasks of the Agency currently include:

- Rulemaking: drafting aviation safety legislation and providing technical advice to the European Commission and to the Member States;
- Inspections, training and standardization programmed to ensure uniform implementation of European aviation safety legislation in all Member States;
- Safety and environmental type-certification of aircraft, engines and parts;
- Approval of aircraft design organizations world-wide as and of production and maintenance organizations outside the EU;
- Authorization of third-country (non EU) operators;
- Coordination of the European Community programmed SAFA (Safety Assessment of Foreign Aircraft) regarding the safety of foreign aircraft using Community airports;
- Data collection, analysis and research to improve aviation safety. [24]

8.3 ICAO

The International Civil Aviation Organization (ICAO) is a UN specialized agency, established by States in 1944 to manage the administration and governance of the Convention on International Civil Aviation (Chicago Convention). [25] ICAO's primary role is to provide a set of standards which will help regulate aviation across the world. It classifies the principles and techniques of international air navigation, as well as the planning and development of international air transport to ensure safety and security. [25]

ICAO works with the Convention's 193 Member States and industry groups to reach consensus on international civil aviation Standards and Recommended Practices (SARPs) and policies in support of a safe, efficient, secure, economically sustainable and environmentally responsible civil aviation sector. [25]

ICAO also helps in coordinating assisting and in support of numerous aviation development objectives; produces global plans to coordinate multilateral strategic progress for safety and air navigation; monitors and reports on numerous air transport sector performance metrics; and audits States' civil aviation oversight capabilities in the areas of safety and security.
It is possible for each member states/countries to modify and adjust these regulations when necessary under ICAO's approval. [25]

8.4 FAA

The FAA which stands for Federal Aviation Administration is the federal agency in the Department of Transportation in United states. Moving the Air transport safely and efficiently is main task of FAA in which the Air traffic organization is the service provision branch for it. Every details of aviation is in the thousands of pages or section in the federal aviation regulation to make out flight safe and comfortable. Instruction on many services like aircraft maintenance, pilot requirement, rules and regulation in the aircraft and everything related to aviation are given by the FAA so that every set of task meets its requirement and aircraft can fly safely in the sky. The aircraft pilot and maintenance staffs need to know the rule of FAA to comply with the process.

Aside from its regulatory role, the FAA is also responsible for research and development of aviation related systems and technologies, air traffic control system, maintenance of air navigation facilities infrastructure, airspace and development of commercial space travel.[26]

Mission:

"The FAA/ATO mission is to provide a safe, efficient, responsive air transportation system that serves the Nation and supports the global aviation community."[26]

8.5 ATA chapters

ATA chapters (sometimes called "ATA 100 System Codes") are a way of categorizing the various systems that are on a plane, originally created by the Air Transport Association in 1956. İt looks at any Component Maintenance Manual (CMM) for any civilian aircraft. For example, Chapter 29 is "Hydraulic Power", and it includes units that are part of the Hydraulic Power system. Chapter **26 Fire Protection** (smoke detectors, fire detectors, fire detector In the Engineering department, Different Engineers are assigned to different ATA chapters so that they can efficiently follow up the Maintenance program.

8.6 SAFETY MANAGEMENT SYSTEM

Safety Management system (SMS) ensures that the risk of the Aircraft maintenance failure remains at the minimum level. It accounts all the maintenance record of an airplane. ULS airlines has 3 planes named TC-SGM,TC-VEL and TC-LER. SMS is formed in every 1 month where the Engineers and Technicians have to maintain the ratio below the indicated risk ratio. IN SMS, it is recorded that how many times the airplane has been put in hold, How many times the airplane has returned after takeoff due to some Internal problems, How many times the documents are not signed or assigned the reference number etc. It tracks all the data and form a ratio level in which the engineers ensure that the ratio doesn’t cross the risk level.

An Airplane can be put into hold if it doesn’t have some Emergency fault like Engine failure, Landing gear fault etc. Hold has 4 category A,B,C and D.

Category A : should be maintained before the designed cycle or hour or can also take the amount of category C

Category B: should be maintained within 3 days.

Category C: should be maintained within 10 days

Category D: should be maintained within 120 days

Engineer can also increase the hold duration if it is approved by the Aircraft safety Engineer. Minimum Equipment list (MEL) contains all the data which classify which category does the fault belongs to. All the failure in particular department named after the ATA 100 chapter are classified according their respected category.SMS also holds the record the number of faults occurred in the particular chapters.

8.7 Airworthiness Directives

Airworthiness Directives (ADs) are changes of rules issued by the FAA or EASA in order to correct an unsafe condition in a product or to give a direction to use the product in an effective way. In short, it is a document that notifies the owners or operators of a particular model of aircraft that is unsafe or potentially unsafe conditions that have been discovered which may affect the airworthiness. The ADs contain mandatory instructions to carry out work on aircraft, engine, propeller or component in order to address an unsafe condition which exists, or is likely to exist, or could develop. National Aviation Authority (NAA) has the responsibility for the set of rules when the aircraft or components are designed and the set of rules are assigned by them.[24]

The NAA of any country need to comply and work with the AD which may be issued by another NAA as the Aircraft or the component used in the aircraft are all set up under the rule. The FAA send ADs to all the aircraft owners and the company operation it. This Ads send to the company contains all the requirement, reasons, subjects, ways to use and so on to make the company understand the process and make the company use it properly so make the aircraft safe. IF there are some suitable ADs for the any airlines, the engineers prepare the Engineering Orders (EOs). EOs are the document that contains the summary, revision reasons, Necessary notes for engineers, references, time, material used and tools and equipment used. It is a order by the

engineers to the technician to apply certain precautions and changes on the product. For example, during full scale fatigue test, cracks were discovered. The EOs required the inspection, by rotating probes, of fastener holes, which are more sensitive to cracks in order to restore the full fatigue life of the area.

8.8 SERVICE BULLETIN (SB) are notices to aircraft operators from a manufacturer notifying them of a product improvement. Usually SBs comes before ADs. service bulletins are issued by the manufacturer (Boeing or Airbus) when a condition exists that the manufacturer feels is a safety related item. These SB usually result in the FAA issuing an AD. The AD will reference the service bulletin as a method of compliance with the airworthiness directive.

9. MAINTENANCE COST

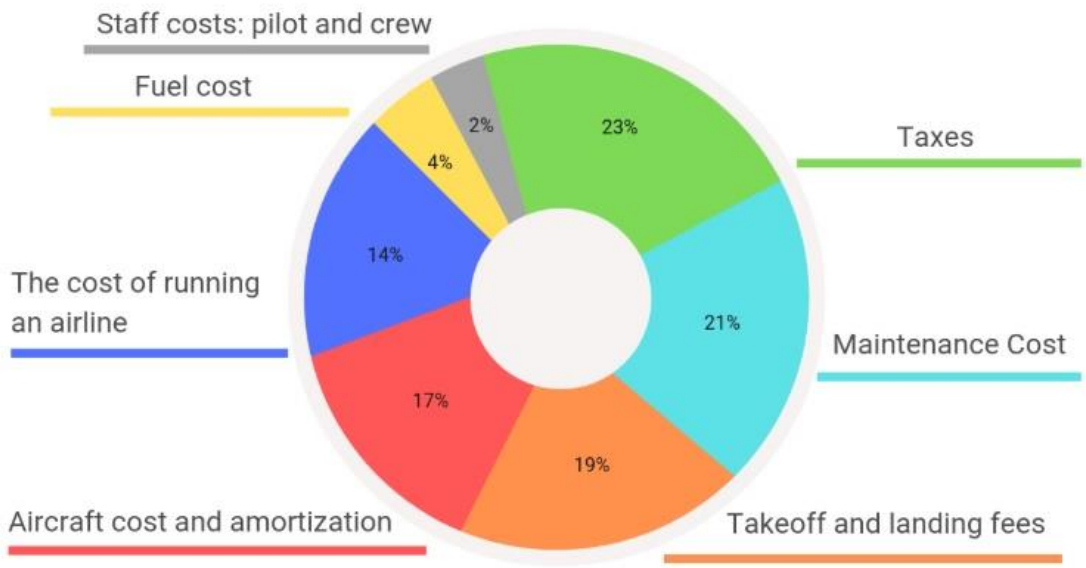


Figure 9 : Cost pie chart of on where the money goes for an Airline ticket

The above figure taken from the Wendover production shows the distribution of the cost of the airlines. It shows on which section; the money of the airline goes. Maintenance costs typically account for 10-20 per cent of aircraft related operating costs in which direct maintenance cost is a significant contribution to operation of an aircraft. Minimizing the cost and maximizing the efficiency of the aircraft are the main goals of every airline's aircraft maintenance team. Direct maintenance cost (DMC) is one of the major constituents of maintenance cost which refers labor and material costs directly expended in performing maintenance of an aircraft or related equipment. The cost of maintenance will vary according to the class of the aircraft. For example, the cost of the maintenance is different on jet engines aircraft, Turboprops, Pistons or helicopters. Also, the Maintenance cost will vary according to the type of the aircraft. For example, Light aircraft, medium range or long range etc. All the surveys, record and industry data show that the range varies from 10 -45 percent of the total yearly operating expenses. Also10 percent seems to be low amount, It gets very significant when even 10 percent results in millions of dollars of expense result in significant amount. [27]

10.MAINTENANCE,REPAIR AND OVERHAUL (MRO)

Commercial aircraft maintenance, repair and overhaul (MRO) is an important necessity to make sure that aircraft are maintained in notified conditions of airworthiness to safely transport cargo and air passengers. With the rising air traffic, Air carriers are more focused towards maintaining the health of their current Air fleet, and they may think of buying the new aircraft as their last option, as the cost of buying a new aircraft is considerably higher compared to the cost for the maintenance of the current fleet.

Differentiating airports have introduced improvement processes to enhance efficiency, and many of them have employed new technological systems to gain additional upgrades and prepare for the bigger data requirements of next-generation aircraft, which may lead to the growth of the market in the near future.

Many government plans or initiatives have given a new dimension to MRO services and have come out in recently to motivate airports to support MRO as a strategic activity. Various

approaches are now being undertaken by the governments to ensure that there is spacious place at various airports within the country for MRO, which may lead to an enhancement in terms of commercial aircraft MRO activities.

More recently, the aviation industry has indicated signs of recovery with considerable growing demand forecast over the next decade in regions such as the Asia-Pacific and Middle East.

10.1 Aircraft Maintenance Process

It is important to know the different between aircraft maintenance process and other general plant and machinery maintenance process. The main difference we can notice is that aircraft maintenance is mandated or guided by the respected authorizes such as FAA , EASA etc. and the whole process of aircraft maintenance process is highly standardized and critical in Maintenance system group (MSG-3) and other directives.

A Maintenance Program is a document which describes the specific maintenance tasks and their frequency of completion, necessary for the continued safe operation of those aircraft to which it applies. (ICAO). A Maintenance Program establishes compliance with instructions for continuing airworthiness issued by type certificate, supplementary type certificate holders and organizations that publish data in accordance with Part 21, instructions issued by the competent authority, instructions defined by the owner or the operator.[28]

10.2 Maintenance Programs Requirement

EASA Part M M.A.302 requires all applicable aircraft to be maintained in accordance with an approved Maintenance Program. The maintenance Program and any subsequent amendments shall be approved by the competent authority. [28]

Maintenance Programs is important because

I.) To ensure realization of the inherent safety and reliability levels of the aircraft

2.) To restore safety and reliability to their inherent levels when deterioration has occurred

3.) To obtain the information necessary for design improvement of those items whose inherent reliability proves inadequate

4.)To accomplish these goals at a minimum total cost, including maintenance costs and the costs of resultant failures [28]

Maintenance Review Board (MRB)

It is a regulatory body and chartered organization of regulatory authorities that recognizes the ATA MSG 3 process as an acceptable standard. An engineer working at any company cannot execute a task on an aircraft without defining and getting the task approved beforehand, just as it is a measure of the completeness of the task description in the MSG-3 procedure that a Licensed Aircraft Engineer cannot turn the screwdriver three times if the Task Card says twice. [28]

The scheduled maintenance development process, comprises representatives of the operators, the manufacturers of the airframe and engine, and the regulating authorities. Management of the development activities is accomplished by an Industry Steering Committee (ISC). Maintenance Working Groups (MWG) will be established depending on the complexity of the aircraft, I.e. systems, powerplant, zonal and structures. The developed maintenance activities will be submitted for approval, to the Maintenance Review Board (MRB). [28]

10.3 Zonal Program .

Zonal inspections are the general visual inspections. They are intended to detect deterioration of the original installations within the defined zones for example cracks, leakage of fluid, corrosion ,duct damage, security, heat and condition of wiring.

11. MRO MARKET

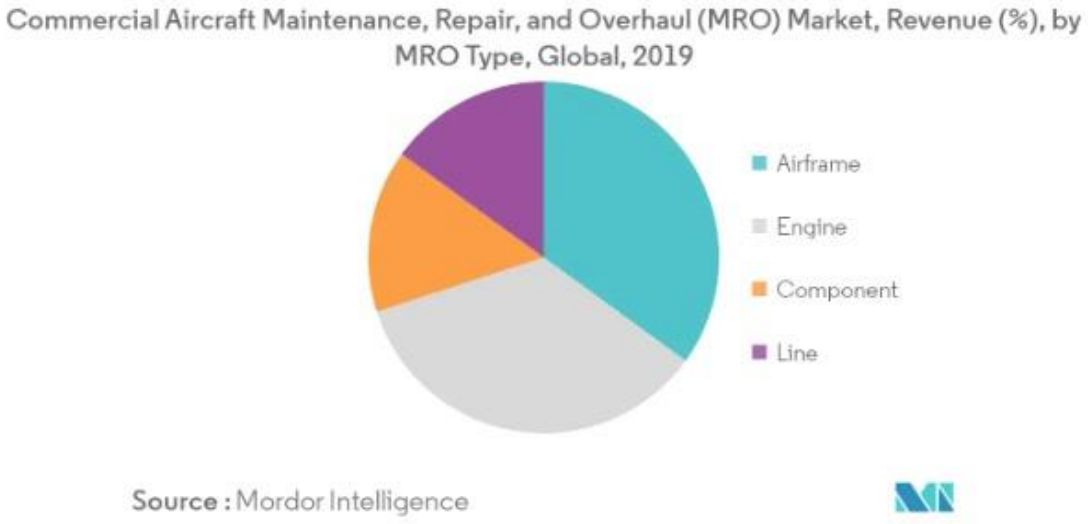


Figure 11 : Revenue earned by MRO from Differet Component

The Engine MRO segment has the highest amount of share among all the MRO segment at the current period and continues to grow in the future period. The number of air passenger travelling in the air is growing at a steady pace, which is motivating the airlines to increase their air flight and create new aircraft to balance the increased demand for air travel and enhance their current market shares. The engines were the highest accidental damages among all the major aircraft components. Aircraft engines were most frequently reported as being damaged by bird strikes, between 1990 and 2017, and were responsible for 28% of all the damaged components according to the FAA. Such sudden and unavoidable accidents have led to the overhauling of the engine in many instances. Since engines are the most vital part of an aircraft, regular engine maintenance checks and periodical repairs are required to

ensure the airworthiness of the aircraft which generates revenues for the engine MRO providers. [29]

12. CASE STUDY OF INDIA AS THE MAJOR HUB FOR MRO

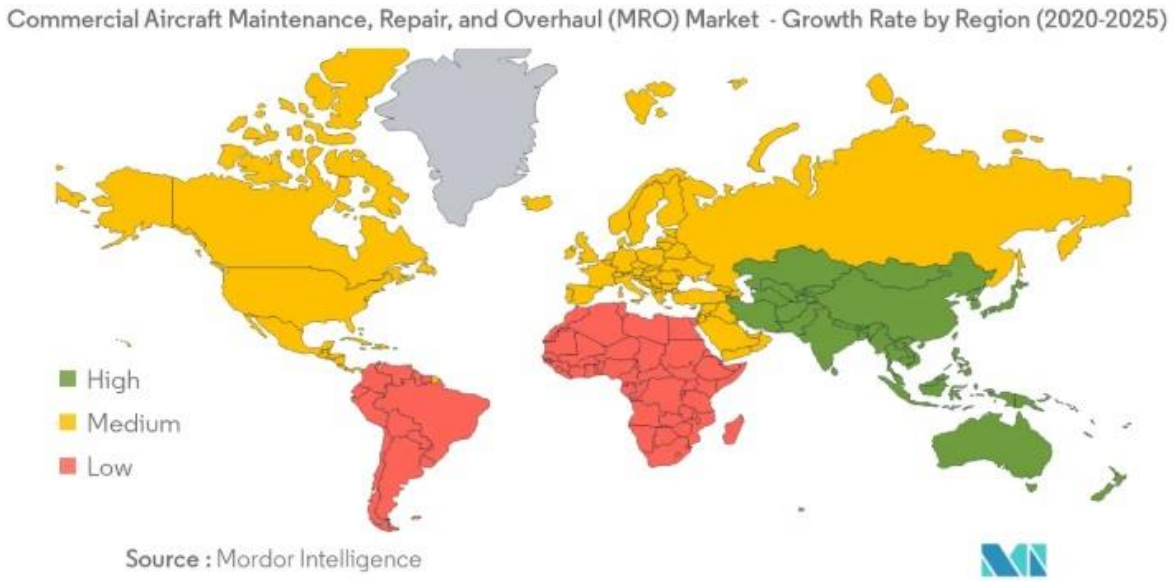


Figure 12.1 : MRO market growth rate in the world

In the current period, Asia-Pacific region are highest generators of revenue in the commercial aircraft MRO market. Singapore and Hong Kong are the main players of MRO market in Asia. Several country in Asia including India, Bangladesh, Pakistan, Indonesia Malaysia, Thailand etc. have increased their investment in MRO facilities, trying to duplicate success story of Asian giants Singapore and Hong Kong . The increase in the low-cost carriers have managed to change the face of civil aviation in Asia pacific region. In accordance with the rise, the market dynamics of aircraft maintenance are also evolving, the dominance of the Singapore in the region is being challenged by the countries like Thailand and Indonesia by the entering in the

market and competing accordingly. The region is the high population in the Asia pacific region and also the cheap labor which is the driving factor of the bloom of MRO industry in this region. [29]

International Air Transport Association (**IATA**) suggested that India is poised to be the 3rd largest aviation market by the year 2024. Rapid growth in the aviation sector is bringing the demand for the MRO services. Around$ 800 million accounts for the current Indian MRO market and is growing at about 8% annually where the world average rate of growth is only 4 %.

Government policies and decisions are anticipated to play a vital role in assisting the growth of the market in this region. For instance, the Government of India is undertaking various initiatives aimed at making the country an MRO hub. Announcing measures to boost the country's domestic aviation sector, Finance Minister Nirmala Sitharaman said steps will be taken to make the country a hub for Maintenance, Repair and Overhaul (MRO) of aircraft. "Not just civil aircraft but defense aircraft can also benefit from the MRO if we make India a huge hub ... Maintenance cost for all airlines will come down and that again will have a ripple effect on passengers. Travelers can probably pay less after that," She also said, "Major engine manufacturers in the world would set up engine repair facilities in India in the coming year," adding that convergence between defense sector and the civil MROs would also be established to create economies of scale. [30]

Recognizing the potential of the MRO business and in line with the 'Make in India' policy, the government of India has introduced certain policy initiatives recently to provide benefits to this business segment. These include

(i) exemption from customs duty for the tools and tool-kits used by the industry;

(ii) (extension of the one-year timeline for utilization of duty-free parts to three years so as to enable economies of scale

(iii) permission for foreign aircraft brought to India for MRO work to stay for the entire period of maintenance or up to 6 months. Earlier, foreign aircraft could not come into India for more than 15 days without a cumbersome approval process. Further, aircrafts

are now allowed to come in with passengers, which were not permitted earlier, leading to losses for the airlines. It is also pertinent to point out that 100% foreign direct investment is allowed under the automatic route in the MRO sector to encourage international participation in this area. [31]

Moreover, due to the huge potential of the Asia-Pacific aviation market, several global players are establishing new centers in the region to cater to the growing demand. All these factors are anticipated to drive the business prospects for commercial aircraft MRO in Asia-Pacific, during the forecast period. [31]

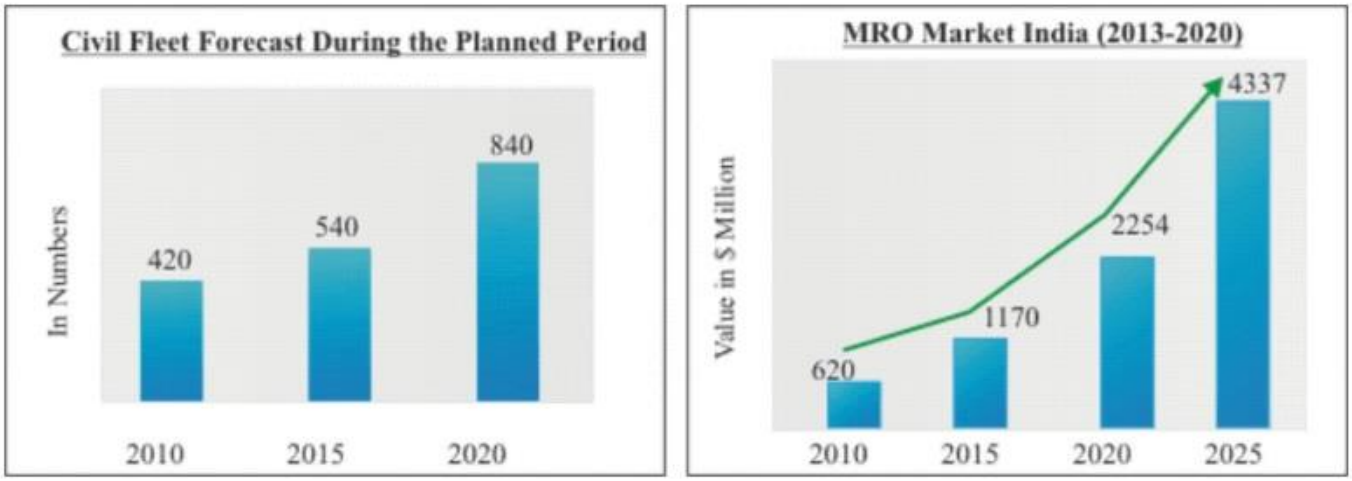


Figure 12.2 : MRO market Number and value in India

The location of India also plays a vital role as it lies between west Asia and east Asia which can used as a transit point.

Table 3 : Domestic and International MRO provider in India

MAJOR MRO PROVIDERS IN INDIA	EMERGING MRO SERVICE PROVIDERS IN INDIA
Taneja Aerospace & Aviation Ltd (TAAL), Pune Max Aerospace & Aviation Ltd, Bangalore Air Works India Engineering Pvt Ltd, Gurgaon, Haryana Air India Limited Hyderabad Aircraft Maintenance Company (HAMCO) Indamer Company Pvt Ltd, Mumbai Arrow Aviation Services Private Limited Cochin International Aviation Services (CIASL), Kochi Eaton Aerospace, Pune Jet Airways Blue Dart Aviation Limited Deccan Aviation Eaton Aerospace	Lufthansa-Technical of Germany with GMR group Boeing and Air India Thales International Taneja Aerospace & Aviation Ltd TAAL Sabena technics of TAT Group, France Airbus SIA engineering of Singapore with Wadia group HAL and Pratt and Whitney Canada (P&WC) Pipavav Defence and Offshore Engineering Co. Ltd

In the absence of well-developed maintenance infrastructure in India, there are currently over 40+ overseas MRO providers. With the increase in the number of civil and military aircrafts, more and more global MRO companies are planning to offer engineering services by forming joint ventures with Indian firms. [32] For instance, GMR Hyderabad International Airport (GHIAL), and MAS Aerospace Engineering (MAE), a wholly-owned subsidiary of Malaysia Airlines, have set up a 50:50 joint venture airframe MRO company in Hyderabad. The company would make an initial investment of US$ 50 million. [32]

13. ROLE OF NEW TECHNOLOGY AT MRO

Many new innovative technologies and techniques have been introduced in the MRO section which has made the work easier for the maintenance technician and engineers. Many different technologies like Robot mechanics, Drones, Machine learning algorithms, Artificial intelligence, 3D printing etc have been a game changer in the industry.[33]

13.1 Smart Maintenance

Artificial intelligence has helped the engineers to design and develop aircraft components in such a manner that it is lighter as well as efficient. We all know that the lighter any component is, the more cost saving it will bring us. Also, the help of the New technology has given opportunity to multiple design options to Engineers and also helped them to finish the task in the lesser time compared in the past. Companies like Airbus are already using and implementing smart AI based maintenance solutions for their aircraft, based on data from different types of sensors. This approach helps develop new products with more functionality, making aircraft more sustainable and lighter in weight. Smart sensors are being used by the maintenance staff and the inside data from sensors gives an insight into problems which can be easily detected. This data will also help predict issues which could otherwise be more prominent. It will also result in in fewer maintenance delays and overall improved flight safety.[33]

14 COST OF MAINTENANCE

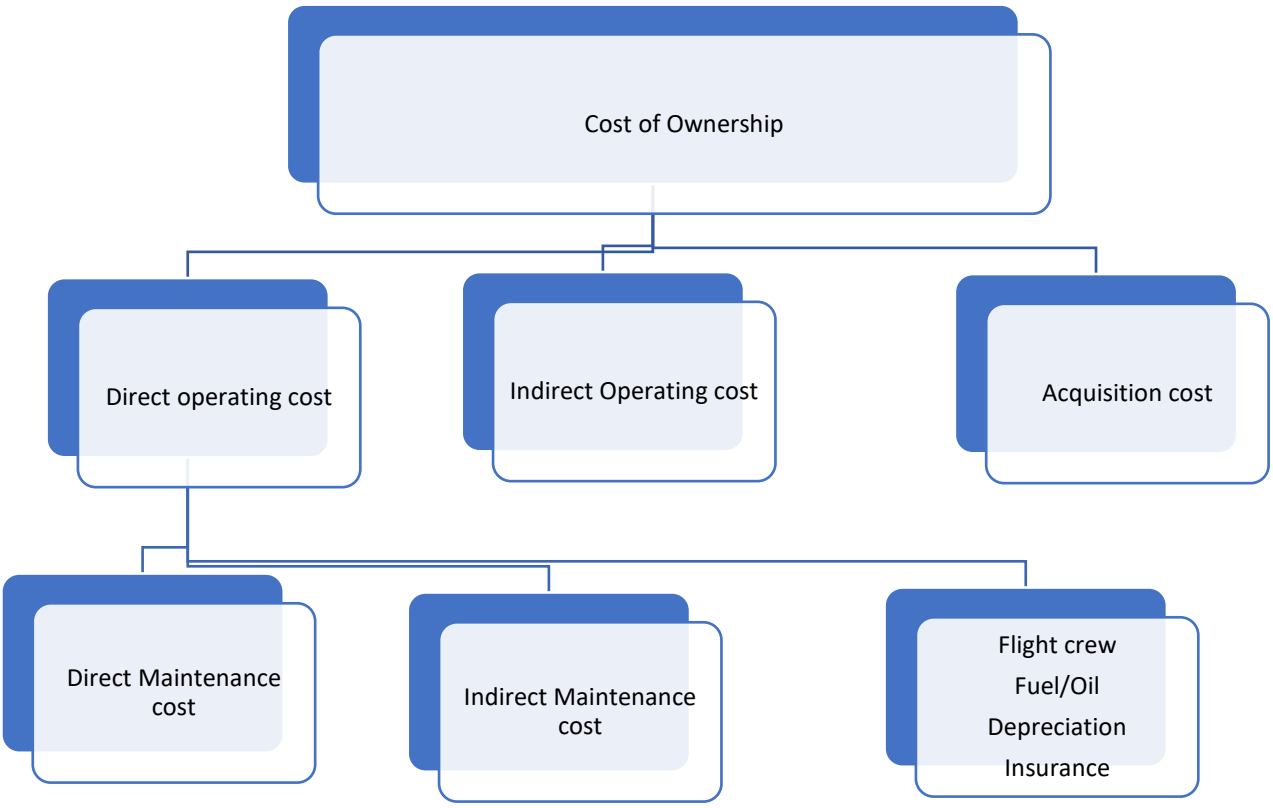


Figure 14.1 : Cost of Ownership chart

Direct Maintenance Costs: Labor and material costs expended in performing maintenance on a component or airplane Example: Scheduled Checks ,Modifications ,Component Overhaul [34]

1. all routine (scheduled) and non-routine (unscheduled) maintenance work on and off the airplane;
2. other labor directly involved in maintaining the airplane.

3. the costs of painting, cleaning, and refurbishing aircraft. The direct maintenance cost is affected by the airplane type, its range, and the air carrier's flights schedule.

Indirect Maintenance Costs: Costs not considered to be direct costs but contribute to the overall maintenance costs Example: l Training ,Reliability ,Accounting Practices , Documentation[34]

1.) the salaries of administration/supervisory staff, engineers/technical staff, and support staff.
2.) the non-productive (on-the-job) time of employees who are directly involved in performing maintenance on the aircraft;
3.) Social Benefits of staff (vacation, sick leave, and employee benefits of all maintenance staff.)

Utilities, communications, rentals, shop supplies, and so forth.

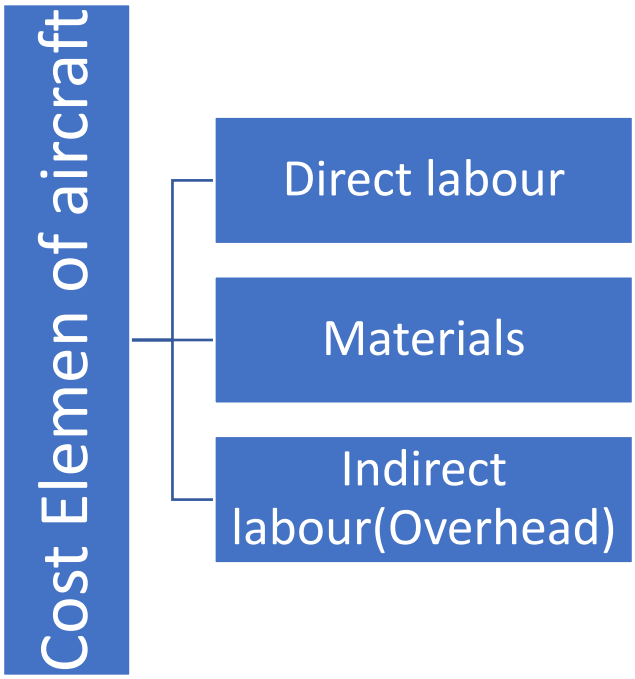


Figure 14.2 : Cost element of Aircraft

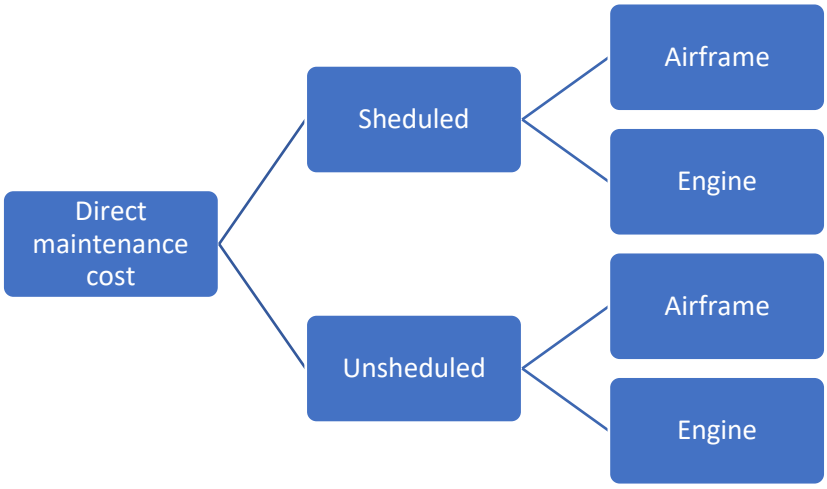


Figure 14.3 : Chart of Direct Maintenance cost

15.REDUCTION OF MAINTENANCE COST

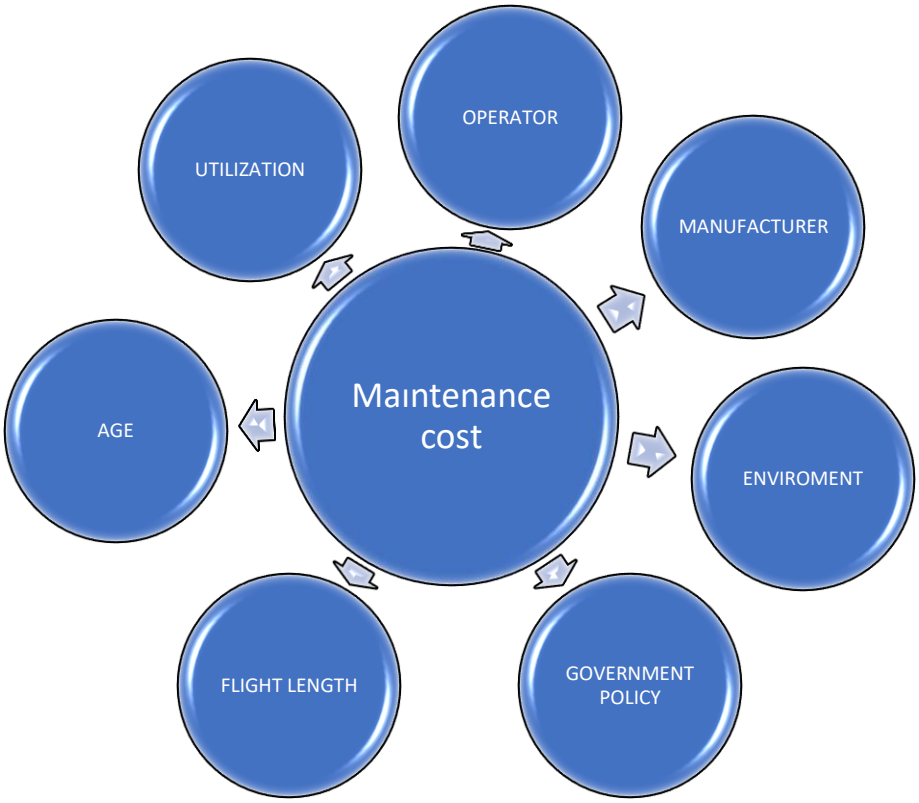


Figure 15.1 : Factors effecting Maintenance Cost

Reducing the maintenance cost is not a one-man task or one section task. It has joint responsibility of the airplane operator, manufacturer, suppliers and many other factors.

It's the responsibility of the manufacturers and suppliers like Boeing and Airbus to provide a reliable and Maintainable airplane. On the other hand, the airplane operators are responsible for providing a maintenance program that has all the reliable operational, technical and commercial requirement to maintain the aircraft. The methods and program used by the airline

company should also provide a proper methods and practice to implement the required task. To ensure that airplane maintenance costs remain at a manageable level, airlines and airplane operators are being forced to critically reassess maintenance practices, policies, management decisions, future investment needs, existing maintenance facilities, and so forth. [34]

Among the numerous variables , flight length and average age of fleet are probably the most significant cost drivers. To reduce airplane maintenance costs, operators must control and reduce the influence of these variables. Additionally, operators can reduce costs by

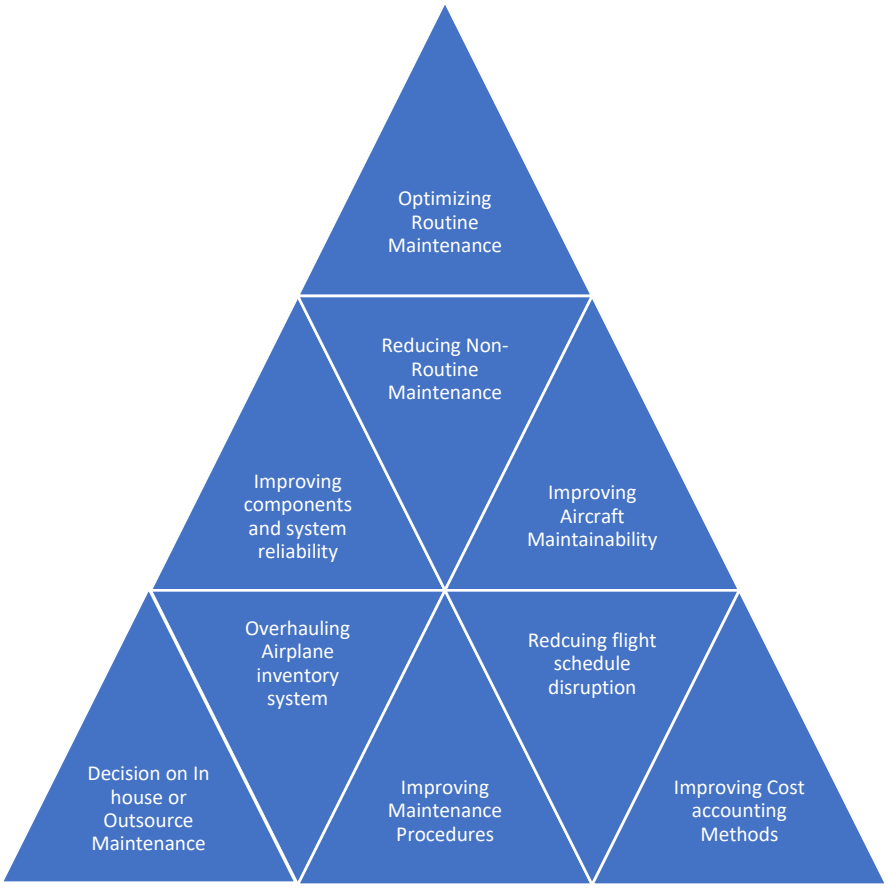


Figure 15.2 : Pyramid on ways to reduce Maintenance cost

1. **Optimize Routine Maintenance**

Competent technicians and engineers are assigned for the routine maintenance check which includes brief inspection to make sure that the aircraft airworthiness. This can also helps to crease the future damage cost as we all know, the faster we know the problem, the faster we can solve it and it will be cheaper. Optimizing routine maintenance can help to prevent aircraft downtimes .This allows technicians to replace components before any breakdown can happen.[35]

2. Reduce Non-Routine Maintenance

Non-routine maintenance is any maintenance work that is not performed at pre-determined intervals. It is actually not a part of the aircraft owner's maintenance program. As such, it is highly possible that the maintenance team might have missed the fault. Occurrences like this must be avoided in order to prevent aircraft downtime. [35]

3. **Improving components and system reliability**

The aerospace industry is a highly regulated one. All aircraft operators are required to comply with government and industry standards to avoid getting grounded. But it is not enough to be just compliant to government standards. As an operator, your company must establish high standards especially with aerospace parts distribution to ensure airworthiness and avoid non/routine maintenance stops. [35]

Outsource a better advantage than in source

Outsourcing helps in reducing airlines from labor costs associated with maintenance, which amounts in huge sum of money as the labor cost in Asian pacific region is cheaper compare of Europe or North America. When maintenance is carried out in-house, airlines may have n limited locations for workshops and hangars. However, when they outsource their aircraft, they may

have access to more facilities in different parts of the world, from various maintenance organizations. Not only does this save time and boost efficiency, it could also lead to fuel cost savings. Third-party maintenance can remove an airline's burden of training costs, and the purchase of specialist equipment. This is especially useful for smaller, and low-cost airlines. Fixed costs, such as costs to set up hangars for in-house maintenance, and other variable costs are no longer necessary if maintenance is performed by a third party. This can bring about immense cost savings for airlines. [36]

Disruption

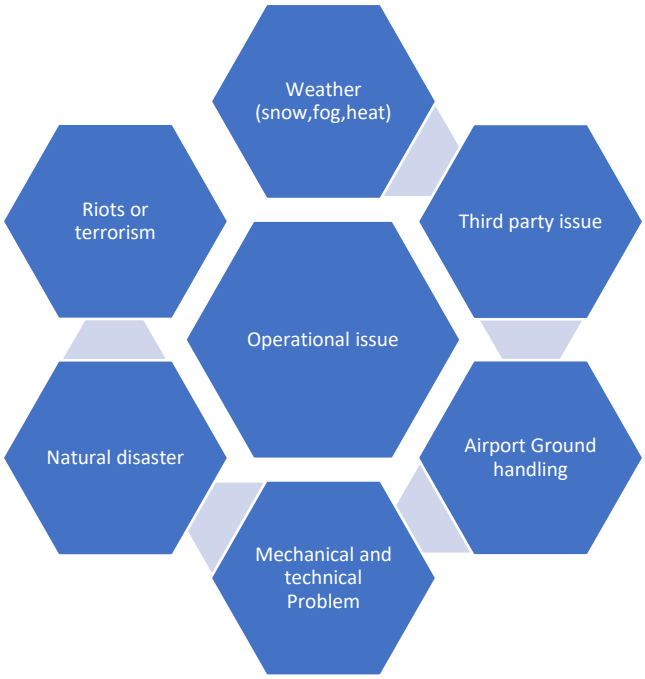


Figure 15.3 : Disruption factors for Aircraft

Different disruption are the cause of the delay of the flight which cost a huge amount of money to the airlines. Usually, the maintenance department have delays on the flight due to the

technical problems but there are also other factors in which disruption takes place. IT Companies are Developing solution prototypes for disruption for Airlines and making them easier to process the data and improving the productivity of airline flight controllers and field managers.

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