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Project Report on

OPTIMIZATION OF AIRPORT COLLABORATIVE DECISION MAKING (A-CDM) FOR KEMPEGOWDA INTERNATIONAL AIRPORT-BENGALURU

Submitted for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

AEROSPACE ENGINEERING

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CERTIFICATE

THIS IS TO CERTIFY THAT THE PROJECT WORK TITLED **OPTIMIZATION OF AIRPORT COLLABARATIVE DECISION MAKING FOR KEMPEGOWDA INTERNATIONAL AIRPORT-BENGALURU** IS CARRIED OUT BY **SHASHANK R RAO (17BTRAE033), SHREYAS B UDUPA (17BTRAE035), SHASHANK A (17BTRAE070), Y SACHIN (17BTRAE113), HITHESH M (17BTRAE126)** BONAFIDE STUDENTS OF BACHELOR OF TECHNOLOGY, AT THE INTERNATIONAL INSTITUTE FOR AEROSPACE ENGINEERING AND MANAGEMENT, JAIN (DEEMED-TO-BE UNIVERSITY), IN FULFILLMENT FOR THE AWARD OF **BACHELOR OF TECHNOLOGY** IN **AEROSPACE ENGINEERING**, DURING THE YEAR **2020- 2021.**

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DECLARATION

We**,** the undersigned students of fourth year B.Tech in Aerospace Engineering, at the International Institute for Aerospace Engineering and Management, Jain (Deemed-to-be) University, hereby declare that the dissertation titled **Optimization Of Airport Collaborative Decision Making for Kempegowda International Airport-Bengaluru**, has been carried out by us and submitted for the award of **Bachelor of Technology in Aerospace Engineering**, during the academic year **2020- 2021**. Further, the matter embodied in the project report has not been submitted previously by anybody for the award of any degree or diploma to any University, to the best of our knowledge and faith.

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ABSTRACT

Airports Collaborative Decision Making (A-CDM), a concept to improve operational efficiency and performance by making the best use of available airspace and airport infrastructure by real time information sharing and Collaborative Decision Making. The airports are getting busier by the passing of time and it is necessary for airports to operate at its maximum potential, in most situations in Air Traffic Management today, "first come, first served" applies, this makes the flow of traffic less optimum. This leads to queuing near the runway and hence long waiting time and in turn great quantities of fuel consumed by aircrafts. A-CDM helps meet these demands. A-CDM by making the best use of operational systems and available data of flights departure and arrivals at respective airports and establishes a collaborative environment amongst different airport & aircraft operators by quick information sharing between these operators. Doing this gives immediate benefits and increase predictability of inbound and outbound traffic. And also offers solution to ease traffic flow, avoid delays and increase all-round efficiency. It also benefits in optimizing the resource utilization, enhancing predictability, better terminal activity management, efficient and orderly flow of departures by reducing aircraft holding delays in the runway, consequently saving fuels by reducing delay at holding points and reducing carbon emission. A-CDM has been fully implemented at 29 European Airports, implemented partially in the Indian Airports. Data has been collected from various sources, which is then optimized using machine learning techniques and a web interface is developed where the flight's crucial information is displayed to the Air Traffic Controller.

ABBREVATIONS AND ACRONYMS

Acronyms	Definition	Explanation
ACDM	Airport Collaborative Decision Making	It is a system that designed by the EUROCONTROL and adopted by European Civil Aviation Conference (ECAC) Transport Ministers in the European Air Traffic Management Strategy to control the overall European airspace and airports
AIBT	Actual In- Block Time	The time that an aircraft arrives in-blocks.
ALDT	Actual Landing Time	The time that an aircraft lands on a runway.
AOBT	Actual Off-Block Time	The time the aircraft pushes back / vacates the parking position.
AOCC	Airline Operations Control Centre	It establishes systems and processes to enable a common focus by all airport stakeholders on punctuality, process quality and continuous improvement.
ASM	Air-Space Management	The purpose of which is to manage airspace - a scarce resource - as efficiently as possible in order to satisfy its many users, both civil and military.
ATFM	Air Traffic Flow Management	It is the central air traffic management unit and balance air traffic demand with the declared capacity across the country.
ATOT	Actual Take Off time	The time that an aircraft takes off from the. runway (Equivalent to ATD–Actual Time. of Departure,
ATM	Air Traffic Management	The aggregation of the airborne and ground-based functions (air traffic services, airspace management and air traffic flow management) required to ensure the safe and efficient movement of aircraft during all phases of operations
ATS	Air Traffic Services	The general purposes of ensuring safe and orderly traffic flow as well as providing the necessary information to flight crews and, in case of an emergency, to the appropriate bodies. ATS is mostly performed by air traffic controllers.

ATC	Air Traffic Control	It is a service provided by ground-based air traffic controllers who direct aircraft on the ground and through controlled airspace, and can provide advisory services to aircraft in non-controlled airspace.
CHI	Computer Human Interface	The study of how people interact with computers and to what extent computers are or are not developed for successful interaction with human beings.
CTOT	Calculated Take Off Time	The time calculated and issued by the appropriate air traffic flow management unit, at which a flight is expected to become airborne
EOBT	Estimated Off Block Time	The estimated time at which the aircraft will start movement associated with departure; also associated with the time filed by the airline in the flight plan
PDS	Pre- Departure Sequencer	It is used to assign to each flight a Target Start-up Approval Time (TSAT) that takes into account the gate where the aircraft is parked and how long it takes for the aircraft to taxi to the departure runaway.
SOBT	Scheduled Off Block Time	The time that an aircraft is scheduled to depart from its parking position; associated with the Airport slot allocated
TAT	Turn-Around Time	It is the time interval from the start of the pre-departure process till its completion.
TTOT	Target Take-Off Time	Is the planned take-off time, taking into account TOBT / TSAT and Estimated Taxi-Out Time
TOBT	Target Off Block Time	The time that an Aircraft Operator or Ground Handler estimates that an aircraft will be ready, all doors closed, boarding bridge removed, push back vehicle available and ready to start up / push back immediately upon reception of clearance from the control tower
TSAT	Target Start- up Approval Time	The time provided by ATC taking into account TOBT, CTOT and/or the traffic situation that an aircraft can expect start- up or push back approval
VTT	Variable Taxi-Time	The estimated time that an aircraft spends taxiing between its parking stand and the active runway or vice versa

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INTRODUCTION

1. INTRODUCTION

The Airport Collaborative Decision Making (A-CDM) is a concept based on transparency and sharing of information which started more than a decade ago in Europe and its equivalent to Surface-CDM in the USA, established a new way to optimize operations at airports through a more efficient collaboration between all partners. These partners include Aircraft Operators, Airport Operators, Ground Handlers, Network Operations and Air Traffic Control (ATC) (Figure 1). With the Implementation of A-CDM, partners work together and make decisions based on more accurate and timely shared information, where every bit of information has the exact same meaning for every partner involved. A-CDM ensures that the right partners get the right information at the right time, which equates A-CDM to be nothing more than better information sharing[1,2].

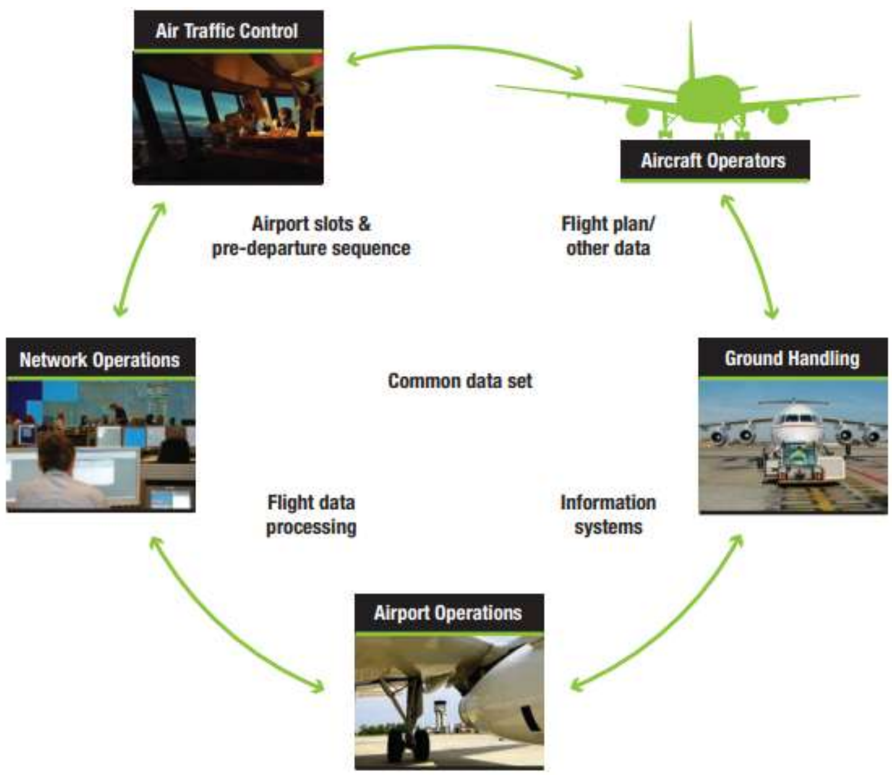


Figure 1 – Information sharing between Airport stake holders [1]

With the airports getting busier by the passing of time, it is necessary for airports to operate at its maximum potential. The very efficiency of air transport depends on the predictability of Air Traffic. Airports are expected to get busier in the coming years, therefore it is necessary for airports to operate to their maximum potential in order to meet these challenges.

With the introduction of A-CDM, it encourages info-sharing and create collaborative decision making between the key stakeholders/partners to increase airport efficiency and performance and make the best use of the resource.

The Collaborative decision making at airports also helps in decreasing the reaction times of the partners by making the best use of everyone's time and resources and there by offering solution to ease traffic flow, avoiding delays and increasing all-round efficiency.

Implementation of A-CDM requires the structured cooperation of many partners. For the successful implementation of A-CDM, all the partners should be aware of what is required of them.

Implementation of A-CDM requires to go across Concept elements:
1) Information Sharing
2) Milestones Approach Turn-round process
3) Variable Taxi Time
4) Collaborative Pre-Departure Sequencing
5) Adverse Conditions
These Concept elements are dependent on each other and hence required to follow the same order of implementation.

A-CDM Information Sharing (Figure 2) is the first concept element and of prime focus. Implementation of Information sharing network, creates a foundation for all other concept elements that follows. The Figure 2, shows the relevance of A-CDM information sharing. With the information sharing implemented, the Target off-block time (TOBT) prediction by the Aircraft operator or Ground Handler becomes the second major step to implement, before all other elements. With the Prediction of TOBT in place, improved prediction of take-off times, start-up times and taxi times will become possible.
A-CDM by defining Milestones to enable close monitoring of significant events, are implemented, Variable Taxi-Time (VTT) is the next essential step. With VTT in place the link between off-block time and take off time becomes transparent to all partners. With the four elements in place, it becomes easier for Pre-departure sequencing, which is the order in which aircraft are planned to depart from their stands (push off blocks) taking into account partners' preferences. The last step is to implement CDM in adverse conditions, a collaborative management of the capacity of A-CDM during periods of a predicted or unpredicted reduction of capacity.

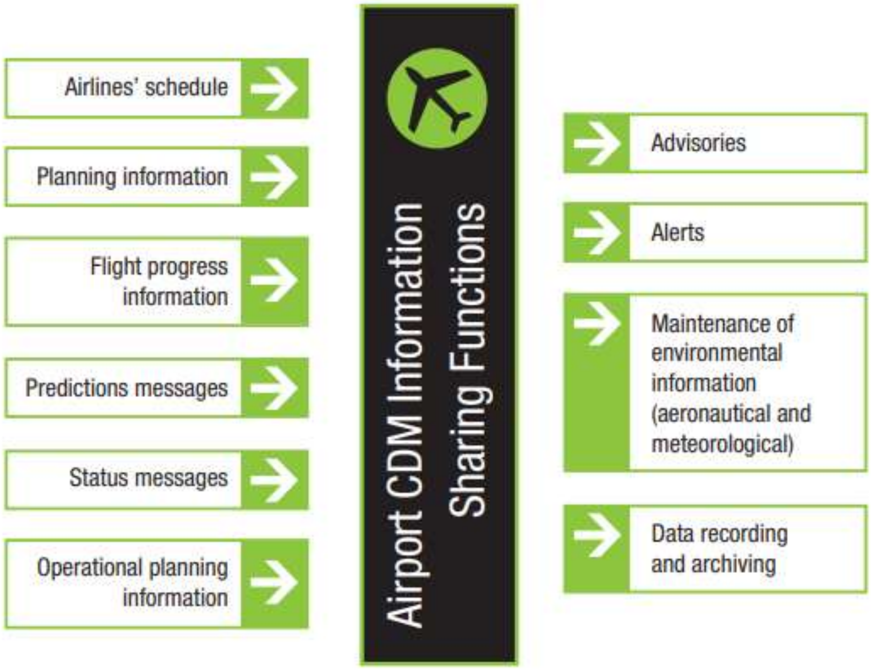


Figure 2 - A-CDM information sharing functions [1]

Turnaround operations (Figure 3) are very critical for the Subsequent scheduling of the aircraft's departure. The flight schedules and their allocated aircraft link the inbound and outbound flights during the turnaround process. The main scope of A-CDM lies in Turnaround operations. A-CDM owns the aircraft for the turnaround and communicates anticipated results of turnaround to all the partners.

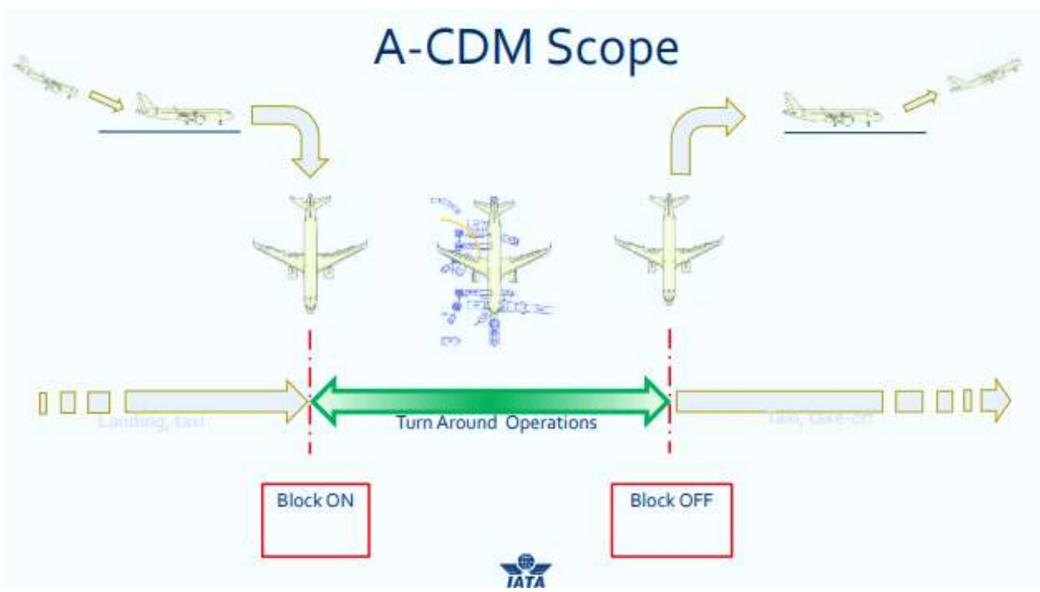


Figure 3 - Turn-around operation to be the main focus of the A-CDM project[3]

In-block (Block-on) means that an aircraft has arrived in the parking position and the parking breaks are activated. Off-block is the moment when an aircraft starts to move from the parking position and prepares to taxi and take-off [4].

By using A-CDM the life-cycle of each flight is be divided into 16 milestones (Figure 4), showing the progress of each aircraft as it comes in to land, throughout its turnaround and subsequent departure. Where A-CDM Information Sharing has been implemented, significant further improvements can be achieved by implementing the Milestone Approach for the turn-round process. Here, the progress of a flight is tracked in the A-CDM Platform by a continuous sequence of different events, known as milestones. Different A-CDM Partners can be responsible for different milestones, with the aim of integrating all of the milestones into a seamless process for the flight. Time efficiency performance, which is measured for each milestone or between two milestones and its update in real-time becomes a fundamental parameter for the Milestone Approach [1].

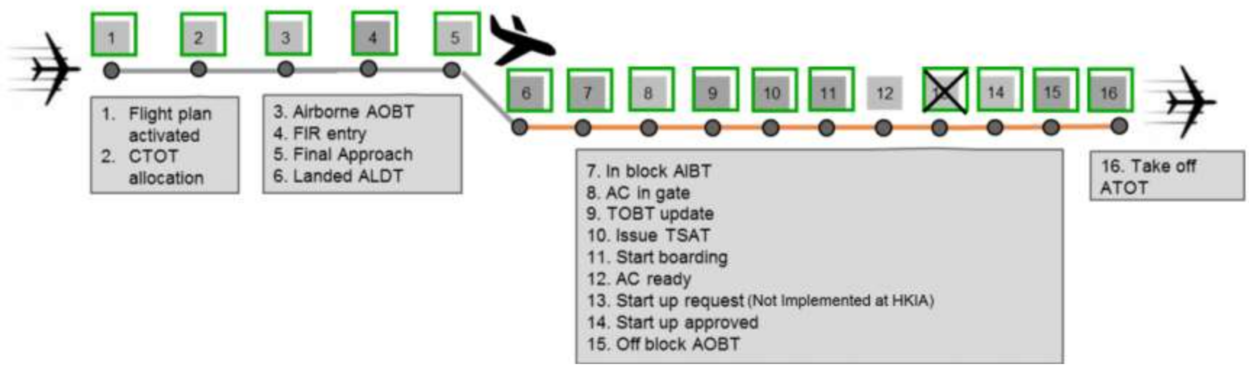


Figure 4 - Milestones of A-CDM [4]

1.1 IMPORTANT PARAMETERS:

The following parameters are the most important in A-CDM process.

1.1.1 Target Off-Block Time (TOBT)

- TOBT stands for Target Off-Block Time. It is the time that an aircraft operator estimates that an aircraft will be ready, all doors closed, boarding bridge removed, push back vehicle present, ready to start up or push back immediately upon reception of clearance from the tower.

- TOBT is the most important timing of the turnaround process and this timing is essential for the calculation of TSAT. The TSAT is derived based on optimization aircraft ground movement and minimization of apron congestion on taxiways.

- TOBT can be predicted by tracking the flight events that occur prior to landing and during the turnaround process. In order to achieve TOBT accuracy, close coordination of turnaround activities and sharing of operational information among different partners are needed.

- TOBT is initially automatically calculated by the Airport Operations Control Centre (AOCC) based on the flight arrival information. Subsequently, airlines and ground handlers will coordinate and update it based on the operational situation [5].

1.1.2 Target Start-up Approval Time (TSAT)

- TSAT stands for Target Start-up Approval Time. It is the time provided by ATC**,** taking into account TOBT and/or the local traffic situation and possible Calculated Take- Off Time (CTOT), that an aircraft can expect start- up / push back approval.

- TSAT is the optimization of the times that aircrafts are planned to depart from the parking stands.

Calculation of TSAT:

- TSAT is calculated by the Pre- Departure Sequencer (PDS) based on the TOBT input from the airlines and ground handlers. The TSAT algorithm considers these key parameters:
    - Flight status example: VVIP, Medi- Vac flights, Military flights.
    - CTOT status
    - TOBT and Variable Taxi Time
    - Parking bay allocation
    - Wake turbulence category and minimum separation between departures
    - Runway configuration and availability

- At 40 minutes prior to departure, Pre-Departure Sequencer (PDS) will calculate the first pre-departure sequence based on TOBT input from airlines and ground handlers. Subsequent TOBT updates triggers a recalculation until the TSAT frozen period. A TSAT is considered as frozen when current time is equal to or less than TSAT- 5 minutes [6][5].

1.1.3 Target Take-Off Time (TTOT)

- TTOT stands for Target Take-Off Time. It is the time which the ATC, airport operators and the ground handlers calculate and try to make the aircraft take-off within that target time.

- The TTOT takes into account the TOBT, TSAT plus the Estimated Taxi-Out Time (EXOT). Each TTOT on one runway is separated from other TTOT or Target Landing Time (TLDT) to represent vortex and Standard Instrument Departure (SID) separation between aircraft [1].

1.2 Importance of A-CDM for India

Over the past decade, the civil aviation industry in India has been growing at a rate of 10% on an average. While the current pandemic scenario has limited travel, these trends are expected to resume over the next couple of years. Analysis conducted by Business World [2] and India Brand Equity Foundation (IBEF) [3] during February-March 2019 indicate that by 2040 a steady rise in air travel is expected. Much of this growth is expected to be in domestic passenger traffic with international passengers following at a slightly slower pace.

While the air traffic movements in India have grown, there is a shortage of available airports in India. Specifically, 83% of flights originate and depart from just the top 15 airports in the country. This is much higher than the capacity handled by the top 15 US and Chinese airports, which is around 57% of total air traffic in their nations. Further many of these airports, for example Bengaluru airport, have only a single operational runway. While construction of multiple runways has been taken up in many of these airports, this may not satisfy the requirement which calls for multiple airports being available in the larger cities. Thus the implementation of A-CDM could alleviate the congestion which is currently being experienced. With A-CDM already being implemented in Mumbai since 2015, there have been some evident changes in the operations. These include enhanced orderly and efficient flow of departures optimization of resource utilization by airport partners, better terminal activities' management. Importantly between the years 2015-17, fuel consumption has reduced by 12417 tons per annum and thus cutting down the CO_2/NOX emissions by 39487 tons per annum. A-CDM is expected to continue to impact the sustainable developments in Indian Aviation and bring in efficient framework to benefit all (including the passengers) [7].

Figure 5 - Aircraft movement growth in India 2007 to 2019 [8]

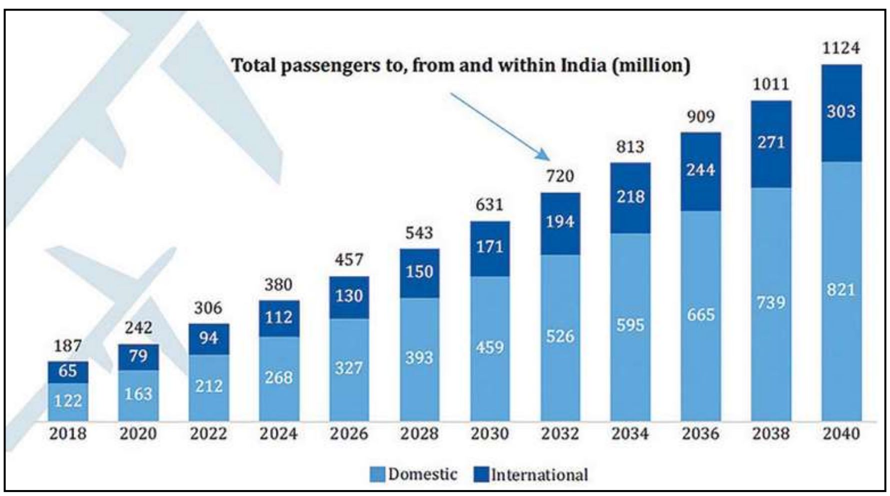


Figure 6 - Air travel growth projection in India till 2040 [8]

1.3 BENEFITS OF A-CDM :

In the case of A-CDM, the specific benefits will vary depending on the application. Majority of the benefits identified would require participation by the ATC facility at the airport. This may preclude some of the benefits from being realized, or at least fully realized, through commercial A-CDM applications intended primarily for use by the airport staff. In general, the greater t the formal participation of the airports' stakeholders, including ATC, the broader the range of potential benefits. Sharing information such as traffic demand, predicted delays, and impacts from traffic management initiatives will give operators more insight into issues affecting a flight before it leaves the gate. Additional coordination based on this insight can result in a better balance between time spent at the gate versus time spent taxiing. Coordination and data exchange can provide airports with more accurate information on resource use.

Better information on short-term gate needs can help with tactically allocating gates to meet demand [9].

Airlines

Reduced taxi times, shorter hold times before runway entry, no waiting in front of an occupied gate, Fuel savings, Decreased delays is greater than the cost savings and customer satisfaction and Increased capacity for the same fleet.

Air Traffic Control

Lowered burden due to more reliable traffic and Lower risk of errors, Improved pre-departure sequence, Higher service quality and Benefits to the network as more airports become CDM accredited.

Ground handlers.

Better resource preparation and allocation translates to lower costs and higher profits, Customer retention has improved and Ground handlers will be able to lower their costs as a result of increased production.

Airport operator

Noise and pollution are reduced, resulting in a lower environmental impact, Regularity has improved, Planning and maintenance of the gate/stand has improved and also Possible extra flights and passengers can be allotted.

Regulators

Benefits in terms of safety and the environment that can assist in meeting EU goals.

The ATM network

More space available en-route and at the airport, better ATFM slot adherence, and less unused slots.

Everyone

Congestion on the apron and taxiway has been reduced , Less burden on the system and the people who work in it because of mutual understanding and trust and Improved service quality has a positive impact on the company's reputation and customer loyalty [10].

Environmental benefits of A-CDM:

Since there are fewer planes in the taxiing queues, there is less noise, Reduced engine run time on the runway as well as the potential to minimize aircraft numbers due to increased predictability, Taxi wait times are shorter, Fuel consumption is reduced, resulting in a higher payload, Lower emissions of carbon dioxide (CO_2), nitrogen oxides (a key air quality pollutant and greenhouse gas), and particulates (important air quality pollutant) and Costs associated with mitigation have been reduced (noise insulation or compensation), lower risk of local, state, regional, or international authorities imposing environmental restrictions. Following the successful implementation of A-CDM in Munich in June 2007 taxi times have been reduced by 10%. Not only does this positively affect local air quality it also reduces noise. This equates to a fuel saving of 3.6MT per year. A similar benefit can be observed in Brussels where the average taxi time decreased by one minute [11].

1.4 PROJECT BACKGROUND

Decision making at the airports is a tedious process due to the fact that decision process at the airports involve different stakeholder (Aircraft Operators, Airport Operators, Ground Handlers, Network Operations and Air Traffic Controller (ATC). Most of the airports even to the present day, go with 'first come first served' rule, this makes the flow of traffic less optimal, sometimes leading to queuing near the runway and hence long waiting time and in turn greater quantities of fuel is consumed by airline operators. Prior to A- CDM, ATC did not have accurate information of departure readiness in advance as pilots request for pushback clearances only when the aircraft is ready. Thus, ATC was unable to forecast actual runway demand, which could help to manage departure queues at the runway holding points. With A- CDM, we target to improve the predictability of runway demand from the TOBT and aim to determine an optimal pushback sequence to ensure smooth take- offs at the runways. By adopting pre- departure sequencing, we expect to reduce the aircraft waiting time at the runway holding points, reduce fuel consumption on the taxiways and improve the passenger experience by having a smoother departure flow.

In the absence of proper decision making set-up, it may lead up to hold-up of aircrafts, delay and in total an operational inefficiency. Also decision making requires an information sharing set-up without which the partners would be involved in a conflicting decisions.
Decision making at airports should not only take into consideration of activities that take place within an Airport premise but should also consider things that happen outside an Airport space, consider an example where a blockage of the airport access road can have a major impact on the number of passengers late for check-in. Airport partners should have a common situational awareness about the obstructions of their passengers and cargo load as in this case and many such situations.

Hence to address these shortcomings, implementation of A-CDM is vital, as it brings together all the information needed for better decision making, irrespective of its origin, local or remote. A-CDM brings substantial benefits to all partners by improving the quality of information on which decisions are made, which leads to enhanced operational efficiency and making the optimal use of available resources [1].

1.5 PROBLEM STATEMENT

- Developing a web interface for the ATC to have a complete visual outcome of the whereabouts and the schedules of all the aircrafts.

- The basic requirements for the development of web interface are the datasets which is either simulated or given by the Airport Authority of India. The datasets will contain parameters or information like,
  - Scheduled Off-Block Time (SOBT)
  - Estimated Off-Block Time (EOBT)
  - Actual Off-Block Time (AOBT)
  - Calculated Take-Off Time (CTOT)
  - Target Take-Off Time (TTOT)
  - Actual Take-Off Time (ATOT)
  - Target Startup Approval Time (TSAT)

- With the help of these parameters an algorithm will have to be developed such that, when the algorithm is converted to the code and is executed in Python software a web interface is shown as the output.

- The dataset will have to have two of the most important parameters which are Target Off-Block time (TOBT) and Target Start-up Approval Time (TSAT) which are used to represent the status of the flight which are represented by different colors, thereby helping the ATC to manipulate or take the decisions accordingly.

- The color code will have to be maintained according to the standards of the Airport Authority of India.

1.6 METHODOLOGY

The main objective of the project is to provide the Air Traffic Controller (ATC) with real-time information of aircraft readiness for flight.
The first stage of the project will be to analyse the data which is simulated and data formats from various faces of aircraft operations in the airport. These data sources would include various parameters such as flight number, destination, and other important parameters such as Target Off Block Time (TOBT), Target Start-up Approval Time (TSAT), Scheduled Off-Block Time (SOBT) which will feature in the web interface.

The second stage of the project will involve data analysis of the acquired data. This stage will have the following components:

- The objective of this stage is to prepare the data for analysis by performing data simulation, data cleaning and standardization.
- Developing algorithms and code to get the coloured outputs for various scenarios.

The third stage will be the design of the website which can be used by the ATC to get periodic updates of the status of a particular aircraft at different terminals/bays at the airport.

The final stage of the project will be simulation and testing of the system by introducing aircraft delays and determining the outcomes of such delays. The software which is used for the data processing and data analysis is python.
The basic structure or the framework for the ATC to visualize and take or make the necessary decisions. The data handling and optimization process is a major aspect in A-CDM as it forms the core of the results which are produced and handed over to the ATC and other respective departments. Two key parameters which are displayed to the ATC are the TOBT and the TSAT. TOBT refers to the time when is a point in time to be monitored and confirmed by the airline or the handling agent at which the ground handling process is concluded. TSAT is the time generated by the ATC at which the aircraft can begin the push-back process from its gate.
These are the parameters which help in optimization of the data and give the required output for the airport for the better utilization of the airport infrastructure. A web interface output is developed where these parameters are shown for the ATC to take the required decisions and to make any kind of changes according to the real time situations.

TOBT is the most important timing of the turnaround process and this timing is essential for the calculation of TSAT. The TSAT is derived based on optimization aircraft ground movement and minimization of apron congestion on taxiways. TOBT can be predicted by tracking the flight events that occur prior to landing and during the turnaround process. In order to achieve TOBT accuracy, close coordination of turnaround activities and sharing of operational information among different partners are needed.

TOBT is initially automatically calculated by the Airport Operations Control Center (AOCC) based on the flight arrival information. Subsequently, airlines and ground handlers will coordinate and update it based on the operational situation.

TSAT is the optimization of the times that aircrafts are planned to depart from the parking stands. TSAT is calculated by the Pre- Departure Sequencer (PDS) based on the TOBT input from the airlines and ground handlers.

The web interface will display the Pre-Departure status of an aircraft, in which the aircraft is scheduled to depart from its gate or stand. A colour coding has also been visualized according to the status of each aircraft.

1) TOBT is the most important timing of the turnaround process and this timing is essential for the calculation of TSAT. The TSAT is derived based on optimization aircraft ground movement and minimization of apron congestion on taxiways.

2) The time provided by ATC, taking into account TOBT and/or the local traffic situation and possible Calculated Take- Off Time (CTOT)'s, that an aircraft can expect start- up / push back approval. If the TSAT matches the TOBT then it is represented with GREEN colour.

3)The colour RED represents the +5 minutes for TSAT. At TSAT+5 minutes, if a pushback request has not been made, ATC clearance and TSAT will be cancelled. AO/GHA is required to submit a new TOBT and once PDS receives the update of new TOBT, a revised TSAT will be issued.

4) Any TOBT changes after the TSAT frozen window /with TOBT>TSAT/ will result in new TSAT allocated outside the frozen window. This will be represented with the colour BLUE.

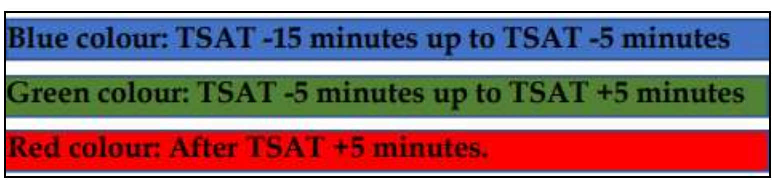


Figure 7 - Colour Visualization of aircraft status [11]

1.7 Applications:

The process of Collaborative Decision Making (CDM) is aimed at combining the input from all stakeholders and therefore at making the best choice from the standpoint of the objectivity. It is typical that decisions made by groups differ from those made by individuals. The decisions made by the group is going to be unbiased and ultimately a better outcome than the one made by Individuals [12].

Apart from CDM at Airports, the CDM finds its use in other spaces as well.

1. Business Intelligence: Business intelligence (BI) leverages software and services to transform data into actionable insights that inform an organization's strategic and tactical business decisions [13].

   "Two heads are better than a one." It may be an old saying but it is still true today. In today's fast-paced, economically challenged environment, CDM is vital to the very survival of businesses. The ability to bring together the appropriate personnel, expose all the pertinent information, make a sound decision, and then act on it immediately gives enterprises a definitive edge over their competitors, and results in happier customers, partners and employees.
   Collaborative Business Intelligence (BI) is a relatively new concept in which the twotechnol ogies ofbusiness intelligence and collaboration are beginning to merge in support of an improved decision-making environment. We define it as: 'The combination of business intelligence and collaborative computing processes and technologies with the objective of enhancing business decision making. This is achieved by improvising user communication and information sharing, adding business knowledge to BI results, and making collaborative decisions' [14].

2. Health care: health care system is poorly structured to provide the sort of coordinated care and preventive services needed to give these patients quality care while reducing costs.
   There are three traditional models of physician-patient dynamics: The paternalistic approach, which is the traditional model in which the physician articulates and implements what is best for the patient; the informative approach in which the physician provides the patient with relevant information (risks, benefits, alternative plans) and asks the patient to select the best course; and, then there's Collaborative decision-making which is more collaborative in which your interactions with the patient are aimed at supporting them in making sound decisions. This approach includes helping the patient select the treatment that is best suited for their condition and unique situation [15].

3. Emergency and disaster management: Flooding is the utmost major natural hazard in Malaysia in terms of populations affected, frequency, area extent, flood duration and social economic damage. The recent flood devastation towards the end of 2014 witnessed almost 250,000 people being displaced from eight states in Peninsular Malaysia. The affected victims required evacuation within a short period of time to the designated evacuation centres. An effective and efficient flood disaster management would assure non-futile efforts for life-saving. Effective flood disaster management requires collective and cooperative emergency teamwork from various government agencies.

Intergovernmental collaborations among government agencies at different levels have become part of flood disaster management due to the need for sharing resources and coordinating efforts. Collaborative decision making during disaster is an integral element in providing prompt and effective response for evacuating the victims [16].

4. Workspace: Collaborative approach works best where work culture supports a high level of engagement. Freedom to creatively solve problems also encourages seamless collaboration.
   few tried & tested steps to make decision making collaborative :

   a. Choose a facilitator - a lead to achieve their goals and objectives.
   b. Identify and scope the problem - Without clear identification of the problem at hand, team can fall off course. This can lead to discouragement and confusion. First step to success is ensuring that each member is able to articulate the problem clearly.
   c. Build a success model and uncover alternative solutions - Rather than dwelling on negative impacts of the current problem, team should focus on finding a solution.
   d. Collect data - It is time to collect data to support proposed solutions.
   e. Evaluate alternative solutions and make a selection - Now the team is finally ready to choose the best solution to the problem. Facilitator can assist team members in organizing their unique thoughts about each proposed solution.
   f. Create an implementation plan for the solution of choice - Selecting a solution doesn't mean that the work is done. Without executing the proposed solution, the problem will remain unsolved [17].

CHAPTER – 2

LITERATURE SURVEY

2 LITERATURE SURVEY

2.1 Air Traffic Management Overview

Air Traffic Management (ATM) comprises a complex system of systems, traditionally characterized by custom communication protocols and self-contained systems used for exchanging information between entities, which include aircraft, air traffic control, aerodrome control towers, aircraft operators and flow managers. The digital transformation of ATM is ongoing, and involves the development of new operational concepts leveraged by optimizing the sharing and use of digital data, and increasing the connectivity of disparate systems to deliver enhanced ATM system performance cost-effectively, while maintaining or improving safety levels. This transformation may, however, result in the ATM system being more vulnerable to cyber-attacks than before, due to increases in the attack surface resulting from the system's inherent complexity and heterogeneity, combined with the integration of new systems, networks, and services [18].

Air Traffic Management comprises three main services:

- **Air Traffic Services (ATS),** with the general purposes of ensuring safe and orderly traffic flow (facilitated by the ATC service) as well as providing the necessary information to flight crews (flight information service, FIS) and, in case of an emergency, to the appropriate (e.g. SAR) bodies (alerting service). ATS is mostly performed by air traffic controllers. Their main functions are to prevent collisions by e.g. applying appropriate separation standards and issue timely clearances and instructions that create orderly flow of air traffic (e.g. accommodate crew requests for desired levels and flight paths, ensure continuous climb and descent operations, reduce holding times in the air and on the ground). ATS relies on tactical interventions by the controllers and direct communication with the flight crews usually during the entire flight.

- **Air Traffic Flow Management (ATFM),** the primary objective of which is to regulate the flow of aircraft as efficiently as possible in order to avoid the congestion of certain control sectors. The ways and means used are increasingly directed towards ensuring the best possible match between supply and demand by staggering the demand over time and space and also by ensuring better planning of the control capacities to be deployed to meet the demand.

  Supply and demand can be managed by imposing various restrictions on certain traffic flows (e.g. assigning CTOTs or requiring flights matching certain criteria to use specific routes). Also, supply can be increased by appropriate sector management (e.g. increasing the number of controllers working at the same time). ATFM measures can be seen as pre-tactical, as they do not affect the current situation but rather the near future.

- **Air-Space Management (ASM),** the purpose of which is to manage airspace - a scarce resource - as efficiently as possible in order to satisfy its many users, both civil and military. This service concerns both the way airspace is allocated to its various users (by means of routes, zones, flight levels, etc.) and the way in which it is structured in order to provide air traffic services.

The flowchart below shows the structure of ATM and explains the relations between ATM, ATS and ATC [19].

Figure 8 - Air Traffic Management services [19]

2.2 A-CDM Overview

Any implementation of A-CDM must be based on assessment of current operational constraints, and the value an A-CDM implementation will generate to reduce such constraints and / or improve current operations. There is no one size fits all solution for A-CDM, and each implementation must be based on careful engagement across all airport stakeholders, but primarily the airport, the airlines using the airport, handling agents and the air traffic service provider [20].
Before the Introduction of A-CDM, airports and airlines worked on the basis of first come first served for their pre-departure sequence. This potentially meant that the best, optimized sequence was not always realized. A-CDM works on the premise of best planned best served, with more accurate and timelier Target Off Block Times (TOBT), the pre-departure sequence is optimal. It is a collaborative approach, and airlines need to be able to understand the rationale and accuracy of TOBT, and the requirement to update TOBT in a timely manner. The TOBT drives all of the targeted departure milestones and so is hugely important in the CDM process [20].

A-CDM approach Implementation at airports should be considered when;

- Inefficiency on the airport due to non-optimized turnaround and sequencing performance
- Poor punctuality and performance (such as airport start delays)
- Lack of transparency on overall airport plan
- First come first served principles for start-up which specifically lead to poor sequencing that adversely impacts airport throughput.
- Poor data into network (where existing) resulting in high regulation to airport
- Poor recovery of airport after disruption.
- Start-up delay due to false demand

• Poor interface with handling agents where airlines do not have access to real time systems on turnaround and delay status [20].

According to Euro control [21], an airport is ready to be considered an A-CDM Airport when information sharing, variable taxi time, pre-departure sequencing, adverse conditions and collaborative management of flight updates elements are successfully implemented at the airport.

The primary objective of the A-CDM is, therefore, to generate a shared situational awareness that will help better decision-making. The A-CDM, however, does not weaken or eliminate the responsibilities associated with decisions. Decisions are still made, and A-CDM partners remain accountable for their actions. They are, however, taken collaboratively and, as a result, are better understood and applied [22].

According to Steiner, Stimac and Melvan [23], the author's state that the system is based on two main elements:

a) Predictability of events - which would result in the optimization of each process related to aircraft and airport operations

b) On-time performance of operations - which would influence the increase in capacity of the airport and ATC on one side and, more directly, the efficiency of airlines and the use of aircraft on the other.

2.2.1 CDM – ICAO Overview

According to ICAO documentation DOC 9971 dealing with the subject [22], CDM defines a process focused on how to decide on a course of action articulated between two or more community members. Through this process, members of the ATM community share information related to that decision, interact, establish everyday choices and apply the approach and principles of decision making. The overall purpose of the process is to improve the performance of the ATM system while balancing the needs of individual members of the ATM community.

According to IATA [20], A-CDM is designed to improve overall airport and network efficiency through improved turnaround processes, harmonizing sequencing, surface and departure management. IATA supports common objectives and performance metrics between all A-CDM stakeholders, based on mutually agreed targets:

a) Airport Operations
b) Aircraft Operators
c) Ground Handling
d) Air Traffic Services
e) Air Traffic Flow Management.

The A-CDM concept defines six core elements that are based upon each other and so need to be implemented: [1]

Element 1: Information-sharing

Information-sharing is basic element that links partners together and forms the foundation for other A-CDM concept elements.

A-CDM Information Sharing supports local decision making for each of the partners and facilitates implementation of A-CDM elements by:

- Connecting A-CDM Partners data processing systems.
- Providing a single, common set of data describing the status and intentions of a flight.
- Serving as a platform for information sharing between partners.

Information Sharing is in fact that ties the partners together in their aim to efficiently coordinate airport activities, and forms the foundation for other A-CDM Concept Elements.
Sharing requires that shared information is available through a common system. This common system is the main Infrastructure, which is known as the A-CDM platform. An example of information sharing of A-CDM platform is shown in Figure 9.

Requirements:

- Format of the data is essential to avoid inconsistencies or data recognition problems. Hence, the requirement of data standards.
- Real time information Transmission, quick updates that lets the partners react on latest information.

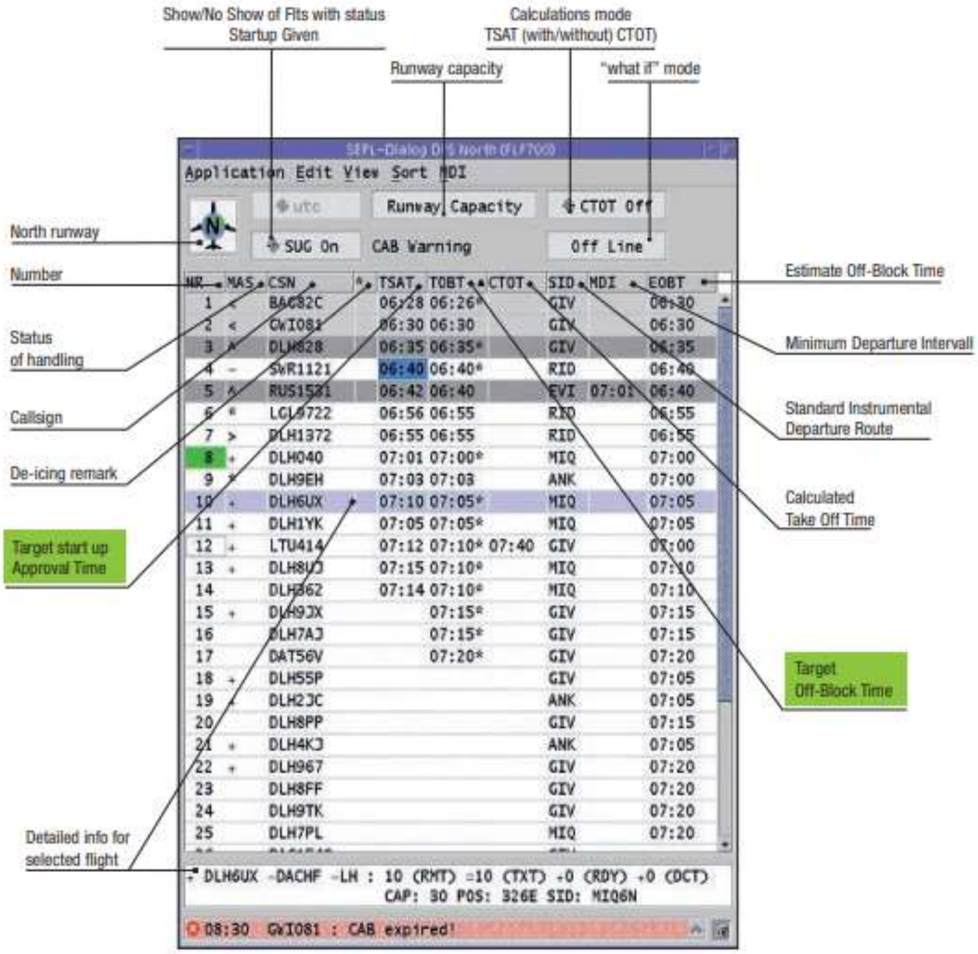


Figure 9 - An example of shared information of A-CDM platform, Munich airport [1]

Element 2: The Milestone Approach

The milestone approach element describes the progress of a flight from initial planning to take-off by defining milestones to track significant events. The milestone approach combined with the information sharing element is the foundation for all other concept elements.

The main objective of the Milestone Approach is to further improve the common situational awareness of all partners when the flight is inbound and in the turnround flight phases. More specifically, the objectives are to:

- Determine significant events in order to track the progress of flights and the distribution of these key events as Milestones.
- Define information updates and triggers: new parameters, downstream estimates updates, alert messages, notifications, etc.
- Specify data quality in terms of accuracy, timeliness, reliability, stability and predictability based on a moving time window.
- Ensure linkage between arriving and departing flights.

- Enable early decision making when there are disruptions to an event.
- Improve quality of information

One of the main contributions to performance from A-CDM is the TOBT. The confidence for decision making relies on the quality of the TOBT.

Element 3: Variable Taxi-Time calculation

At complex airports, the layout of runways and parking stands can result in large differences in taxi time. Instead of using a standard default value, a calculation of permutations based upon historic data operational experience will provide a set of more realistic individual taxi times. The variable taxi time calculation will enable higher predictability for arriving and departing aircraft. Knowledge of realistic taxi times under changing conditions will enable ATC to optimize the push back, taxi and take off sequence and hence reduce queuing and taxiway congestion.

The most common parameters affecting taxi times are:

- Airport layout and infrastructure
- Runway in use (including the distance of the taxi holding positions from the runway)
- Number of runway crossings required
- Aircraft parking stand location
- Meteorological conditions
- Aircraft type and operator
- Aircraft weight
- Push back approval delivery time
- Remote de-icing / anti-icing
- Traffic density
- Local operating procedures

Element 4: Pre-departure sequencing

Collaboratively establishes an off-block sequence by publishing a target off-block time (TOBT) and related target start-up approval time (TSAT). The TOBT is calculated from the nominated calculated take-off time (CTOT) adjusted for the Variable Taxi Time taking into account operational capacity, traffic disposition, taxiway configuration, and potential restrictions. Figure 10 shows the collaborative pre-departure sequencing. Pre-Departure Sequencing facilitates regulated, steady, traffic flows towards the runways, with minimal queuing and delay at the departure holding point.

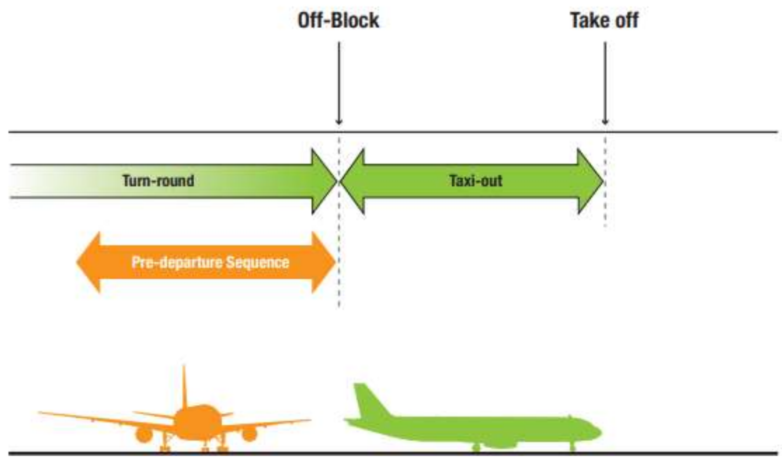


Figure 10 - Collaborative Pre-departure Sequencing [1]

Element 5: CDM in adverse conditions

Many events, both planned and unforeseen, can disrupt normal operations at an airport and reduce capacity to below normal operations. Some adverse conditions can be foreseen with scope and consequences variably predictable. Others unforeseen require reactive intervention to optimize the airport's degraded performance. The adverse conditions element aims to facilitate a swift return to normal capacity once adverse conditions have passed by using the improved information-sharing results from the previous elements.

2.3 Turnaround Time Analysis:

The Aircraft Turnaround has been identified to be crucial for airline schedule adherence, for high customer satisfaction, and economic productivity. A number of ground operations have to be processed, in sequence, to service the aircraft. These comprise Placing of chocks (rubber blocks that prevent aircraft from moving) in front of the aircraft's wheels after it comes to full stop, unloading of passengers and baggage, post-flight administration, pre-flight administration, catering replenishment aircraft cleaning, security checks, loading of passengers and baggage, and removal of chocks for departure. Cleaners, ground handlers and engineers execute these processes and shall best coordinate their activities to provide a seamless aircraft turnaround [33].

All these processes are being scheduled against the Scheduled Time of Arrival (STA) and - by assuming a dedicated taxi-in time - scheduled against the "on block (chock)" times at the assigned aircraft stand, either remote or at the terminal building according to the airport's stand allocation scheme.

The dataset for this particular analysis is simulated from various sources and has 30 records which includes all the parameters causing the major delay for an aircraft.

2.4 Human factors for display design in Air Traffic Management:

Computer Human Interface (CHI):

Design of the Computer Human Interface is made up of physical parts such as computer screen, input devices which supports the transfer of information between computer and human. The objective of design and evaluation activities is to make the physical and functional interfaces as compatible as possible with the cognitive interface. Critical human factors objectives for CHI design are usability, operational suitability, and workforce acceptance.

In order to design and evaluate the CHI in the ATC context, three basic problems of information transfer must be addressed:

- Communication of the controller's purpose to the computer and the corresponding response/feedback and their effects provided by the computer.
- Control on the computer system, focusing on the reaction of the controller and response given by the computer based on the inputs provided.
- System tools and its capabilities must be fully accessible with high quality.

Before designing a display formant with high accuracy and consistency which allows the controller to perform the required task efficiently, a task analysis should be conducted. The selection and presentation of information for displays must be managed so that the display provide only the information that is needed, when it is needed, and in a form that is useful and operationally suitable.

Elements which are commonly found on a visual display are full page display, window and window controls, symbol, menu, icon and push button [24].

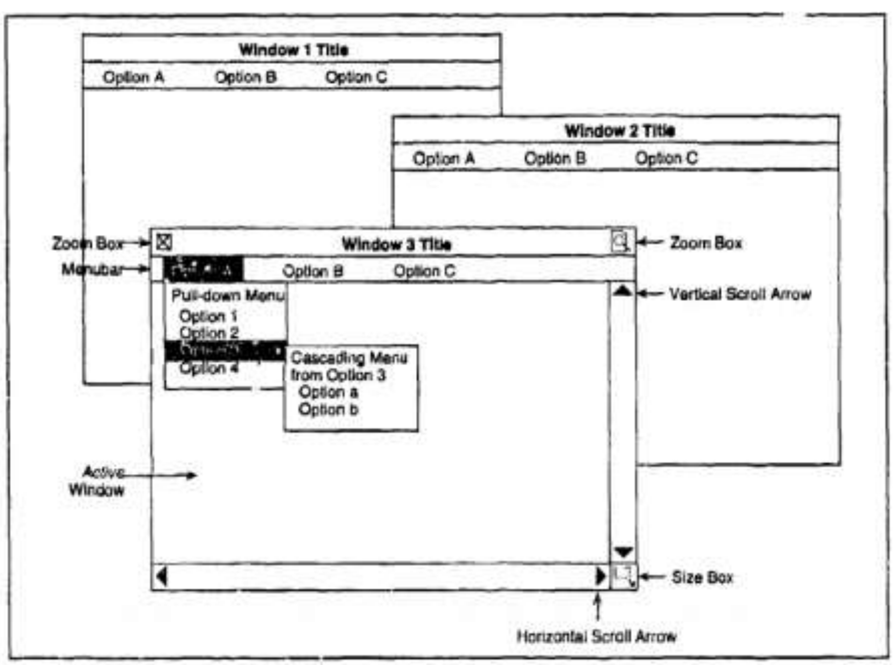


Figure 11 - Overlapping Windows, Pull-Down Menu, Cascading Menu,

and Embedded Control Devices [24]

When a new system or system upgrade is being designed, it would be beneficial if the known symbols and acronyms are retained. Designers should not try to overlap the new meaning for the existing terms, acronyms and symbols. Symbology selection determines how specific information elements will be represented within the display. Symbols should be intuitive so that they are easily recognized and understood.

Display format determines the framework within which the information will be presented (for example; the organization and location of data). Once designers determine information requirements and general display organization, they can refer to hundreds of well established, very specific human factors guidelines in developing the initial visual displays. These guidelines can be translated into an ATC system style guide, a set of specific design rules for developers to follow.

Rapid prototyping and usability testing can assist designers in evaluating symbology and format to organize display elements into a unified whole. Rapid prototyping helps the user to quickly transfer their ideas in the computer. This software helps the designers to generate the screen panels that look and act like ATC displays , but the software does not process the command and information.

<u>Graphical display over textual display:</u>

Graphics are used to represent the relationship between the physical space and the computer in a pictorial format. Situation displays are important ATC graphical displays which combines the geographical locations with the ongoing event (example: Aircraft location). Monitoring changing data is also easier using graphic displays which is called a direct manipulation visual display. For example, the controller may want to see a graphic depiction of the performance characteristics of an aircraft climb rate. The, controller could display this data for information and then delete it from the display area by clicking on the data chart itself.

<u>Visual display flickering:</u>

Visual displays are actually flickering from bright to dim all the time at a constant rate. The causes of display flicker is one's threshold to flicker as compared to the display's flicker rate. Under most conditions, the human threshold for perceiving flicker is under 65 cycles per second. This means that, under these conditions, if the refresh rate of a display is at least 65 cycles per second , the display will always appear to be steady. If the refresh rate of the display is below the observer's threshold for flicker, then display flicker will be noticeable.

The two major factors that can change an individual's threshold:

- Whether the controller is using the display in a brightly lit or dimly lit room.
- From what angle the controller is viewing the display.

<u>Size of text and symbol:</u>

To account for both the size and distance of symbols and characters, the angle that the symbol or character forms with the eye is used as the unit of measurement. This is referred to as the visual angle. Visual Angle are specified in terms of arc or degree (1 degree – 60 minutes of arc).

The minimum size for characters - presented in colour will depend upon the colours of the text background, and other colours used in the display.

EXAMPLE : Character size is measured by the height of the character in terms of its visual angle. For a monochromatic display, characters should have character heights of at least 16 minutes of arc with a preferred height of 20 to 22 minutes of arc. At a viewing distance of 18 inches, this translates into values of approximately .08, .11, and, .12 0 inches, respectively. When colour discrimination is important, symbols and characters need to be bigger than when they are displayed monochromatically.

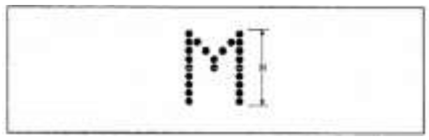


Figure 12 - Character Height [24]

Visual Alert Signal:

The goal of visual alerts are to effectively direct the controller's attention to important information that might otherwise be missed or critical situations that might otherwise take longer to recognize. Visual alerts will be recognized more quickly when placed in the area of the visual field that has the best visual acuity than when placed in the periphery. This optimal area can be thought of as a cone extending from the normal line of sight with a radius of 15 degrees.

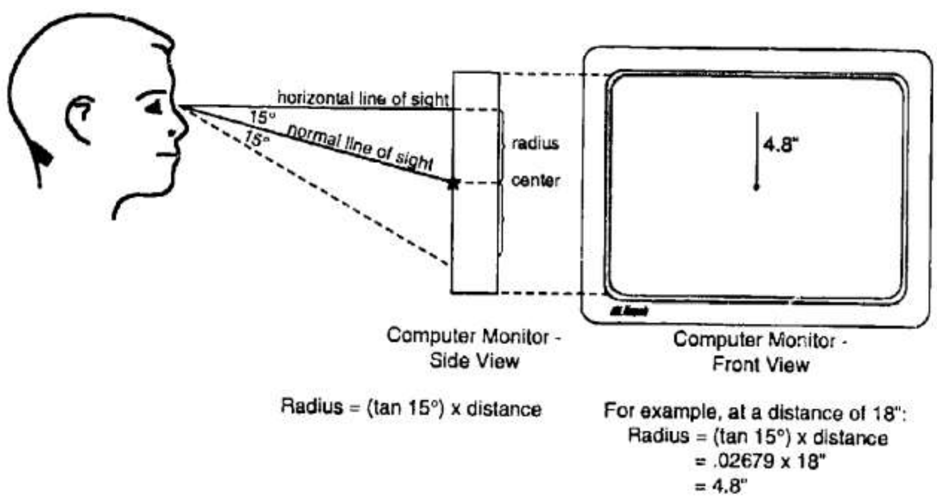


Figure 13 - Recommended placement of Visual Alert Signals [24]

Colour Coding:

A colour-coded display allows for quicker searches of information than are possible when the display is monochromatic .Colour coding is especially useful for highlighting or categorizing information on a display. Highlighting must be used sparingly so that emphasized items will actually "pop out" from the others. Colour also "catches" attention and can reduce error, if used appropriately. Colour should be used only for functional, not decorative, purposes on ATC displays. However advantages to color-coding decreased as more than five to six colours were employed. A research was conducted on human short-term memory characteristics, which indicates that memory-based codes limited to five to six dimensions present the least difficulty to humans.

Human Aspects on Typographical aspects of display:

- The wording from the displayed text must either be in common English or an ATC terminology.
- Abbreviations should be used efficiently i.e., one word must have only one abbreviation.
- Punctuation should be used only within complete sentences, when needed for clarity, or to partition long data items .
- Upper case should be reserved for the first letter in a sentence or a typically capitalized word, and acronyms should be upper case. Text presented in all upper case is more difficult to read as compared to mixed case. Upper case can be used for short items to draw the controller's attention to important text.
- When controllers must read a lengthy amount of text, they should be given printouts. Reading from the computer screen can be 20 to 30 percent slower than reading from a hard copy.
- Commands should be written in the active voice
- Commands should be written in such a way that it should tell the user what to do rather than what not to do.
- Error messages should give the user a clear instruction in what to do next to recover from the error.

Implementation of windows:

Windows allow the user to look into a portion of a data set that is too large to fit within the window frame. A user should be able to perform the following window management tasks: moving windows, resizing windows, shrinking display pages into icons, and opening and closing windows. The user should be able to enter data or execute commands within the active window. The number of windows that need to be displayed on the screen simultaneously should be kept to a minimum since the controllers won’t be familiar with the window usage. If windows are to be placed on a background that the controller is using for operational purposes, they cannot block critical information, and their size must be kept to a minimum [24].

Basic Human Factors for the design of menu and commands:

- The computer should indicate which commands are currently available by displaying the command set relevant to the task at hand. Often, commands that are applicable to the current task but that currently cannot be executed are displayed but are "grayed-out" (e.g., dimmed so that the menu option is shown in faint grey letters).
- If many parameters must be specified, an easy mechanism should be provided for the controller to enter this information.
- When the controller types in a command or a command parameter, the computer should treat upper- and lower-case letters as equivalent.
- If there are very few menu options (e.g., three or fewer), the menu may be merged with another short menu that is functionally similar. if there are more than 10 menu options, the menu may need to be broken down into two menus.

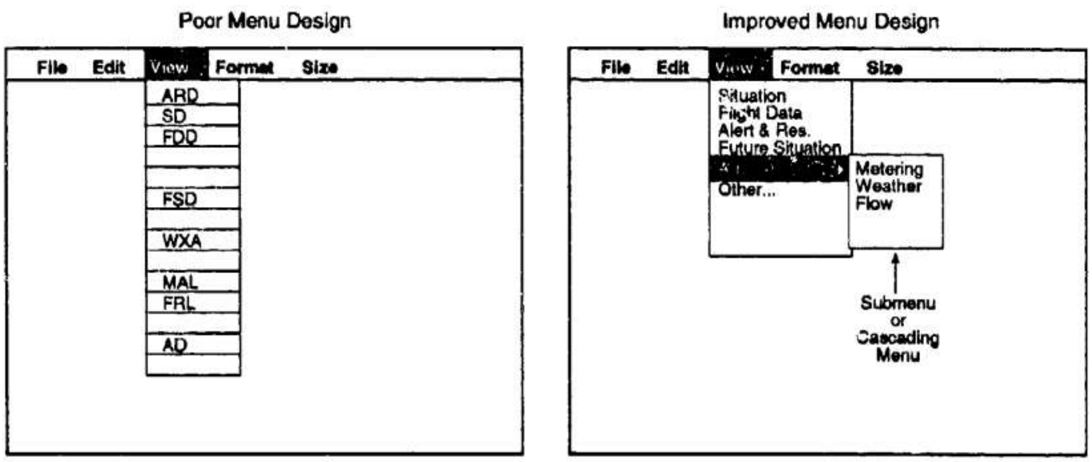


Figure 14 - Poor and Improved menu design [24]

- Use of a style guide promotes a standardized look and method for command activation, for example; menu options and push buttons.
- The computer should indicate the current operational mode (such as keyboard input mode, help mode, or save mode).
- Command ordering should be consistent from window to window.
- When the controller does not execute a probable command, the computer should not take control, but should prompt the controller to perform the action.
- The controller should receive some type of feedback so that it is clear that tie computer has executed a command.

Auditory display:

It denotes the use of sound to transmit information to a human receiver. Just as light energy is displayed or presented to the eye, sound waves are displayed or presented to the ear. Use of both auditory and visual displays is sometimes recommended to enhance human performance. Auditory displays can be divided into two main types: signal(also called tonal or sound) displays, and speech (or voice) displays. Signal displays may take the form of tones, beeps, buzzing sounds, ringing bells, and so forth. Speech displays are verbal messages delivered by live speakers, recordings, or voice synthesizers. Typically, auditory displays are used either to present low-level information in the form of alerts, alarms, and warnings (using signal displays), or they are used to transmit speech communications .

Principles derived from human factors for auditory display:

- It should be impossible for more than a few auditory displays to be presented simultaneously In any situation.
- Newly installed must not interrupt the previously installed working ATC signals .
- Auditory displays should make use of natural signals which will directly alert the controller based on what signal he hears, e.g., wailing signals mean emergency.
- Auditory displays should be easily recognized among the other signals and noise.
- The same signal should always be used to indicate the same information and should not be used for any secondary purpose.
- Signal volume should be loud enough to be heard over background noise. Depending on the frequencies present in the signal and noise, warning signals need to be 5 to 15 dB more intense than the ambient noise. Messages presented in natural speech should be at least 6 dB more intense than the surrounding noise.
- Use a representative controller sample to make sure these users can detect the signals in their working environment. All signals should be tested in all realistic ATC work conditions to ensure that the controller can distinguish between signals.
- When there is a replacement between the auditory display an visual display , the change in transition must be shown on the screen.
- The controller should be able to cancel auditory signals [24].

2.5 Machine learning:

Machine learning is defined as computational techniques utilizing the experience to enhance performance or to achieve precise predictions. The experience denotes the previous information available to the learner that is naturally received from the electronic data recorded and made available for investigation. In all situations the data size and quality are critical for the accomplishment of the predictions made by the predictor [25]

Machine learning is composed of creating competent and precise prediction algorithms. As the performance of a learning technique is based on the data and features employed machine learning is characteristically associated with statistics and data analysis.

Machine learning frame works:

1. Data collection: this task is undertaken to extract ,record and collect the required data needed for analysis. Generally, this includes utilization of historical data warehouses, data marts, data lakes and so on. An evaluation is carried out based on the data available in the organization and if additional data is needed. The samples are collected by scraping a website and extracting data. This data can be taken from the web or it can be taken from other channels, such as service, purchases, experiments, and simulations.

2. Data description: data description includes an initial analysis of the data to comprehend more about the data, its source, attributes, volume and its relationships. The following aspects are critical to create a suitable data description they are:
   - Data sources (SQL ,MS - Excel), record of origin record of reference.
   - Data volume (size, number of records, total database tables)
   - Data attributes and their description (variables, data types)
   - Relationship and mapping skills (understand attribute representations)
   - Basic descriptive statistics (mean, median, variance)
   - Focus on which attribute are important for the problem statement.

3. Exploratory data analysis: Exploratory data analysis is one of the first win analysis steps in the life-cycle. The aim is to explore and understand the data in detail. Descriptive statistics, charts, plots and visualization can be utilized to look at the various data attributes and find relations and correlations. The data collected must be in a usable format.

4. Data quality analysis: Data quality analysis is the final step in the data understanding stage in which the quality of data is analyzed in the data set and potential shortcomings errors and issues are determined .these need to be resolved before analyzing the data further or starting modelling efforts. The focus on the data quality analysis includes missing values , inconsistent values, wrong information due to data errors (manual or automated), wrong metadata information.

2.6 Machine Learning using Regression:

2.6.1 Linear regression:

Regression analysis is a statistical technique for investigating and modelling the relationship between variables. Application of regression are numerous and occur in almost every field. Regression analysis is used extensively in data mining and is a basic tool of data science and analysis. Because of its wide applicability to a range of problems, regression analysis may be the most widely used statistical technique. The generalized equation for a linear regression :

$$y = \beta_0 + \beta_1 x \qquad (1)$$

Where,

β_0 is the intercept
β_1 is the slope
'x' is called the independent variable
'y' is called independent variable.

When a graph is plotted between y and x , ($\beta_0 + \beta_1 x$) is considered to be a straight line. The difference between the observed value of y and the straight line will be an error 'ε'.

It is convenient to think of it as a statistical error; that is, it is a random variable that accounts for the failure of the model to fit the data exactly.

The error may be made up of the effects of other variables .

The equation for a more plausible model is given by:

$$y = \beta_0 + \beta_1 x + \varepsilon \qquad (2)$$

Where,

β_0 is the intercept
β_1 is the slope
'x' is called the independent variable
'y' is called independent variable
$'\varepsilon'$ is the error.

Equation 2 is called a simple linear regression model as it involves only one regressor variable.

To avoid misinterpretation 'x' is referred to as free director or regressor variable and 'y' response variable.

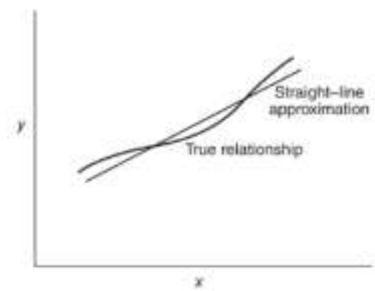


Figure 15 - Linear regression approximation of a complex relationship [26]

The above figure may also be known as empirical models . Figure 15 illustrates a situation where the true relationship between ‘y’ and ‘x’ is relatively complex yet it may be approximated quite well by a linear regression equation.

In simple linear regression model the errors are assumed to have mean zero and unknown variance ‘σ^2’. Additionally we also assume that the value of one error does not depend on the value of any other error. It is convenient to view the regressor x is controlled by the data analyst and measured with negligible error, by the response y is a random variable. That is, there is a probability distribution for why at each possible value of x.

The mean of this distribution is :

$$E(y \mid x) = \beta_0 + \beta_1 x \qquad (3)$$

Where,

β_0 is the intercept
β_1 is the slope
‘x’ is called the independent variable
$E(y \mid x)$ is the mean of distribution.

The variance is:

$$Var(y|x) = Var(\beta_0 + \beta_1 x + \varepsilon) = \sigma^2 \qquad (4)$$

Where,

β_0 is the intercept
β_1 is the slope
‘x’ is called the independent variable
$'\varepsilon'$ is the error
σ^2 is the unknown variance

2.6.2 Multiple Linear Regression

Linear regression attempts to model the relationship between two variables by fitting a linear equation to observed data. One variable is considered to be an independent variable, and the other is considered to be a dependent variable. For example, relating the weights of individuals to their heights using a linear regression model.

Before attempting to fit a linear model to observed data, we should first determine whether or not there is a relationship between the variables of interest. If there appears to be no association between the proposed independent and dependent variables then fitting a linear regression model to the data probably will not provide a useful model [27].

A linear regression line has an equation of the form:

$$y = a + bx \qquad (5)$$

Where,
x is the independent variable
y is the dependent variable
b *is the* slope of the line
a is the intercept (the value of y when $x = 0$)

Now, what if there are two or independent variable? In this case we use Multiple linear regression.

Multiple linear regression is the most common form of linear regression analysis. The multiple linear regression is used to explain the relationship between one continuous dependent variable and two or more independent variables.

There are 3 major uses for multiple linear regression analysis.
First, it might be used to identify the strength of the effect that the independent variables have on a dependent variable.
Second, it can be used to forecast effects or impacts of changes. That is, multiple linear regression analysis helps us to understand how much will the dependent variable change when we change the independent variables.
Third, multiple linear regression analysis predicts trends and future values. The multiple linear regression analysis can be used to get point estimates.

While trying to fit a model, another important aspect to consider is adding independent variables to a multiple linear regression model will always increase the amount of explained variance in the dependent variable. Therefore, adding too many independent variables without any theoretical justification may result in an over-fit model [28].

The general expression of Multiple linear regression is

$$y_i = \beta_0 + \beta_1 x_i 1 + \beta_2 x_i 2 + \ldots + \beta_p x_i p \quad (6)$$

Where, for i=n observations:
y_i is the dependent variable
x_i is the independent variables
β_0 is the y-intercept (constant term)
β_p is the slope coefficients for each explanatory variable.

2.7 Role of the computer :

Building a regression model is an iterative process. The model building process is illustrated in the Figure 16.

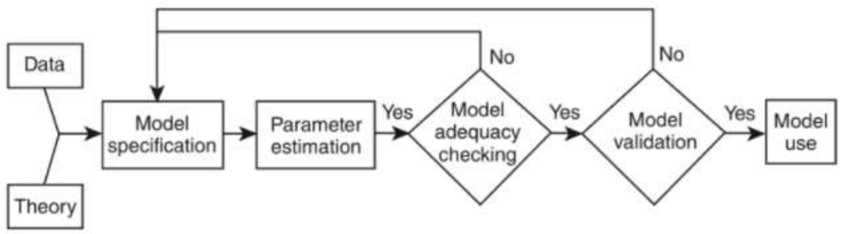


Figure 16 - Regression Model Building Process [26]

It begins by using any theoretical knowledge of the process that is being studied and available data to specify an initial regression model. Then the parameters of the model are estimated , typically by either least squares for maximum likelihood. A good regression computer program is a necessary tool in the model building process. However , the routine application of standard regression computer programs often does not lead to successful results. The computer is not a substitute for creative thinking about the problem. Regression analysis requires the intelligent and artful use of the computer [26].

2.7.1 The python machine learning environment:

A programming language must be understandable by a wide range of people. Moreover, the programming language should have libraries written for a number of tasks .a programming language with an active developer community is needed. Python is the best choice for these reasons, and it is a great language for machine learning for a large number of reasons. First python has clear syntax. The clear syntax of python has earned name executable pseud- code. With python it is easy to process and manipulate text that makes it perfect for processing non numerical data. A number of scientific library such as scipy and numpy allow to do vector and matrix operations easily. Python is easy to learn, supports multiple programming paradigms, extensible, active open-source community [25].

Two of the major libraries that are extensively helpful and used in machine learning are[25]:

- Numpy: numpy is the backbone of machine learning in python. It is one of the most important libraries in python for numeric computations. It adds support to core python for multidimensional arrays and fast vectorized operations on this. It is employed in almost all machine learning and scientific computing libraries.
- Pandas: pandas is a vital python library for data manipulation, wrangling and analysis. It functions as an intuitive and easy to use set of tools for execution operation on any kind of data. Pandas allowed to work with both cross-sectional data and time series based data.

2.7.2 Software and libraries used:

Python is used for the optimization of the data which is simulated and various other libraries such as pandas, numpy, datetime, streamlit are used to get the desired outputs.
Pandas helps us to retrieve the data which is in the csv format and also helps us in cleaning the data by helping us drop the unwanted values in the table. They also help us in performing the analysis of the required columns (in this case TOBT and TSAT) by using the data frame which is a function of pandas. Numpy helps us with all the numerical calculations and the logic that we have to provide for the color code. The data which is simulated is in the form of object data type which has to be converted to the time data type hence we use datetime library to convert the same.
Streamlit is used to create the website [29].

2.8 Data collection

1) The main approach for the data collection is from a YouTube video (Titled 'FlySafAir – We turn our aircraft in 25 minutes' [30]) which is about an aircraft turnaround process. The start and end time between each process such as, jet bridge connecting time, deboarding of passengers, unloading of cargo, refueling, cleaning, restocking of food, re-boarding and jet bridge detachment. These times were taken into reference to understand the time gap between each process and to help us simulate the other flights' data.

Figure 17 – The Refueling process is shown as an example here. The firsts image shows the that the refueling process started at 4 minutes 35 seconds and ended at 14 minutes 40 seconds. This means that the refueling process took about 10 minutes and 5 seconds.

2) The flight numbers were obtained from the Kempegowda International Airport website [31] of all the departing flights from the airport.

3) The understanding of the delay times of different pre-departure processes were from the document titled 'Delay Impacts onto Turnaround Performance' [32] and learnt the optimal time for minimizing delay. The domestic aircraft fleet in India majorly comprises of Airbus A320 family and Boeing 737 aircrafts and the average turnaround time for these aircrafts is found to be 30-53 minutes. So the time gap between each processes were noted and corresponding data was simulated.

CHAPTER – 3

Visit to Air Traffic Control Tower

3. Visit to the Air Traffic Control Tower:

To learn the actual procedures which takes place in the air traffic management process in India, we contacted few personnel of the Airports Authority of India and we got an opportunity to visit the Air Traffic Control Tower-Kempegowda International Airport, Bengaluru on 24th of February this year. The objective of the visit was to learn the working procedures, understand the requirements of the air traffic controllers when the A-CDM is implemented. The following are the different departments at the base of the tower, which are known as the Air Navigation Services:

- **Air Traffic Management**- The dynamic, integrated management of air traffic and airspace (including Air Traffic Services, Airspace Management and Air Traffic Flow Management) safely economically, and efficiently—through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions.
  - Air Traffic Services (ATSs) - Services that regulate and assist aircraft in real time to ensure their safe operations.
  - Air Traffic Control (ATC) -Service is provided for the purpose of preventing collisions between aircrafts, to maintain an orderly flow of air traffic and maneuvering aircraft on the ground.
  - Flight Information Services -Service provided for the purpose of giving advice and information useful for the safe and efficient conduct of flights.
  - Alerting services - A service to warn the relevant bodies when an aircraft is in difficulty and need assistance.
  - Air Traffic Advisory Service - A service provided within advisory airspace to ensure separation between aircraft that are operating on Instrument Flight Rules (IFR) flight plans.
  - Air Traffic Flow Management - A service established with the objective of contributing to a safe, orderly, and expeditious flow of air traffic by ensuring that ATC capacity is utilized to the maximum extent possible and that the traffic volume is compatible with the capacities declared by the appropriate ATS authority.
  - Airspace Management - The task of planning and publishing the management of airspace, divided up into air routes, and civil and military control areas reserved for airports, while at the same time guaranteeing the safety and fluidity of traffic.

- **Communication, Navigation, Surveillance** - Essential technological systems, procedures, and programs for the pilots and the Air Traffic Controllers who facilitates the process of where the aircraft is and, when and how it plans to arrive at its destination.
  - Communication - The use of communications technologies for airborne and ground-based coordination (passing data and instructions between pilots and controller and between control centers).
  - Navigation - Applications that are used to maximize the capacity of airspace by facilitating flow of traffic between airports and maximizing safe and efficient access to airports (assists pilots to direct their aircraft along safe paths).

- Surveillance - Infrastructure that is used to enable a safe, efficient, and cost-effective air navigation service.

➢ **Meteorological Services** - Provision of meteorological information for aviation users necessary for safe and efficient civil aviation operations, including the provision of observations, forecasts, warnings, and advisories.

➢ **Aeronautical Information Services** - A service established within the defined area of coverage responsible for the provision of aeronautical data and aeronautical information necessary for the safety, regularity, and efficiency of air navigation. This will be very helpful in search and rescue services like assisting an aircraft in distress.

At the top of the tower, there are few other departments which communicate directly with the pilot, ground handlers and airline operators to guide an aircraft to navigate through the airport or to land or take-off.

They are:

- <u>Flight Data Processing (FDP) Manager</u>:

The FDP manager gets the data from the ATC briefing office then they process the data and check the flight status of the particular flight and pass on to the clearance delivery section. The FDP Manager processes the data given by the ground handlers and airline operators.

- <u>Clearance Delivery Unit</u>:

The aircraft calls this unit to provide all details, such as which route it is going to take, fuel requirement, number of passengers on board and so on. CDU will coordinate with area control unit, which conveys the go-head for clearance.

Departure Frequency: Pilots are given the frequency on which they will receive the long-range clearance direct from the ATC depending on the availability of the flight level(altitude). Transponder codes will be assigned to link the aircraft to assigned flight plan.

- <u>Ground Controller:</u>

Ground controller is responsible for the movement of aircraft through taxi instructions on the airport surface area. There are basically two ground controllers:

Ground controller 1: Monitors the aircraft surface movements and allocates the taxi way till the aircraft reaches to the holding point.

Ground controller 2: They take over from the Ground Controller 1 and allocate the strips to reach the runway.

This ATC instruction is not an authorization to take off. In instances where the pilot has been instructed to line up and wait and has been advised of a reason it might be wake turbulence, traffic or the reason is clearly visible that the aircraft that has landed on or is taking off on the same runway and later the pilot should expect an approach to take off clearance, unless advised of a delay. If a take-off clearance is not received within a reasonable amount of time after clearance to line up and wait, ATC is contacted again.

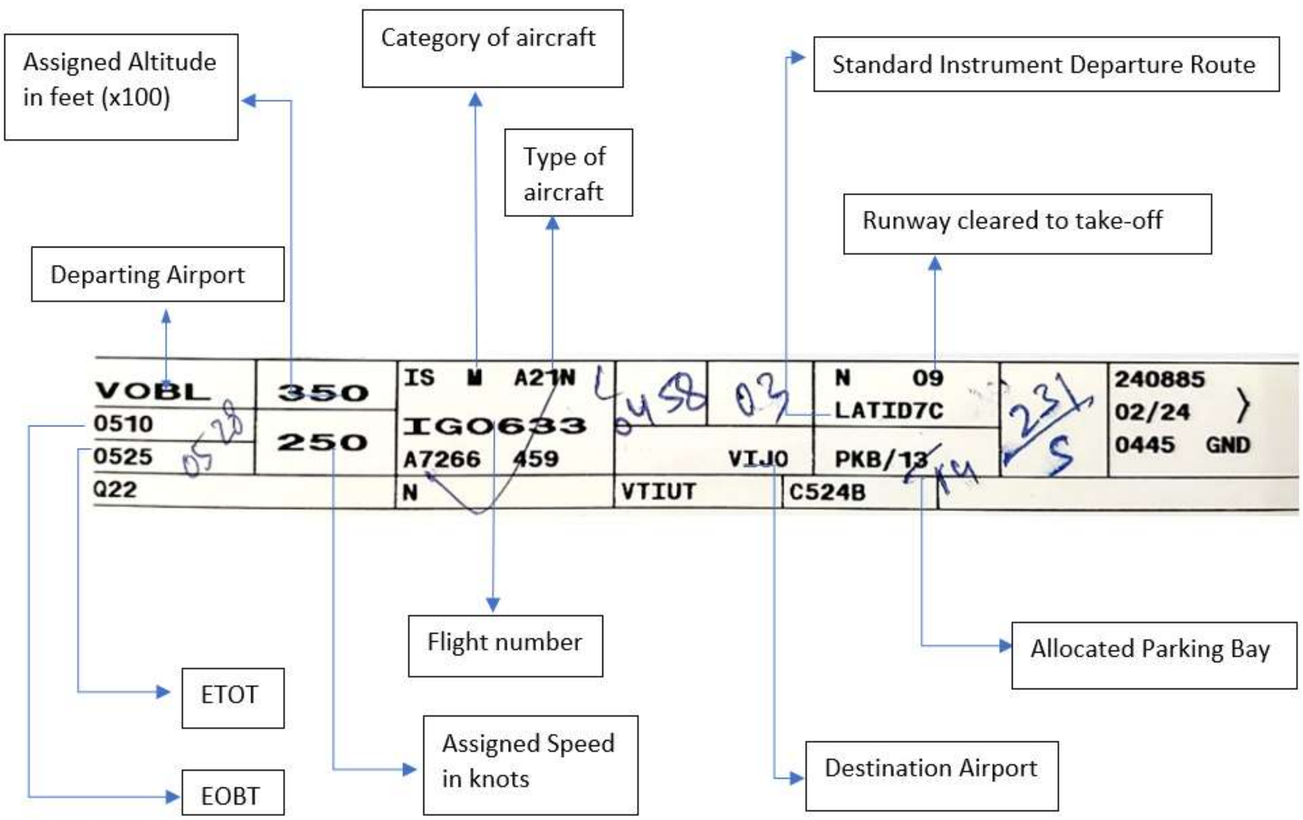


Figure 18 - Departure Clearance Strip

The content in the above image is called 'Departure Clearance Strip', which is used by the controller to depart an aircraft from the airport. The controller gets to know the flights information by reading the aircraft's different time slots and other information. The blank space is filled by the controller with the actual time parameters that takes place.

Figure 19 - Digital form the Departure Clearance Strip.

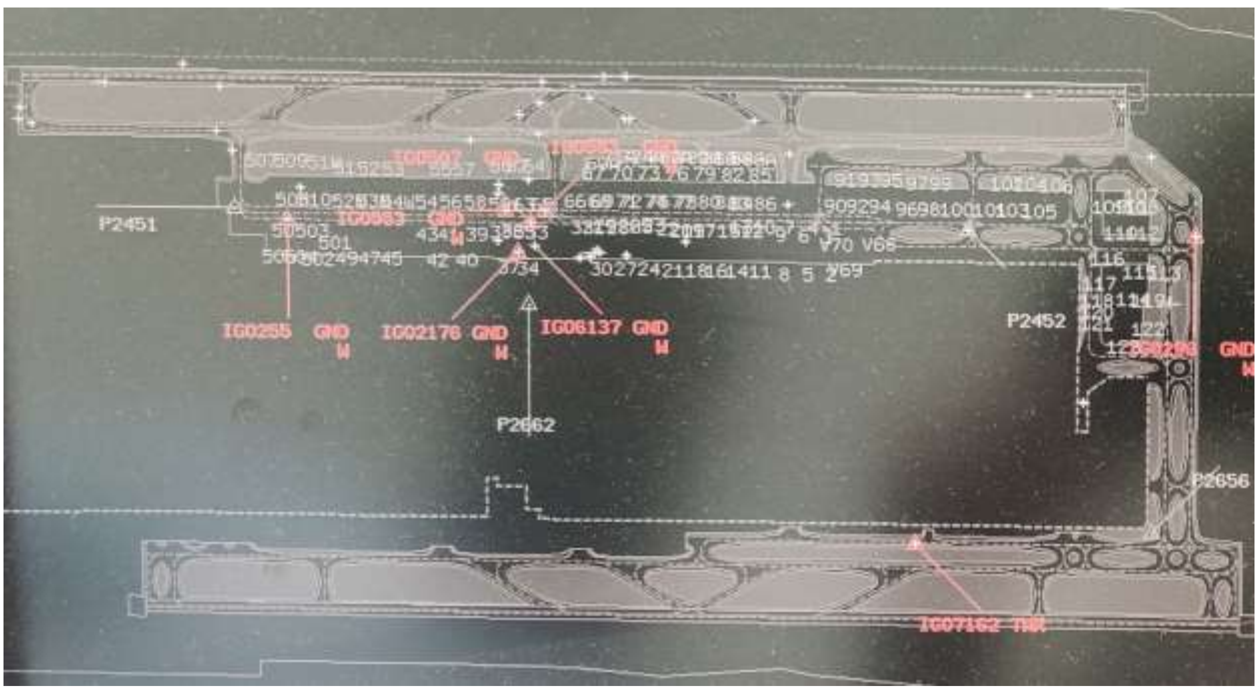


Figure 20 - Kempegowda International Airport- Apron layout display

The above image shows the layout of parking bays, runway, taxiway and the position of the aircraft with its flight number, at the Kempegowda International Airport. The air traffic controller can view all the on-ground movement of the aircrafts through this display.

CHAPTER – 4

PROJECT DESIGN

4. Project Design:

Well established design can be proposed to the ATC only when one is aware about their working procedures and requirements. The design of the output web interface was inspired from the field trip to the ATC tower of the Kempegowda International Airport and from few of the documents of the A-CDM manuals from airports across the world. We aim to develop a web interface for the ATC to have a complete visual outcome of the whereabouts and the schedules of all the aircrafts. When we spoke to the air traffic controller at the tower, we understood the requirements in the output, from controller point of view and we tried to implement it in our project. As we have discussed in the other sections, TOBT and TSAT are the most important parameters which are required for the implementation of A-CDM and giving real time information of the aircraft's status regarding the boarding, refueling, cleaning, and other information, with updating of the same between 0-5 minutes is recommended for an effective A-CDM system.

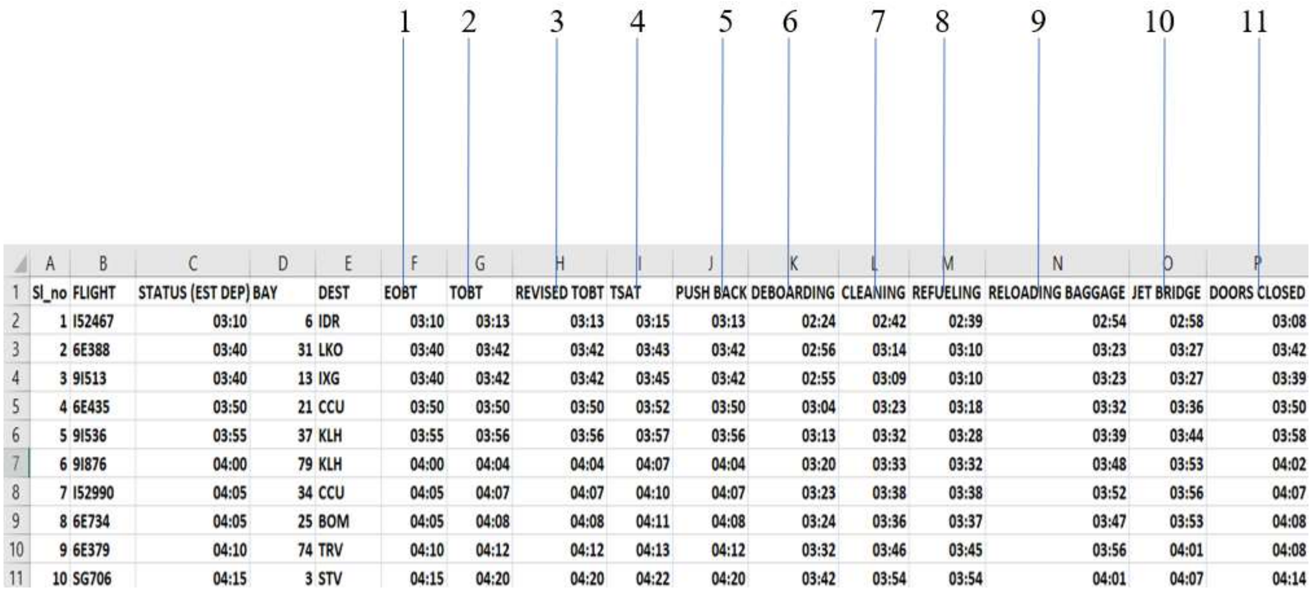
4.1 Data Collection:

Data collection is an essential aspect of regression analysis and in our case, multiple linear regression analysis. Due to the relevant conditions of the pandemic, the actual data collection from the Kempegowda International Airport was unfortunately not possible. Therefore, the data had to simulated ourselves. Some of the basic methods used in data collection are: Retro prospective study, an observational study and design experiment.

- <u>Retro prospective study</u>: It uses either all of the sample data or a sample of the historical processes data over some period of time.
- <u>Observational study</u>: This method simply observes the process or population. We interact or disturb the process only as much is required to obtain relevant data. With proper planning, these studies can ensure accurate, complete and reliable data.
- <u>Design experiment:</u> This is used to create our environment where we would manipulate the data as per the requirements and the dataset creation is explained in the section 2.7 in the Chapter 2.

4.2 Simulation of data

The following image shows the simulated data:



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Sl_no	FLIGHT	STATUS (EST DEP)	BAY	DEST	EOBT	TOBT	REVISED TOBT	TSAT	PUSH BACK	DEBOARDING	CLEANING	REFUELING	RELOADING BAGGAGE	JET BRIDGE	DOORS CLOSED
2	1	I52467	03:10	6	IDR	03:10	03:13	03:13	03:15	03:13	02:24	02:42	02:39	02:54	02:58	03:08
3	2	6E388	03:40	31	LKO	03:40	03:42	03:42	03:43	03:42	02:56	03:14	03:10	03:23	03:27	03:42
4	3	9I513	03:40	13	IXG	03:40	03:42	03:42	03:45	03:42	02:55	03:09	03:10	03:23	03:27	03:39
5	4	6E435	03:50	21	CCU	03:50	03:50	03:50	03:52	03:50	03:04	03:23	03:18	03:32	03:36	03:50
6	5	9I536	03:55	37	KLH	03:55	03:56	03:56	03:57	03:56	03:13	03:32	03:28	03:39	03:44	03:58
7	6	9I876	04:00	79	KLH	04:00	04:04	04:04	04:07	04:04	03:20	03:33	03:32	03:48	03:53	04:02
8	7	I52990	04:05	34	CCU	04:05	04:07	04:07	04:10	04:07	03:23	03:38	03:38	03:52	03:56	04:07
9	8	6E734	04:05	25	BOM	04:05	04:08	04:08	04:11	04:08	03:24	03:36	03:37	03:47	03:53	04:08
10	9	6E379	04:10	74	TRV	04:10	04:12	04:12	04:13	04:12	03:32	03:46	03:45	03:56	04:01	04:08
11	10	SG706	04:15	3	STV	04:15	04:20	04:20	04:22	04:20	03:42	03:54	03:54	04:01	04:07	04:14

Figure 21 – Simulated Data

The flight numbers, Estimated Departure, the parking bay and destination were obtained from the Kempegowda International Airport website of all the departing flights from the airport. The turnaround process takes about 30-53 minutes for an Airbus A320 or Boeing 737. These two types of aircraft are the most widely used aircrafts in the country for domestic flights.

1. **EOBT** – Estimated Off-Block Time – It is the time estimated at which the aircraft will start movement associated with the departure. It is filed with the flight plan and is same as 'Estimated Departure'. The flight plan can be submitted even before 12 days of the date of flight.

2. **TOBT** – Target Off-Block Time – It is the time that an aircraft operator estimates that an aircraft will be ready for pushback. It less than or equal to 5 minutes of EOBT. If TOBT is earlier than EOBT, then the EOBT is displayed as TOBT, until confirmed by aircraft operator or ground handler.

TOBT =TIME(HOUR(EOBT),MINUTE(EOBT)+RANDBETWEEN(0,5),SECOND(EOBT))

The above 'TIME' function is a built-in function that allows to create time with individual hours and minutes. The 'TIME' function is useful when one want to assemble a proper time inside another formula.

The syntax for the 'TIME' function is:
TIME(HOUR(x),MINUTE(x),SECOND(x))
Where,
x is the value of each cell.

The 'RANDBETWEEN' function is used to input random values automatically within the given limits. The syntax for 'RANDBETWEEN' function is:

RANDBETWEEN(x,y)

Where,
x is the upper limit
y is the lower limit.

Similarly, all the other time parameters are derived by using the 'TIME' and 'RANDBETWEEN' functions.

3. **REVISED TOBT** – It is the updated version of TOBT. If there are any delays in the pre-departure processes, the revised TOBT will be effective and is automatically updated.

4. **TSAT** – Target Start-up Approval Time – It is the time when the ATC gives approval for the pushback. The TSAT is taken 1-3 minutes after TOBT.

5. **PUSHBACK** – It is the time when the aircraft actually pushes back from its parking bay. Here, the pushback is same as the revised TOBT.

6. **DEBOARDING** – It is the time taken for the deboarding of passengers from the previous flight. The de-boarding time is assumed to be 12 minutes before the refueling time.

7. **CLEANING** – It is the time taken for the cleaning of the aircraft after the de-boarding of passengers from the previous flight. The Cleaning time is assumed to be -1 to 5 minutes before refueling time.

8. **REFUELING –** It is the time when the refueling process is completed.
   Refueling time is assumed to be 12 to 22 minutes before the jet bridge detach time.

9. **RELOADING BAGGAGE** – It is the time when the baggage are loaded into the aircraft. Reloading of baggage time is assumed to be 4 to 6 minutes before the jet bridge detach time

10. **JET BRIDGE** – It is the time when the jet bridge is detached from the aircraft, after the doors are closed. The Jet bridge closing time is assumed to be 10 to 15 minutes before the TOBT.

11. **DOORS CLOSED** – It is the time when the doors of the aircraft are closed, after the boarding of passengers. The doors closing time is assumed to be 1 to 3 minutes before the TOBT.

The table below shows the maximum range, minimum range for all the pre-departure processes, which are taken as explained in the section 2.8 of Chapter 2 and based on these range values, the time parameters are obtained.

Table 1 – Range of values for each parameter

Parameters	**Range**
TOBT	0 to 5 minutes <= EOBT
Revised TOBT	Same as 'TOBT', changes when there is delay in pre-departure processes
TSAT	1 to 3 minutes after TOBT
Pushback	Same as 'Revised TOBT'
Doors Closed	1 to 3 minutes before TOBT
Jet Bridge	10 to 15 minutes before TOBT
Reloading of Baggage	4 to 6 minutes less than Jet Bridge time
Refueling	12 to 22 minutes less than Jet Bridge time
Cleaning	-1 to 5 minutes before Refueling time
Deboarding	0 to 12 minutes before Refueling time

4.3 Algorithm for the data analysis:

The code is performed in Google Collab Notebook.

- Importing all the necessary libraries (pandas, NumPy, matplotlib, date-time, time delta)
- Simulating the data from various sources.
- Uploading the data set to google collab notebook and assigning the variable to the assigned path.
- Cleaning the data by dropping the values which are not read by python.
- Converting all the parameters into date – time data type.
- To get the total turnaround time (take off - expected arrival).
- Take the mean value of the Turn-Around Time (TAT).
- Calculating frequency of occurrence for scheduled turnaround time.
- Analysis for parameters using Multiple Linear Regression for all the 6 processes namely:
  a) Deboarding
  b) Cleaning
  c) Refueling
  d) Reloading of Baggage
  e) Boarding
  f) Door closed
- Considering all the six processes as the independent variable and pushback process as the dependent variable.
- Applying the multiple linear regression equation $y_i = \beta_0 + \beta_1 x_i 1 + \beta_2 x_i 2 + \ldots + \beta_p x_i p$ to all the parameters.
- The slope β_1 is different for all the processes but the intercept is same for all the process.
- Predicting the TOBT .
- Analyzing the expected result.

4.4 Flowchart of Data analysis :

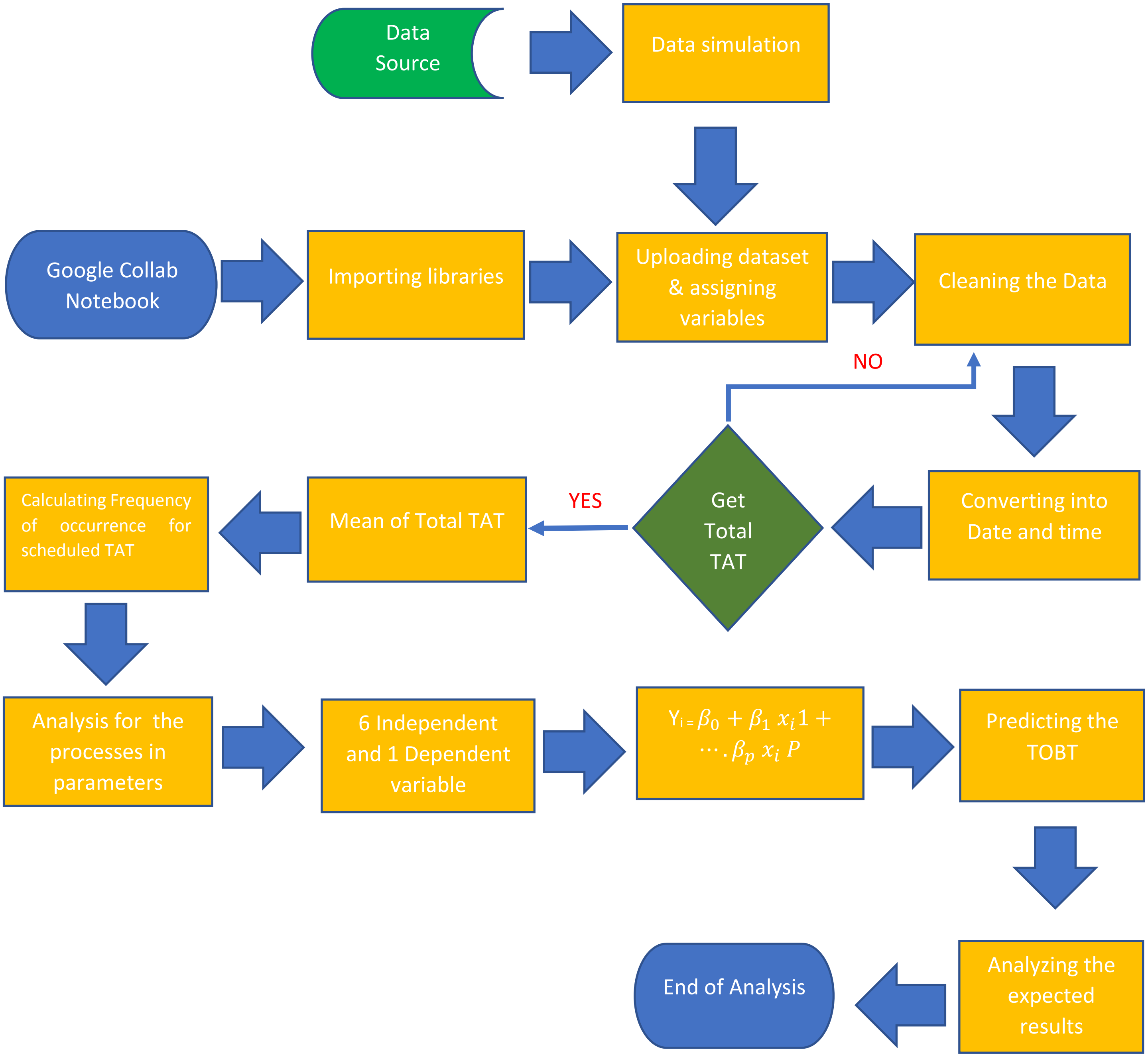


Figure 22- Flow chart of data analysis

CHAPTER – 5

IMPLEMENTATION AND DISCUSSIONS

5.1 Implementation

5.1.1 Python code for the web interface.

```python
#importing the libraries
import pandas as pd
import numpy as np
from datetime import datetime, timedelta
import streamlit as st
from PIL import Image
#current time
from datetime import datetime
import time
#importing the dataset in csv format
sampledata=pd.read_csv("SAMPLEDATA2.csv")

from datetime import datetime

now = datetime.now()
df = pd.read_csv("SAMPLEDATA2.csv") #displaying the entire dataset
st.title("FLIGHT DATA")  # add a title
st.write(df)
current_time = now.strftime("%H:%M:%S") #displaying the current time in hh:mm:ss
st.write("Current Time: ", current_time)

Flight_name = st.text_input("Enter Your FLIGHT number here.") #creating the textbox to input the flight number
sampledata=pd.read_csv("SAMPLEDATA2.csv")

def start_fun(F_name):
    sampledata["TOBT"] = sampledata["TOBT"].astype('datetime64[ns]')

    sampledata.dropna(inplace=True)
```

```python
    time_delta = timedelta(hours=0, minutes=5, seconds=0, microseconds=0)
    df = pd.DataFrame(sampledata, columns=["FLIGHT","TOBT", "TSAT",])
    data = pd.DataFrame(df, columns=["FLIGHT","TOBT", "TSAT", "five+","five-" ])

    for item in df["TOBT"]:
        df["fivep"] = df["TOBT"] + time_delta
        df["fivem"] = df["TOBT"] - time_delta

    comparison_column = np.where(((data.TSAT <= df.fivep ) & (data.TSAT >= df.fivem )) ,"GREEN",
    "-")
    comparison_column1= np.where((data.TSAT < df.fivem),"BLUE","-")
    comparison_column2= np.where((data.TSAT > df.fivep),"RED","-")


def boarding_status(F_name): #displaying the data for the entered flight number
    df = pd.DataFrame(sampledata, columns=["FLIGHT","STATUS (EST DEP)","BAY","REVISED TOBT","TSAT","DEBOARDING", "DOORS CLOSED","REFUELING","DOORS CLOSED"])
    df['FLIGHT'] = df['FLIGHT'].astype('str')
    name = str(F_name)
    df1 = df[df["FLIGHT"].str.contains(name)]
    return df1

def getTimeValues(first_var, second_var): #logic to display the flight for the next 30 minutes based on tobt
    if second_var + 30 >60:
        second_bar = second_var +30
        rem = second_bar % 60
        first_fin = first_var +1
        second_fin = rem
    else:
```

```python
        first_fin = first_var
        second_fin = second_var + 30
    return first_fin,second_fin

def getList(f_name, row_numm): #information which are displayed for the flights (next 30 mins)
    df2=pd.read_csv("SAMPLEDATA2.csv")


    df2['FLIGHT'] = df2['FLIGHT'].astype('str')
    name = str(f_name)
    long_df = df2[df2["FLIGHT"].str.contains(name)]
    number_list = long_df['Sl_no'].tolist()
    number = number_list[0]

    dff = pd.DataFrame(data=None, columns=["Sl_no","FLIGHT","BAY","TOBT","REVISED TOBT","TSAT","DEBOARDING","REFUELING","CLEANING","DOORS CLOSED"])
    tobt_val = long_df["TOBT"].values[0]
    st.write("TOBT OF THE PRESENT FLIGHT IS: ")
    st.write(tobt_val)
    split_list = tobt_val.split(":")
    first_var = int(split_list[0])
    second_var = int(split_list[1])

    res1, res2 = getTimeValues(first_var, second_var)

    fff = []

    for i in range(number, number+row_numm+1):
```

```python
        dfg = df2.loc[i]
        tobt_val1 = dfg["TOBT"]
        tobt_val1 = str(tobt_val1)
        split_list1 = tobt_val1.split(":")
        first_var1 = int(split_list1[0])
        second_var1 = int(split_list1[1])


        if first_var1 <= res1:
            if second_var1 <= res2:
                fff.append(df2.loc[i])

        else:
            continue

    new_df = dff.append(fff, ignore_index=True)


    return new_df


if(st.button('Submit',key="r")):


    F_name = Flight_name.title()
    if F_name =='':
        st.write("enter the flight name ")
```

```python
    elif F_name =='':
        st.write("enter the flight name and try again!!")

    else:
        output = start_fun(F_name)
    if output == "FLIGHT DELAYED":
        st.error(output)

    elif output == "FLIGHT ON TIME":
        st.success(output)
    elif output == "FLIGHT EARLY":
        st.info(output)
    else:
        st.write("")

        bs = boarding_status(F_name)
        st.write(bs)

        row_numm = 8

        li = getList(F_name, row_numm)

        st.write("THE FLIGHTS WITHIN THE NEXT 30 MINUTES ARE: ")
        st.write(li)
```

```python
#import keyboard

#timer = 0

#auto updating the user interface every 2 mins
#while timer < 1000:
#    time.sleep(20)
#    timer += 1
#   keyboard.press('r')
```

5.1.2 Flowchart for implementation of python code

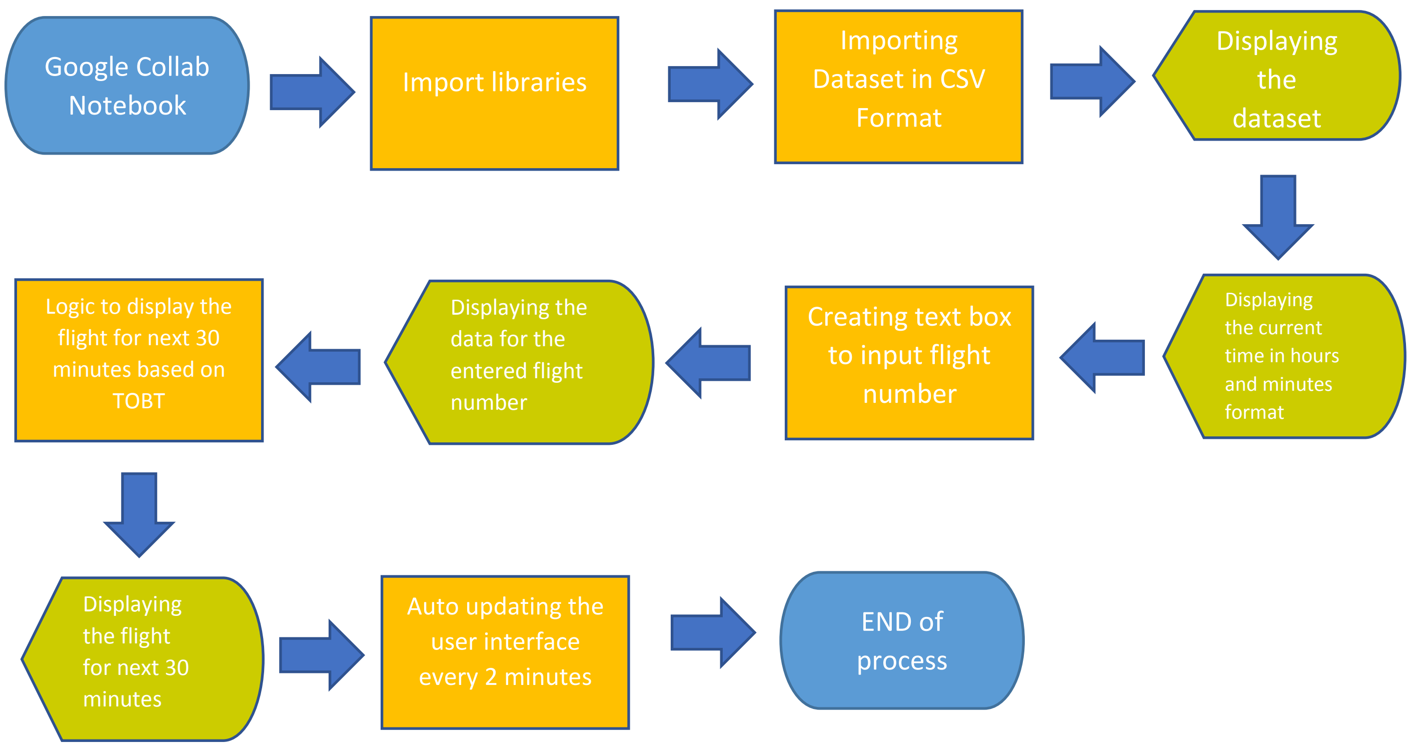


Figure 23 - Flowchart for implementation of python code

5.1.3 Output of the Web-interface :

- The entire flight data with all its parameters are displayed in the web interface. The sample output of the flight data is shown in the Figure 22.

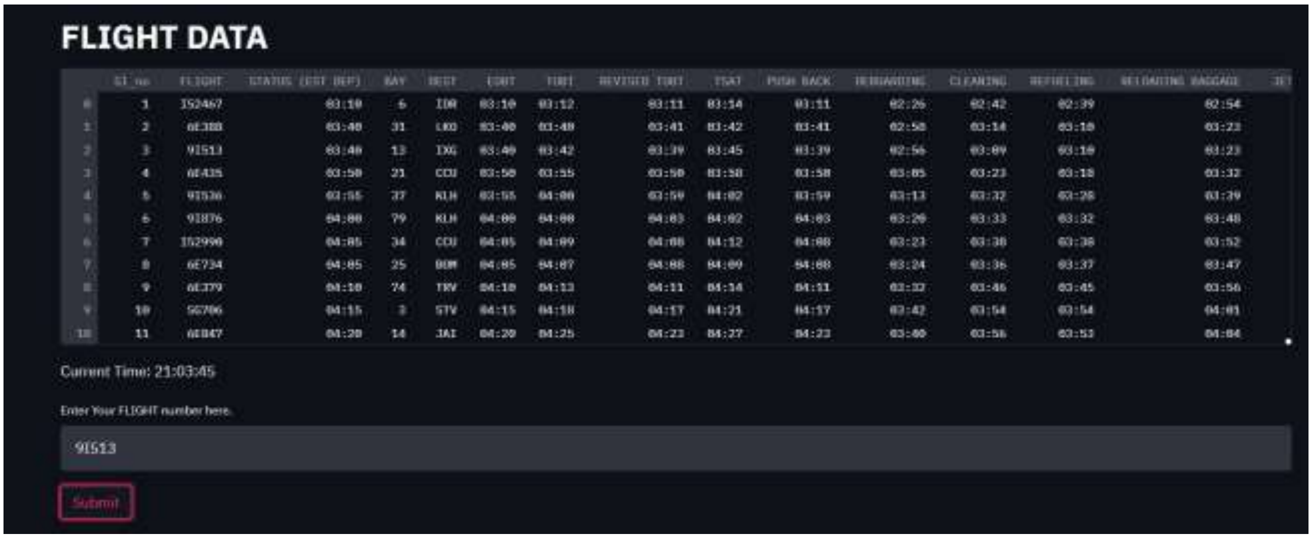


Figure 24 - Sample output of the web interface 1

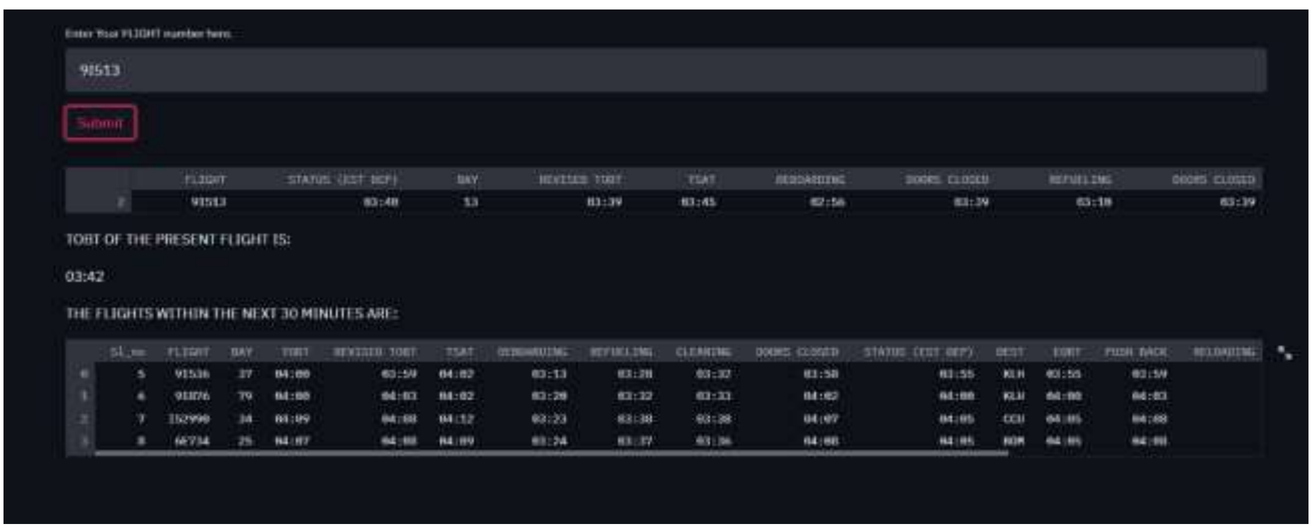


Figure 25 - Sample output of the web interface 2

5.2 Discussion

5.2.1 Web Interface:

- The live data is updated every two minutes and the web interface refreshes after the updating of data in the excel sheet.
- Below the 'Flight Data' table, the current time is displayed in the hh:mm:ss format.
- If one wants to know the entire data of a particular flight, its flight number is entered in the text box given below the 'Current Time' and the details of that flight and the next thirty minutes flights data are shown after clicking the 'SUBMIT' button.
- Revised TOBT is shown for every flight and any changes in the critical activities when entered by the ground handlers will cause a change in the revised TOBT column.
- The entire page is auto-updated every two minutes.

5.2.2 Multiple linear regression to obtain the revised Target-Off Block Time (TOBT):

In the given dataset, the different pre-departure processes are taken into consideration. These processes are:

- Deboarding
- Cleaning
- Refueling
- Reloading of baggage
- Boarding
- Doors closed

The time taken for each process to complete is taken and these act as independent variables in our multiple linear regression. Time taken to complete the TOBT process is taken as our dependent variable. The regression is performed and we obtain the following parameters for the equation.

β_0 is the y-intercept, β_1 is the slope or the co-efficient and $x1, x2, x3, x4, x5, x6$ are the processes which act as the independent variables.

Y is the revised TOBT which has to be predicted.

Equation for multiple linear regression is

$$y = \beta_0 + \beta_1(x1) + \beta_1(x2) + \beta_1(x3) + \beta_1(x4) + \beta_1(x5) + \beta_1(x6)$$

The parameters obtained are β_0= -1.4256, β_1 for deboarding is -0.393, β_1 for cleaning is 0.0574, β_1 for refueling is 0.3882, β_1 for reloading of baggage is -0.64205, β_1 for jet bridge is 0.9571, β_1 for doors closed is 0.6304.

Prediction for the first row of data is as shown below,

$$Y = -1.4256 + (-0.393)(131) + (0.0574)(140) + (0.3882)(150) + (-0.64205)(143) + (0.9571)(155) + (0.6304)(160)$$

$$Y = 191\ min$$

$$Y = 3hr\ 11min$$

This value of y when compared to the actual TOBT which is 191 min which is 3hours and 11 minutes, is very close to TOBT. The R^2 obtained is 0.973 which means that, closer the R^2 to 1 the better the co-relation between the pre-departure processes(independent variable) and the revised TOBT (dependent variable).

Table 2 - Summary Output

SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.973904381
R Square	0.948489743
Adjusted R Square	0.945130379
Standard Error	1.015380176
Observations	99

Table 3 – Coefficient of pre-departure processes

	Coefficient
Intercept	-1.4256
Deboarding	-0.393
Cleaning	0.0574
Refueling	0.3882
Bags	-0.64205
Boarding	0.9571
Doors Closed	0.6304

CHAPTER – 6

CONCLUSION AND SCOPE FOR FUTURE WORK

6.1 Conclusion

- Excel is used to store the data and Regression analysis was conducted on critical activities to predict the revised TOBT which is a crucial factor the decision making of the ATC.
- With the help of python software, a web user interface is created for the ATC and the flow of information between the ground handlers and the ATC is established in the display screen.
- This web user interface will affect the decision making of the ATC as the updates of the status of the flights are given every two minutes.
- This will avoid mass confusion between the Ground Handlers, Pilots and the ATC as the ATC will have a clear picture on the status of the flight and its ongoing processes.
- Since the data used here is static, auto updating for the live update of the data cannot be demonstrated but the process is designed in such a way that when the live data is obtained the auto updating happens every two minutes.
- At present, the air traffic controller looks out of the window using binoculars and watch the aircraft and estimates whether its pre-departure processes are completed or not. With the implementation of A-CDM, all the required information of the pre-departure status are displayed on the screen and the air traffic controller need not look out of their windows.

6.2 Scope for future work

Since we had a limited number of data, the results may not be accurate. Access to larger dataset and implementation of complex machine learning techniques help us to obtain accurate statistical results and to create a robust web interface as per the requirements of the ATC.

In India, A-CDM was first implemented at the Mumbai airport in 2015. Subsequently, Kolkata, Chennai, Jaipur, Guwahati, Ahmedabad and Thiruvananthapuram airports have also been included in the A-CDM framework. Further implementation in airports around the country has been initiated.

Each of these instances where A-CDM is being used or is in the process of being developed must be essentially considered as separate entities which are connected to each other through a central hub for information exchange.

In most cases, operational benefits may also bring about financial advantages. This is typically the case when meteorological conditions get worse. With A-CDM, normal traffic operations can be maintained for longer periods of time, which reduces the delays that would otherwise be generated because of the adverse conditions. A-CDM may also optimize the use of gates and stands, which may, in turn, reduce the need for extra expenditures such as expansion, especially in areas where space is limited. These are examples of situations where A-CDM has a direct positive financial impact on general operations. So, by implementing A-CDM in Kempegowda International Airport, we can reduce the departure delay time caused by the pre-departure processes and enhance the efficiency of the airport.

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APPENDIX

Appendix – 1

SIMULATED DATASET

Sl_no	FLIGHT	STATUS (EST DEP)	BAY	DEST	EOBT	TOBT	REVISED TOBT	TSAT	PUSH BACK	DEBOARDING	CLEANING	REFUELING	RELOADING BAGGAGE	JET BRIDGE	DOORS CLOSED
1	I52467	03:10	6	IDR	03:10	03:13	03:13	03:15	03:13	02:24	02:42	02:39	02:54	02:58	03:08
2	6E388	03:40	31	LKO	03:40	03:42	03:42	03:43	03:42	02:56	03:14	03:10	03:23	03:27	03:42
3	9I513	03:40	13	IXG	03:40	03:42	03:42	03:45	03:42	02:55	03:09	03:10	03:23	03:27	03:39
4	6E435	03:50	21	CCU	03:50	03:50	03:50	03:52	03:50	03:04	03:23	03:18	03:32	03:36	03:50
5	9I536	03:55	37	KLH	03:55	03:56	03:56	03:57	03:56	03:13	03:32	03:28	03:39	03:44	03:58
6	9I876	04:00	79	KLH	04:00	04:04	04:04	04:07	04:04	03:20	03:33	03:32	03:48	03:53	04:02
7	I52990	04:05	34	CCU	04:05	04:07	04:07	04:10	04:07	03:23	03:38	03:38	03:52	03:56	04:07
8	6E734	04:05	25	BOM	04:05	04:08	04:08	04:11	04:08	03:24	03:36	03:37	03:47	03:53	04:08
9	6E379	04:10	76	TRV	04:10	04:12	04:12	04:13	04:12	03:32	03:46	03:45	03:56	04:01	04:08
10	SG706	04:15	3	STV	04:15	04:20	04:20	04:22	04:20	03:42	03:54	03:54	04:01	04:07	04:14
11	6E847	04:20	14	JAI	04:20	04:20	04:20	04:23	04:20	03:40	03:56	03:53	04:04	04:09	04:23
12	G8834	04:25	8	BBI	04:25	04:29	04:29	04:32	04:29	03:46	04:06	04:01	04:12	04:16	04:28
13	6E477	04:30	14	GAU	04:30	04:32	04:32	04:35	04:32	03:47	04:01	04:00	04:16	04:20	04:30
14	6E332	04:35	25	BBI	04:35	04:39	04:39	04:41	04:39	03:52	04:09	04:06	04:24	04:28	04:38
15	G8805	04:45	30	LKO	04:45	04:48	04:48	04:50	04:48	04:03	04:20	04:18	04:32	04:37	04:44
16	6E6188	04:50	21	HYD	04:50	04:55	04:55	04:56	04:55	04:15	04:30	04:27	04:34	04:39	04:49
17	6E8239	04:50	13	MAA	04:50	04:50	04:50	04:51	04:50	04:11	04:29	04:26	04:35	04:41	04:48
18	AI503	04:55	102	DXB	04:55	04:59	04:59	05:01	04:59	04:12	04:27	04:25	04:41	04:47	04:58
19	I51624	05:00	26	DEL	05:00	05:05	05:05	05:06	05:05	04:22	04:39	04:36	04:46	04:52	05:02
20	G8406	05:05	109	VNS	05:05	05:07	05:07	05:08	05:07	04:28	04:44	04:41	04:50	04:55	05:09
21	6E2487	05:10	21	DEL	05:10	05:15	05:15	05:16	05:15	04:26	04:41	04:40	04:53	04:57	05:12
22	6E1456	05:15	1	DXB	05:15	05:20	05:20	05:22	05:20	04:34	04:46	04:46	05:04	05:08	05:18
23	6E6139	05:15	114	IXC	05:15	05:16	05:16	05:17	05:16	04:34	04:51	04:48	04:56	05:02	05:18
24	I5304	05:20	14	CCU	05:20	05:23	05:23	05:24	05:23	04:41	05:01	04:56	05:07	05:12	05:21
25	6E6932	05:25	3	JAI	05:25	05:27	05:27	05:28	05:27	04:40	04:58	04:53	05:06	05:12	05:26
26	I51983	05:30	123	LKO	05:30	05:30	05:30	05:33	05:30	04:45	05:01	04:58	05:14	05:19	05:34
27	G8808	05:30	145	HYD	05:30	05:33	05:33	05:35	05:33	04:42	04:59	04:56	05:12	05:18	05:29
28	6E841	05:35	4	GAU	05:35	05:40	05:40	05:43	05:40	04:54	05:12	05:07	05:23	05:27	05:36

30	29	6E7223	05:40	76	VNS	05:40	05:44	05:44	05:46	05:44	05:03	05:18	05:18	05:27	05:33	05:42
31	30	9I876	05:45	82	LKO	05:45	05:45	05:45	05:46	05:45	04:57	05:16	05:11	05:28	05:32	05:46
32	31	6E1109	05:50	1	STV	05:50	05:55	05:55	05:56	05:55	05:11	05:29	05:24	05:32	05:38	05:51
33	32	I51322	05:55	25	BBI	05:55	05:56	05:56	05:59	05:56	05:11	05:27	05:23	05:39	05:44	05:54
34	33	SG3023	05:55	30	DXB	05:55	05:58	05:58	06:01	05:58	05:17	05:33	05:29	05:41	05:46	05:57
35	34	6E602	06:00	98	MAA	06:00	06:02	06:02	06:03	06:02	05:17	05:35	05:32	05:44	05:49	06:00
36	35	G8285	06:00	3	GAU	06:00	06:04	06:04	06:07	06:04	05:15	05:28	05:28	05:40	05:46	06:02
37	36	2T621	06:05	30	HYD	06:05	06:08	06:08	06:11	06:08	05:24	05:43	05:39	05:52	05:56	06:05
38	37	6E7162	06:05	23	JAI	06:05	06:06	06:06	06:09	06:06	05:19	05:37	05:32	05:46	05:52	06:05
39	38	6E6507	06:10	12	BBI	06:10	06:13	06:13	06:14	06:13	05:27	05:42	05:39	05:51	05:56	06:11
40	39	6E6507	06:15	100	VNS	06:15	06:15	06:15	06:18	06:15	05:32	05:51	05:47	06:03	06:08	06:15
41	40	I5831	06:20	3	DEL	06:20	06:21	06:21	06:23	06:21	05:38	05:51	05:52	06:04	06:10	06:19
42	41	6E5161	06:30	111	DXB	06:30	06:35	06:35	06:38	06:35	05:55	06:12	06:07	06:15	06:19	06:30
43	42	I5972	06:35	5	IXC	06:35	06:35	06:35	06:36	06:35	06:03	06:17	06:15	06:25	06:29	06:35
44	43	G8320	06:35	7	HYD	06:35	06:35	06:35	06:37	06:35	05:57	06:17	06:12	06:19	06:25	06:37
45	44	6E466	06:40	26	IXC	06:40	06:45	06:45	06:48	06:45	05:54	06:08	06:09	06:24	06:30	06:40
46	45	6E6817	06:45	3	JAI	06:45	06:50	06:50	06:52	06:50	06:02	06:13	06:14	06:31	06:36	06:48
47	46	6E7246	06:50	30	GAU	06:50	06:53	06:53	06:54	06:53	06:06	06:21	06:21	06:31	06:37	06:50
48	47	I52469	06:55	23	DEL	06:55	06:56	06:56	06:57	06:56	06:07	06:23	06:22	06:37	06:42	06:53
49	48	6E467	06:55	26	CCU	06:55	06:58	06:58	07:00	06:58	06:16	06:32	06:33	06:46	06:50	06:56
50	49	I51562	07:00	14	STV	07:00	07:03	07:03	07:06	07:03	06:14	06:27	06:28	06:44	06:50	07:02
51	50	6E53533	07:05	25	VNS	07:05	07:06	07:06	07:07	07:06	06:29	06:48	06:43	06:52	06:56	07:07
52	51	SG3008	07:10	23	GAU	07:10	07:14	07:14	07:17	07:14	06:31	06:46	06:44	06:59	07:04	07:13
53	52	6E968	07:15	14	BBI	07:15	07:15	07:15	07:16	07:15	06:27	06:46	06:41	06:58	07:03	07:15
54	53	6E942	07:20	1	DXB	07:20	07:21	07:21	07:24	07:21	06:38	06:55	06:51	07:02	07:07	07:20
55	54	6E34555	07:30	3	IXC	07:30	07:32	07:32	07:34	07:32	06:47	07:01	07:01	07:10	07:16	07:32
56	55	6E356	07:30	59	STV	07:30	07:34	07:34	07:35	07:34	06:51	07:03	07:03	07:16	07:21	07:29
57	56	6E741	07:35	6	LKO	07:35	07:38	07:38	07:41	07:38	07:04	07:23	07:18	07:26	07:30	07:38
58	57	G8815	07:40	25	BBI	07:40	07:44	07:44	07:45	07:44	06:54	07:08	07:06	07:23	07:28	07:43
59	58	6E451	07:45	13	STV	07:45	07:47	07:47	07:50	07:47	07:10	07:23	07:24	07:31	07:36	07:47
60	59	I51334	07:50	125	PAT	07:50	07:53	07:53	07:56	07:53	07:14	07:33	07:29	07:36	07:41	07:48
61	60	6E2174	07:55	135	MAA	07:55	07:55	07:55	07:56	07:55	07:21	07:34	07:34	07:43	07:49	07:54
62	61	AI503	07:55	14	AMD	07:55	07:56	07:56	07:59	07:56	07:19	07:30	07:31	07:44	07:48	07:56
63	62	6E738	08:00	5	PAT	08:00	08:00	08:00	08:02	08:00	07:15	07:28	07:28	07:42	07:48	07:58
64	63	UK820	08:00	2	IXM	08:00	08:04	08:04	08:06	08:04	07:22	07:39	07:34	07:50	07:54	07:59
65	64	6E7974	08:05	23	BBI	08:05	08:08	08:08	08:10	08:08	07:20	07:39	07:34	07:45	07:51	08:05
66	65	SG517	08:10	77	DXB	08:10	08:11	08:11	08:13	08:11	07:30	07:42	07:42	07:54	07:58	08:11
67	66	6E687	08:15	7	HYD	08:15	08:17	08:17	08:20	08:17	07:32	07:49	07:45	07:58	08:04	08:14
68	67	6E485	08:20	37	DEL	08:20	08:20	08:20	08:23	08:20	07:45	08:00	07:58	08:04	08:10	08:24
69	68	G8274	08:25	44	GAU	08:25	08:26	08:26	08:27	08:26	07:51	08:04	08:05	08:11	08:17	08:25
70	69	6E6017	08:30	48	AMD	08:30	08:30	08:30	08:31	08:30	07:54	08:12	08:09	08:15	08:21	08:32
71	70	6E411	08:30	56	PAT	08:30	08:35	08:35	08:37	08:35	07:45	08:01	07:59	08:10	08:16	08:33
72	71	6E5005	08:35	51	IXC	08:35	08:40	08:40	08:43	08:40	07:50	08:07	08:04	08:16	08:21	08:37
73	72	I51321	08:40	23	IXM	08:40	08:43	08:43	08:46	08:43	08:06	08:18	08:19	08:25	08:31	08:41
74	73	6E6128	08:45	7	STV	08:45	08:46	08:46	08:49	08:46	07:57	08:11	08:12	08:26	08:32	08:46
75	74	SG3233	09:00	2	HYD	09:00	09:00	09:00	09:01	09:00	08:17	08:30	08:29	08:41	08:46	08:58
76	75	6E676	09:05	1	PAT	09:05	09:06	09:06	09:08	09:06	08:28	08:46	08:41	08:51	08:55	09:07
77	76	6E1799	09:10	26	DEL	09:10	09:11	09:11	09:14	09:11	08:31	08:51	08:46	08:55	09:00	09:09
78	77	I5996	09:45	2	MAA	09:45	09:46	09:46	09:49	09:46	09:09	09:27	09:23	09:32	09:37	09:43
79	78	AI610	09:55	21	PAT	09:55	09:59	09:59	10:00	09:59	09:08	09:21	09:22	09:36	09:42	09:55
80	79	UK818	10:15	5	DEL	10:15	10:15	10:15	10:18	10:15	09:36	09:52	09:48	09:58	10:03	10:14
81	80	SG3431	10:25	1	COK	10:25	10:29	10:29	10:32	10:29	09:40	09:54	09:54	10:06	10:10	10:27
82	81	6E855	10:30	30	BOM	10:30	10:31	10:31	10:32	10:31	09:55	10:06	10:07	10:18	10:22	10:34
83	82	I5991	10:40	26	BOM	10:40	10:40	10:40	10:41	10:40	10:03	10:22	10:18	10:25	10:30	10:43
84	83	UK850	10:50	2	COK	10:50	10:55	10:55	10:58	10:55	10:04	10:16	10:17	10:32	10:38	10:52
85	84	6E5413	10:50	23	PAT	10:50	10:50	10:50	10:52	10:50	10:17	10:28	10:29	10:36	10:41	10:53

APPENDIX – 2

Research Paper on Implementation of Airport Collaborative Decision Making in India, presented in the conference 'Jnana Chilume', organized by Jain deemed-to-be University.

Implementation of Airports Collaborative Decision Making in India

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Abstract: **Airports Collaborative Decision Making (ACDM), a concept to improve operational efficiency and performance by making the best use of available airspace and airport infrastructure by real time information sharing and Collaborative Decision Making. The airports are getting busier by the passing of time and it is necessary for airports to operate at its maximum potential, ACDM helps meet these demands. ACDM by making the best use of operational systems and available data of flights departure and arrivals at respective airports and establishes a collaborative environment amongst different airport & aircraft operators by quick information sharing between these operators. Doing this gives immediate benefits and increase predictability of inbound and outbound traffic. And also offers solution to ease traffic flow, avoid delays and increase all-round efficiency. It also benefits in optimizing the resource utilization, enhancing predictability, better terminal activity management, efficient and orderly flow of departures by reducing aircraft holding delays in the runway, consequently saving fuels by reducing delay at holding points and reducing carbon emission. ACDM has been fully implemented at 29 European Airports, implemented partially in the Indian Airports. This paper discusses about its importance, application and its future in Indian Airports.**

Keyword: **Collaborative Decision Making, International Civil Aviation Organization, Air Traffic Flow Management, Target Start-up Approval Time, Target Off Block Time**

I. INTRODUCTION

The very efficiency of our air transport system depends on the predictability of the flow of air traffic within the airspace. Achieving the predictability of Air Traffic mostly based on the Collaborative Decision Making (CDM), that is a quick exchange information between different partners, namely, Aircraft Operators, Air Traffic Service Providers, Airport Operators and Ground Handlers. For instance, flight update messages from the Air Traffic Flow Management (ATFM) system is used provide real time arrival updates to airports. Simultaneously, the departure planning information message from airports which provides realistic departure updates to ATFM [1].

With the increasing Air traffic day by day the predictability of the Air Traffic has been hampered. It is very common to see a long queue of departing aircrafts on the taxiway waiting to take-off. Airports Collaborative Decision Making (ACDM) plays a vital role in mitigating delaying factors within an airport. Implementation ACDM also benefits in optimizing the resource utilization, enhancing predictability, better terminal activity management, efficient and orderly flow of departures by reducing aircraft holding delays in the runway, consequently saving fuels by reducing delay at holding points and reducing carbon emission [4]. The key to developing an effective ACDM system is through information sharing between all the stakeholders who operate in an airport setting, this system is shown in Figure 1.

Fig 1: Stakeholder interaction for ACDM implementation [3]

1.1. ICAO guidance on ACDM

The International Civil Aviation Organization (ICAO) has been spearheading the development of CDM since its conception in 2003. The goal of CDM was to provide a framework to bring together all the stakeholders of the air traffic management system to contribute to increasing their mutual efficiency. The contribution of CDM directly impacts the ATFM system as a whole. Implementation of ATFM is linked to airport performance area including aerodrome operations, globally-interoperable systems and data, optimum capacity and flexible flights, efficient flight paths. For a harmonic and smooth working procedure of ATFM, there are certain operational needs. The data from the ATM which includes flight planning, surveillance, airspace capacities (the total number of flights that a controller can handle within a sector), airport capacities (total number of movements that an airport can handle during a given period of time), operational capacities (capacity associated with the tactical situation at the airport or airspace) restricted and reserved airspace must be given accurately and spontaneously [2].

Airports Collaborative Decision Making (ACDM) is designed around a group of partners working together to share high quality information by making decisions based on those high quality information where every bit of information has the exact same meaning to each and every partner. ACDM was introduced to mainly cope with heavy capacity reductions due mainly to enroute or airport bad weather conditions. The main objective of ACDM is therefore to generate a common situational awareness that would foster improved decision-making. ACDM does in no way dilute or suppress the responsibilities associated with decisions. ACDM partners are accountable for the decisions made by them and responsible for their actions. ACDM allows aerodromes, aircraft operators, air traffic controllers, ground handling agents, pilots and air traffic flow managers to exchange operational information and work together to efficiently manage operations at aerodromes.

ICAO has split the implementation of ACDM into two modules: B0-ACDM and B1-ACDM [2]. Each block identifies targeted timelines for the operational improvements associated with ACDM technologies and procedures.

B0-ACDM: The first block pertaining to A-CDM is entitled Improved Airport Operations through Airport-CDM. This module is defined so as to implement “collaborative applications “that will allow the sharing of surface operations data among the different stakeholders on the airport. This will improve surface traffic management reducing delays on movement and manoeuvring areas and enhance safety, efficiency, and situational awareness". The module is applicable locally "for equipped/capable fleets and already established airport surface infrastructure."

B1-ACDM: B1-ACDM (Figure 2) is entitled Optimized Airport Operations through ACDM Total Airport Management. The module is defined so as to enhance the planning and management of airport operations and allow their full integration for ATM using performance targets compliant with those of the surrounding airspace. This entails implementing collaborative airport operations planning and, where needed, an Airport Operations Centre (APOC).

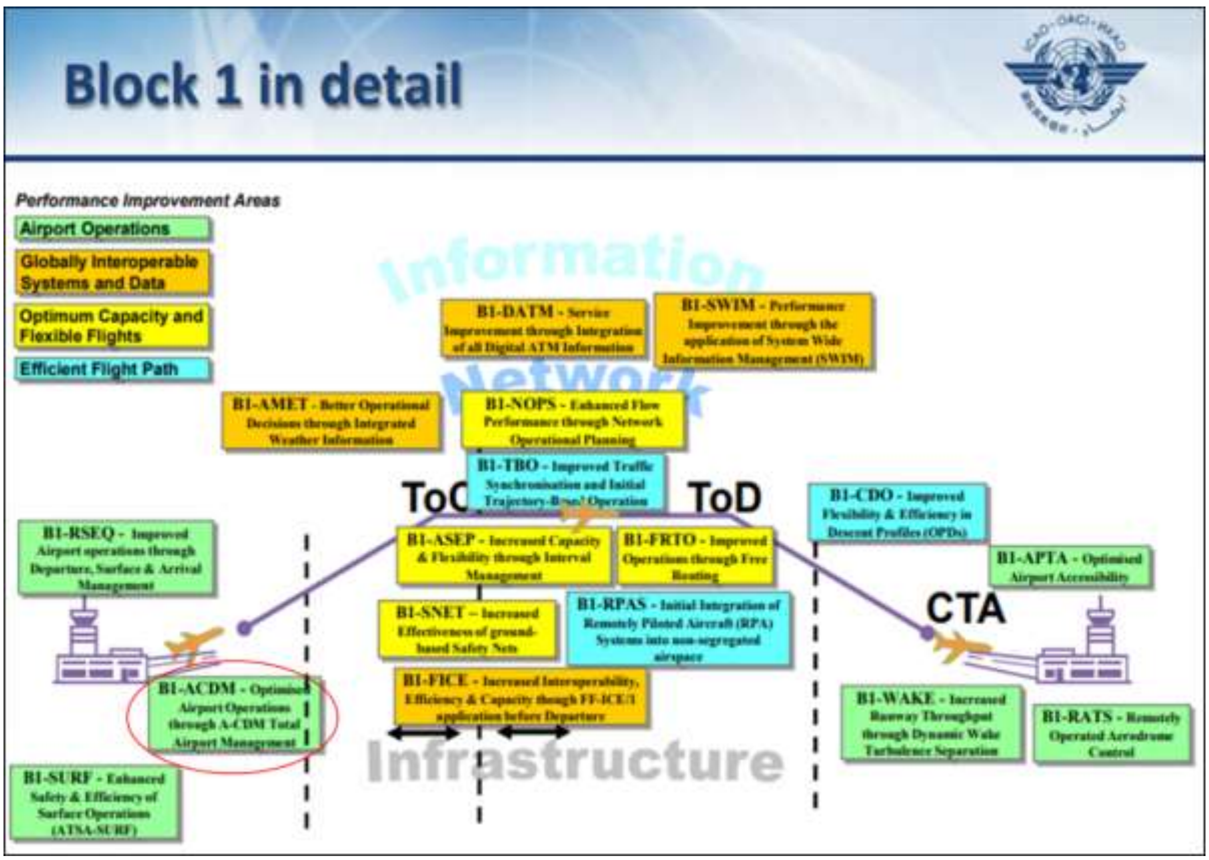

Figure 2: ICAO Airports System Block Upgrades, Block 1 [5]

1.2. IATA recommendations regarding ACDM

The International Air Transport Association (IATA) is a is a trade association of the world's airlines for the past 70 years. The stated goal for IATA is "to assist airlines by simplifying processes and increasing passenger convenience while reducing costs and improving efficiency" [6]. Hence, IATA has a keen interest in the implementation of ACDM and has provided its recommendations regarding ACDM.

One the key factors which have to be considered while designing ACDM is to realise that the system may vary between airport operators and air traffic service providers. For this reason, IATA recommends that all relevant personnel should be educated with respect to ACDM terminology. Further, ACDM parameters must be clearly defined in a manner that can be understood globally as many pilots may not be familiar with local definitions. Finally, IATA stresses on the need to design Target Start-up Approval Time (TSAT) generation algorithm to ensure equity among airlines and the need for effective communication of critical data among airlines [6].

II. REVIEW OF LITERATURE

2.1. Importance of ACDM for India

Over the past decade, the civil aviation industry in India has been growing at a rate of 10% on an average (Figure 3). While the current pandemic scenario has limited travel, these trends are expected to resume over the next couple of years. Analysis conducted by Business World [7] and India Brand Equity Foundation (IBEF) [8] during February-March 2019 indicate that by 2040 a steady rise in air travel is expected. Much of this growth is expected to be in domestic passenger traffic with international passengers following at a slightly slower pace (Figure 4).

While the air traffic movements in India have grown, there is a shortage of available airports in India. Specifically, 83% of flights originate and depart from just the top 15 airports in the country. This is much higher than the capacity handled by the top 15 US and Chinese airports, which is around 57% of total air traffic in their nations. Further many of these airports, for example Bengaluru airport, have only a single operational runway. While construction of multiple runways have been taken up in many of these airports, this may not satisfy the requirement which calls for multiple airports being available in the larger cities. Thus the implementation of ACDM could alleviate the congestion which is currently being experienced. With ACDM already being implemented in Mumbai since 2015, there have been some evident changes in the operations. These include enhanced orderly and efficient flow of departures, optimization of resource utilization by Airport Partners, better terminal activities' management. Importantly between the years 2015-17, fuel consumption has reduced by 12417 tons per annum and thus cutting down the CO2/NOX emissions by 39487 tons per annum. ACDM is expected to continue to impact the sustainable developments in Indian Aviation and bring in efficient framework to benefit all (including the passengers) [10].

Figure 3: Aircraft movement growth in India 2007 to 2019 [8]

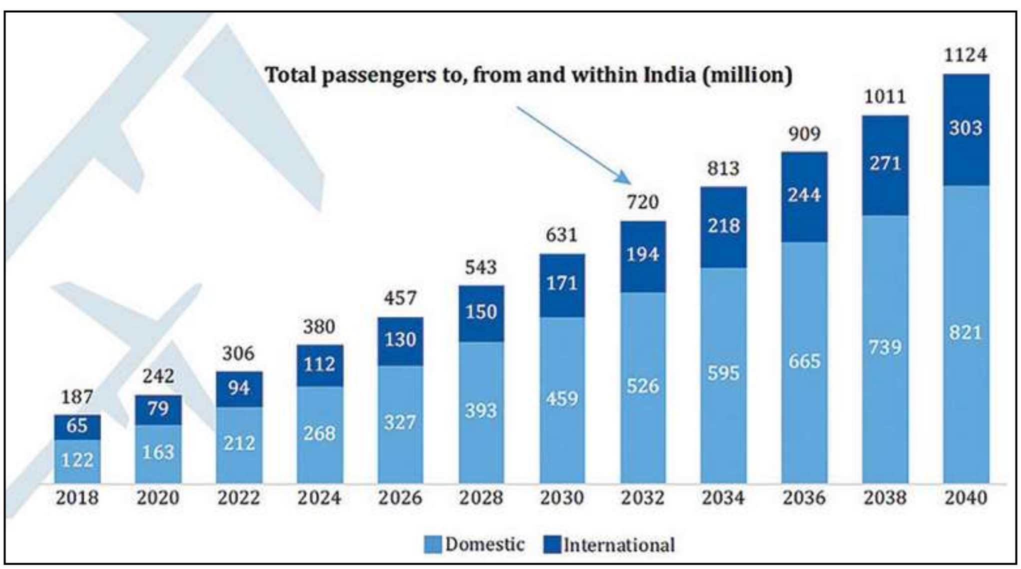

Figure 4: Air travel growth projection 2040 [7]

2.2. ACDM implementation at Indian airports

In India, AAI took initiative to implement A-CDM at Mumbai Airport which is operational since 10-12-2015. Implementation of ACDM in Mumbai, one of the world's busiest single-runway operations airports has taken a step towards Sustainable Aviation by reducing congestion. Subsequently, ACDM system is also made operational at Kolkata and Chennai Airports. The Government of India's Civil Aviation Policy also mentions the need of A-CDM implementation at all other major Indian airports. ACDM implementation at Ahmedabad, Jaipur, Guwahati and Trivandrum Airports is in the final stages. The Delhi, Hyderabad, Bengaluru and Kochi airports have evinced interest in the Airport Collaborative Decision Making (ACDM) system developed in-house by the Airports Authority of India (AAI). Data integration between Mumbai, Kolkata and Chennai A-CDM sites and ATFM has also been achieved [11]. The Adaptation of ACDM in Mumbai and Kolkata Airports has resulted in higher coordination between all operational partners, improved ground handling processes and improved programmability due to increased stability for all operational processes (e.g. Airlines, Airport and ATC) based on reliable target times.

2.3. Framework of ACDM for Indian Air Traffic Service Providers

The basic structure or the framework for the Air Traffic Controller (ATC) to visualize and take or make the necessary decisions. The data handling and optimization process is a major aspect in ACDM as it forms the core of the results which are produced and handed over to the ATC and other respective departments. Two key parameters which are displayed to the ATC are the Target Off Block Time (TOBT) and the Target Start-up Approval Time (TSAT). TOBT refers to the time when is a point in time to be monitored and confirmed by the airline/handling agent at which the ground handling process is concluded. TSAT is the time generated by the ATC at which the aircraft can begin the push-back process from its gate [9].

In the Indian context, the ACDM output to airline operators at Mumbai airport is shown in Figure 4. The system is designed to accept updates from aircraft operations on the ground to generate accurate TOBT data [10]. The TSAT generated by this system uses TOBT updates to determine the time when the aircraft is expected to begin the pushback process. This information is simultaneously shared with all the airline operators so that updates are transmitted in real time throughout the airport. A similar system has been developed for specific ATC use and is shown in Figure 5. While the relevant information is displayed, the Graphical User Interface (GUI) provided to the ATC allows selection of parameters which the ATC desires to monitor. Other features provided to the ATC include dynamic capacity updates, automated strip movement, automated runway change updates, etc.

One common feature of both displays is the colour coding of TSAT information. The colours are used to differentiate the aircraft status with respect to TSAT, which is shown in Figure 6. The start-up and the push back process forms the major part of the off-block time of an aircraft. The pilot will first contact the clearance delivery to request an en-route clearance between TSAT - 15 minutes to TSAT - 5 minutes which falls under the blue zone. The aircraft must be ready to Start-up/Push-back at TOBT and request SMC (GROUND) for Start-up/Push-back at TSAT – 5 minutes and TSAT + 5 minutes. This process falls under the green zone and if at TSAT +5 minutes which falls under the Red Zone, if the ATC has not received Start-up/Push-back request, the aircraft will lose its position in sequence. [9]

While the GUI designed to implement ACDM is discussed based on the Mumbai airport, other airports in India which are equipped with ACDM are expected to have a similar setup with modifications based on specific airport design.

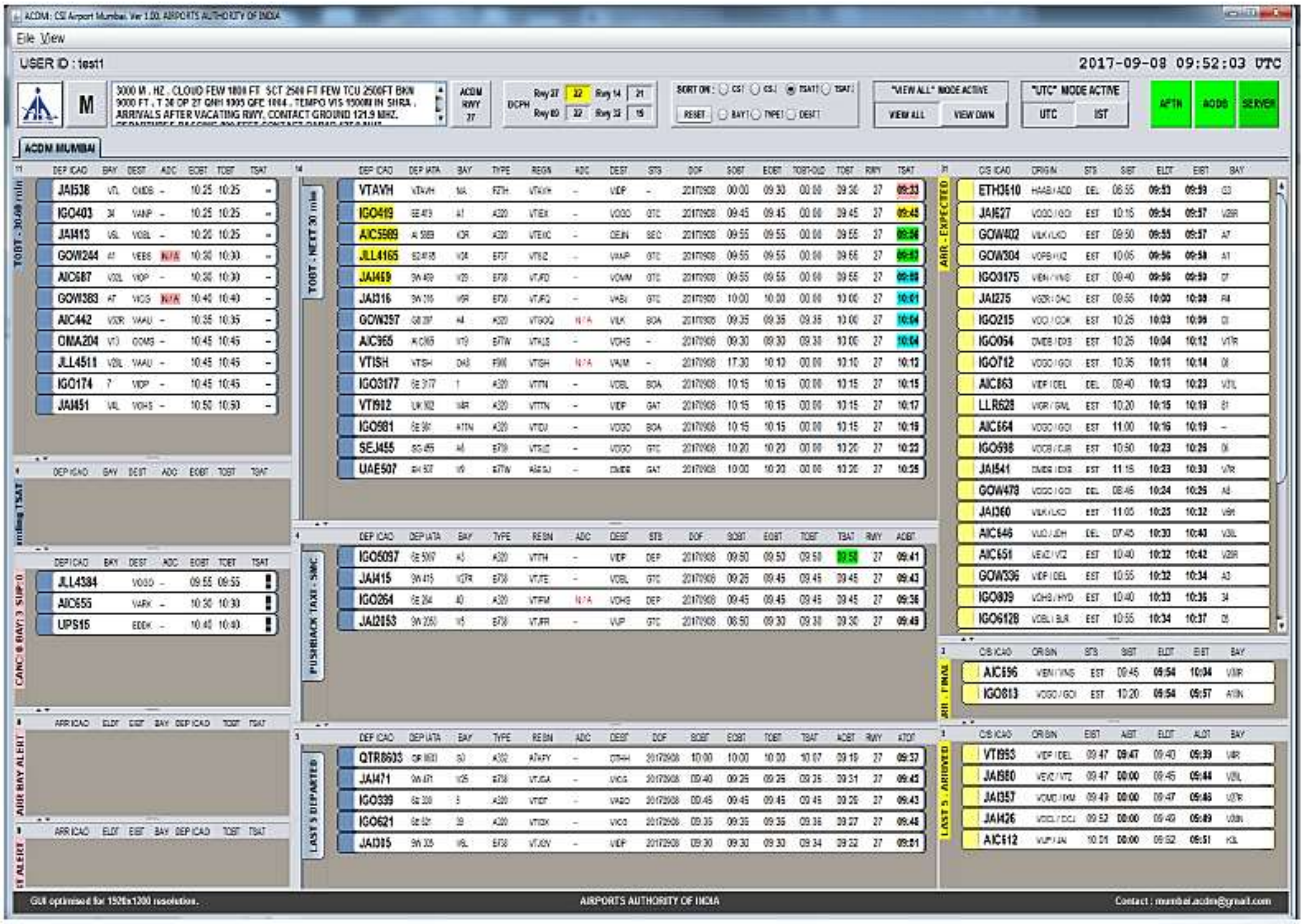

Figure 5: ACDM GUI for Airlines designed for Mumbai Airport [10]

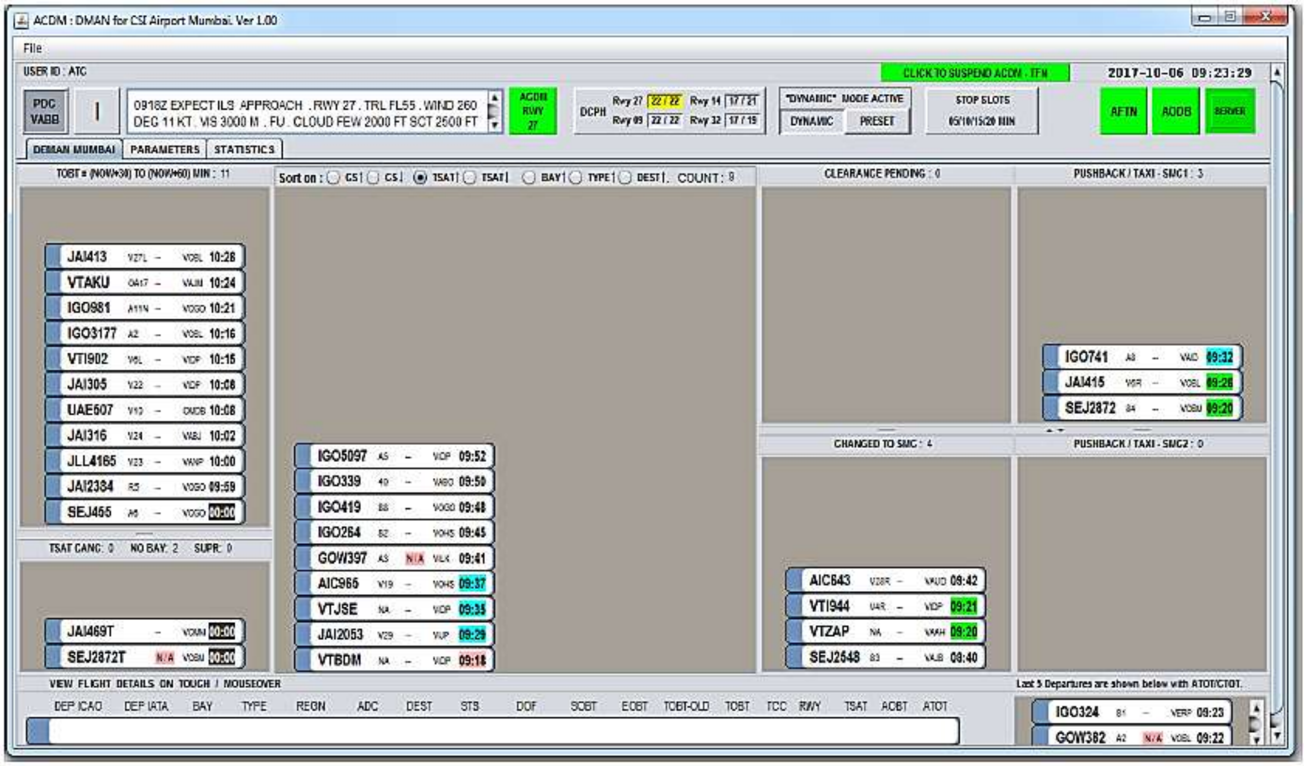

Figure 6: ACDM GUI for ATC designed for Mumbai airport [10]

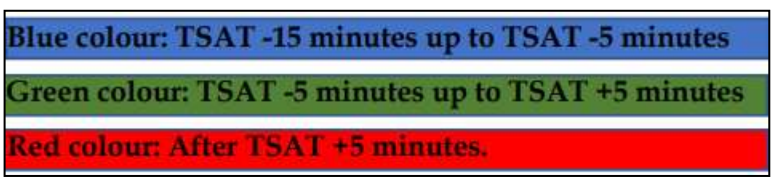

Figure 7: Colour code for TSAT [9]

V. CONCLUSION

Airports Collaborative Decision Making (ACDM) is a concept which was envisioned by ICAO in 2003 to enable efficient use of airport infrastructure. ACDM was developed as a part of the Air Traffic Flow Management (ATFM) process which enables improvement in quality of air traffic movements across the globe. In India, ACDM was first implemented at the Mumbai airport in 2015. Subsequently, Kolkata, Chennai, Jaipur, Guwahati, Ahmedabad and Thiruvananthapuram airports have also been included in the ACDM framework. Further implementation in airports around the country has been initiated. Each of these instances where ACDM is being used or is in the process of being developed must be essentially considered as separate entities which are connected to each other through a central hub for information exchange. The Graphical User Interface (GUI) deigned for each airport may vary as per the airport requirements but have a common structure which is required for usage by airlines and pilots from different airports. As multiple airports become equipped with regional ACDM, the future outlook would be to implement the ICAO B1-ACDM framework. This would provide enhanced, cross-border, application of Collaborative Decision Making using the System Wide Information Management (SWIM). The advantage of a well-executed SWIM would be experienced by all the stakeholders of the civilian aircraft industry, which would extend beyond the confines of the aerodrome.

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