Air Traffic Control Database Management System for Seamless Transit

Varun Bhat[1], Manasee Parulekar[2], Professor Kajal Jewani[3]

[1-2]Student, Dept. of Electronics and Telecommunication Engineering, Vivekanand Education Society's Institute of Technology, Maharashtra, India

[3]Assistant Professor, Dept. of Computer Engineering, Vivekanand Education Society's Institute of Technology, Maharashtra, India

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Abstract - *An Air Traffic control system is one of the key elements of a functional airport. However big or small an airport may be, without an air traffic control tower (ATC tower) and an air traffic controller managing the activities in the ATC tower, the airport cannot function properly. It is very important for an air traffic controller to have the necessary provisions, relating to dispatch, in place for a seamless transit of airplanes, cargo and passengers. In this paper we have evaluated several other literature papers relating to air traffic control management and then proposed our own database management system relating to air traffic control.*

***Key Words*: Air Traffic control system, Dispatch, ATC tower, Transit, Database management system**

1.INTRODUCTION

Since the onset of the new millennium, air travel as a sector started to grow at an unparalleled rate. According to the statistics, the aircraft fleets will increase in the next few years, which will lead to the congestion of airspace; the growth of fuel consumption and the process by which aircrafts are safely separated in the sky will be more complicated [10].

There are three main reasons for this phenomenon: Firstly, the growth of the middle class and the upper middle class has led to substantial increase in the success of the commercial aviation department. Second, the increase in the number of low and ultra-low-cost carriers has enabled the market to function at prices that were previously unimagined. This has led to these carriers capturing higher market share with every passing year. Finally, the authorities that manage the airport infrastructure are investing in growth of the size and carrying capacity of an airport. In one way or the other, this leads to an upscale in global carrying capacity. In terms of modeling of a robust system, there have been several major types proposed in the literature, as shown in [6]. Lagrangian models [7], [8] are used to describe flight trajectories of individual aircraft [9].

Apart from these three major reasons, an increase in air traffic can also be associated to growth in the number of destinations accessible via air-travel. In the early 1990s, the provision of an airport was mainly restricted to Tier-1 and some of Tier-2 cities in India. This trend has changed over the course of last decade, with airports coming up in almost all of Tier-2 cities. With globalization reaching every small city of India, this expansion has led to airports coming up in cities of other tiers too.

The following chart shows the number of scheduled passengers (in millions of people) boarded by the global airline industry. The range of years for this chart is from 2004 to 2022.

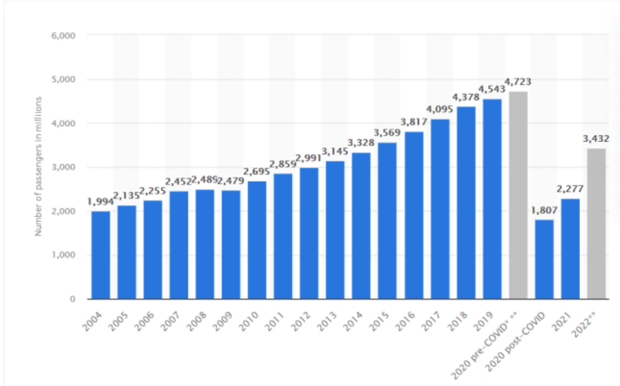

Chart -1: Number of scheduled passengers (in millions) boarded by the global airline industry from 2004 to 2022 [12, fig 4]

In this paper, we compare different Air Traffic Control management systems. Next, we propose our model for an ideal ATC database management system using MySQL and Xampp.

2.1 Air Traffic Control System

Ground-based air traffic controllers assist airplanes to navigate on the ground and through controlled airspace. Apart from this they provide advising services to aircrafts in non-controlled airspace. The paramount objective of air traffic control (ATC) around the globe is to circumvent crashes, organize and accelerate air traffic flow, and offer pilots imperative information and necessary support. ATC has its application in security or defense in some countries, and is operated by the military in others.

The air traffic controllers communicate with the pilots via radio and monitor the flight plan and the flight's location via a radar. The main role of the air traffic controller is to make sure that the overall functioning of the airport is smooth and hassle free. Minor delays could cost the airline and the airport a huge sum of money.

The following are the processes for a flight by an air traffic controller:

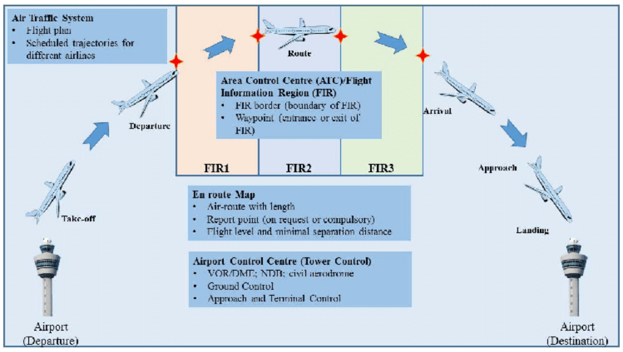

Fig -1: Flight map for an aircraft [13, fig 2]

The aforementioned figure shows a flight plan that an airplane follows as it travels from a departure airport to a destination airport. The process from the perspective of an air traffic controller is as follows:

When a flight is set for departure from the departure airport to the destination, the aircraft is assisted to pushback from the gate. The air traffic controller has a set of unique identification alphanumerical values assigned to each aircraft going in and out of the airport. The pushback command is given after all the contents of a flight are loaded. In the case of commercial airlines, it is after all the passengers and their luggage has boarded the fight. After receiving the pushback command, the flight starts its journey towards the runway. This process is called taxiing. This process is the same for an aircraft arriving (landing) and departing (taking off) from the airport. The air traffic controller guides the aircraft from its gate to the runway through the taxi way. The controller has to do this very efficiently as each aircraft is set to depart at a fixed time and any delays would cost the airline and the airport a huge amount. The controllers also have to manage multiple aircrafts as at a busy airport in a busy time frame there are multiple flights getting in and out of the airport every minute. After the aircraft reaches the runway, the controller has to convey the exact time at which the flight can be allowed to depart. The controller has to make sure that the runway is clear of any obstacles and the direction in which the aircraft would be flying is clear of other airplanes.

After the controller gives the aircraft a green signal for taking off, the aircraft takes off from the runway. The controller has to make sure that the aircraft is at an altitude which would not create any other problems for airplanes flying in the same region. After achieving a certain altitude, the aircraft enters the area control center or Flight Information Region (FIR). A flight information region is a designated area of airspace where a flight information service and an alerting service (ALRS) are offered in aviation. The International Civil Aviation Organization (ICAO) assigns operational responsibility of a specified FIR to a particular country. The airspace of smaller countries is covered by a single FIR, while the airspace of larger countries is divided into multiple regional FIRs.

After completing most part of the travel, the aircraft approaches the destination. This process is similar to the taking off process but this process takes place in an opposite chronology. The destination airport's ATC tower receives the aircraft's location on their radar. A controller is assigned to guide this aircraft to the destination airport. As the aircraft starts the approach, the controller starts vacating the runway and a spot in the airport (in the form of a vacant gate). After the controller gives the aircraft a green signal to land on the runway, the aircraft lands and starts the process of taxiing to the assigned gate. The controller guides the aircraft to the gate and moves on to the next flight.

This is how an aircraft completes its flight's path.

2.2. Shortcomings in the current model

There is an ever-growing need for increasing the efficiency of the air traffic control system. A delay in the magnitude of minutes can lead to substantial loss for the airport and the airline. Airplanes are prone to aviation manufacturing defects wherein a component of an aircraft or a complete aircraft is manufactured differently than its pre-decided original design or specifications and becomes unreasonably dangerous. Now, if we consider a situation of an airplane malfunctioning on the runway, it can create a huge delay for the scheduling of other flights coming in and out of the airport. Environmental factors are an addition to the list of spontaneous occurring shortcomings for an air traffic controller. Neglecting human error, there are other malfunctions that can occur in the equipment of functioning for the controller.

3. Literature Review

In [1] MINGTEN TSAI has proposed that with growing machine-based approach and automation, enough margin should be given to expert Air Traffic Controller since their skills, systematic procedures and knowledge would improve the efficiency and safety of the system. The controllers must be proficient with technical organization and must be prepared for non-uniformity of the level of automation for different aircrafts while failures in the system.

Here, CNS based technology is implemented functioning on Communication, Navigation and Surveillance. It maintains the data and voice exchange between pilots with the airport crew and the air traffic controller. The satellites transmit GPS signals and the GPS receiver gives pilot the positioning, velocity and precise timing information while cruising the aircraft so they could estimate their location on Earth. Also, here the ground-based network stations monitor the accuracy of the satellite positions. Hence the controller would be able to access data and conduct air traffic control. On the other side, another issue that has to be considered is that the keep increasing automation level will limit the ATC controller's margin and they cannot effectively monitor the ATC procedure at some point [2]. This could be dangerous when the automation system failure or unpredicted environmental disturbances occur.

The typical flight includes several phases: ground operations from the gate to the taxi way and holding short at the runway, takeoff clearance and climb to reach the cruising altitude, cross-country flight to the destination, approach and landing guidance at the destination airport, and finally taxi back to the gate.

In [2] CHENG-LUNG WU and ROBERT E. CAVES showcase the situation of research in air traffic control till the year of 2001. The intention behind writing this paper was to review the relevant research papers relating to issues of air traffic control and prioritize productive research areas. The research papers to be reviewed were categorized into two areas namely "system" and "airport".

After understanding the basic functioning of an air traffic control system, the authors give us a literature review structure for research papers relating to the system. Each and every block of the structure is reviewed in detail with an emphasis on minimizing errors.

The authors next move to the research paper review of the airport. Research papers relating to airport capacity, airport facility utilization, aircraft operations in the airport terminal maneuvering area and airport ground operations were reviewed and relevant information was zeroed out.

It was concluded that a common goal was to establish a safe, reliable and environmentally sustainable gate-to-gate air transport system. For future research in this domain, certain valuable fields were to be focused upon. First, a link between broad-network air traffic flow management and local ATC in the airport is required for system-wide integration. Second, future development should concentrate on developing an airport information system that incorporates features for aircraft processing in the TMA as well as a dependable airport capacity allocation and prediction mechanism. Third, research should be conducted to improve the regularity and consistency with which schedules are implemented.

In [3] Esa M. Rantanen and Peter M. Vlach in the year 2007, describe their take on a database populated with the results of past assessments of ATC research literature, structured according to a novel ATC measures taxonomy, and available via the World Wide Web and a custom web interface. The proposed database system will also allow for ongoing upgrades, allowing the database's contents to grow and remain relevant for the foreseeable future.

The goal of this paper was to organize the measurements presented in the ATC research literature in a way that would allow the authors to assess the current state of the art in ATC research, gauge progress since Hopkin's (1980) study, and highlight areas that needed more research. To achieve these goals, the authors created a measure taxonomy that allows for cross-referencing between different types of measures, their purposes, and the data needed, potentially facilitating the development of comprehensive models of ATC performance and hence additional measures as new data sources become available.

Next up, the authors give a detailed description about taxonomy of ATC measures. The taxonomy presented in the paper is based on an extensive review of literature related to ATC R&D. After understanding about the taxonomy, the authors move to the basic database design. The ATC measures database used in the paper was constructed using the MySQL open source, relational database management system.

In conclusion, through this paper the authors create a database of different measures and metrics used in ATC R&D, as reported in published literature. Because the database and its maintenance tools are available on the internet, it is hoped that a number of ATC researchers would opt to contribute to the database's ongoing update as new research is published or old, important, but maybe obscure studies are discovered. The database can be developed into a truly valuable tool for all future ATC R&D activities around the world as a result of these collaborative efforts.

In [4], the author G.Hemanth Sai describes the air traffic control and management system. The design of an efficient system should be administered to alleviate the congestion between air stations by recommending a selection of shorter and safer routes to pilots and managers of the system. The software created will be working with a gateway connecting clients, pilots, traffic controllers and the admin. The manager will receive updates from the database regarding the divergence in flights, probability of clashing and time-scaled with current velocity. The manager then connects with managers through an email system in a pre-formatted reply form. The admin monitors the working of the overall systems. The web application is connected to the database to provide users with real-time data.

The project is being developed using the Java and PHP programming languages. Building software to operate the air traffic control system and direct distinct flight routes for different flights travelling from the source to the destination, with the "Prim's Algorithm" for calculating the shortest distance between the stations and providing pilots with quick suggestions.

In [5], the authors introduce the air traffic command monitoring system (ATCCMS), a new system for air traffic control based on the information integration technique that can reduce the controller's man-made errors and ensure flight safety and it covers some of the most important aspects of ATCCMS. Human controllers' focus and stress levels are so high during high-volume aviation operations that their mistakes are a significant source of risk to flight safety. The majority of errors are caused by the controller's speech.

The model includes a temperature sensor, a visibility sensor, a speed sensor, and an accelerometer. It gives analogue information on the parameters, which is then transformed to digital using the ADC IC0808. The ADC's output is then sent to the microprocessor. The ADC's data is then sent to the microprocessor. The microcontroller output is connected to the LCD in the plane circuit to display parameters to the pilot so that he or she may locate the malfunction. The output of the microprocessor is also sent to the control room via a Zigbee module. A Zigbee module is also included in the receiver. It receives the signal transmitted by the transmitter and connects to the computer via USB. It receives the signal from the transmitter and connects to the computer via USB to detect any obstacles on the runway in order to prevent accidents and plane collisions. However, the ATCCMS speech recognition component currently uses a Verbex voice recognition card which does not allow dynamic call signs or complicated multi-instruction signals, which air traffic controllers desperately want. As a consequence, the system must be updated.

3. Proposed Database Management for an ATC system

We use phpMyAdmin which is a free and open-source administration tool for MySQL. We create our model database on this platform and perform operations to create a seamless transit between airplanes. Along with phpMyAdmin, we also use XAMPP. XAMPP is an acronym that stands for "X" or Cross-Platform, "A" or Apache, "M" or MySQL, with the Ps standing for PHP and Perl, respectively [11]. XAMPP allows a local host or server to test a functional website or client on computers and laptops before uploading it to the main server. It is a medium that provides a suitable environment for verifying and testing the functionality of systems based on the aforementioned criteria using the host's system.

3.1 ER Diagram

ER Diagram or Entity-Relationship diagram is a schematic representation of the entities or factors involved in the functioning of a model. It shows the relationship between the entities and the attributes of each entity with a mention of key attributes.

The following diagram shows the ER Diagram of the proposed model:

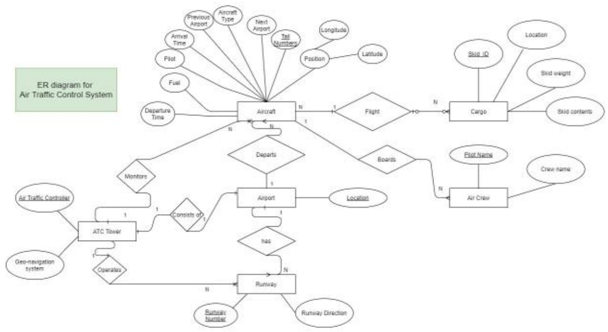

Fig -2: Entity Relationship Diagram

To understand the aforementioned ER diagram, we need to look at the different entities present and their relationships with other entities. The aircraft entity has the following attributes: departure time, fuel, pilot, arrival time, previous airport, aircraft type, next airport, tail numbers (key attribute) and position. The tail numbers attribute is unique for each aircraft and hence is the primary attribute. Several aircrafts depart from an airport which is why there exists a "1 to N" relation between airport and aircraft. Location is the primary attribute of the airport entity. One airport has many runways which is why the relationship between airport and runway is "1 to N". Runway has two attributes: runway direction and runway number (primary attribute). One aircraft boards air crew which is why the relationship between aircraft and aircrew is "1 to N". Aircrew has Pilot name (primary attribute) and crew name as its attributes. Aircraft and cargo have "N to N" relation with cargo having its own set of attributes as mentioned in the schematic diagram.

Moving to the ATC tower entity, this entity is the foundational block of the entire airport. Every airport has one air traffic control tower and it monitors many aircrafts. This is the reason for its relationship being "1 to N". ATC tower also operates multiple runways of the airport and hence the relationship between the two entities is "1 to N". If an airport has only one functional runway at a time (ex. Gatwick airport, London), the relationship here would be "1 to 1". The ATC tower entity has two important attributes. One attribute is Geo-navigation system which helps the controller locate and direct airplanes in and out of the airport. The other attribute is air traffic controller. This is the primary attribute of this entity

3.2 The Database and important queries

The model database consists of all the previously mentioned entities and their attributes along with their relationships with one another. The database also contains triggers and views which are essential for updating and viewing queries which showcase limited information.

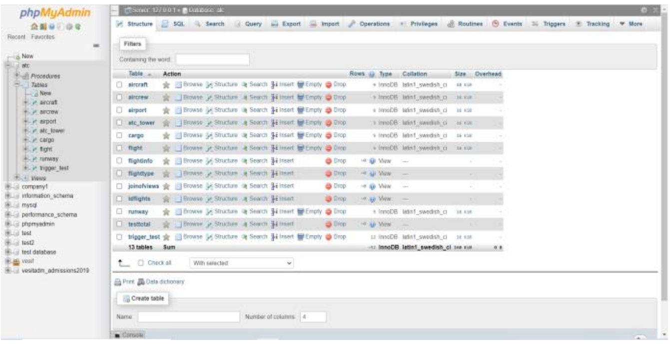

Fig -3: Model Database

- Geographical information

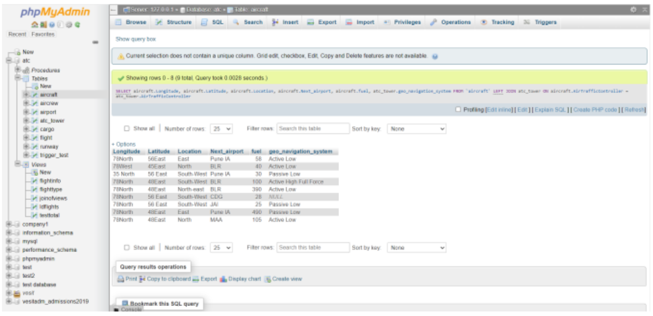

Fig -4: Query for Geographical information

This query helps the air traffic controller to manage flights and minimise delays. This query takes into consideration the geographical elements of the flight that the controller tracks via the geo-navigation system. Along with the geographical aspects, an economic viewpoint can be drawn from this query by estimating the amount of fuel that the airport will require to sustain all flights coming into the airport. The geo-navigation system can be adjusted according to the traffic at the airport. The system can function at active low at times when there is lesser activity at the airport.

- Complete Flight information

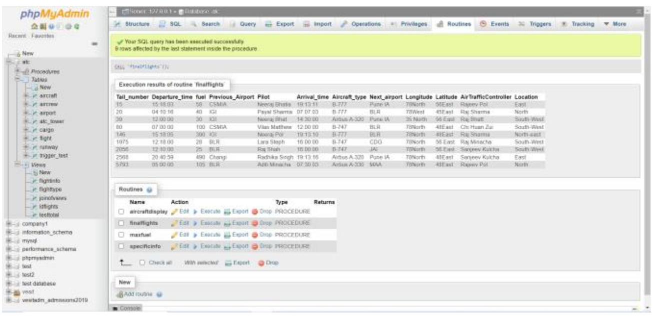

Fig -5: Query for Flight information

This query is a procedure that enables the air traffic controller to attain complete information about a flight. The controller can look at this procedure to understand the current status of a flight. Knowing the arrival and the departure time of an aircraft, the controller can block a gate for an aircraft. At this gate, prior requirements of fuel and food supply trucks can be arranged to minimise delay and increase efficiency of functioning.

- Updating the database

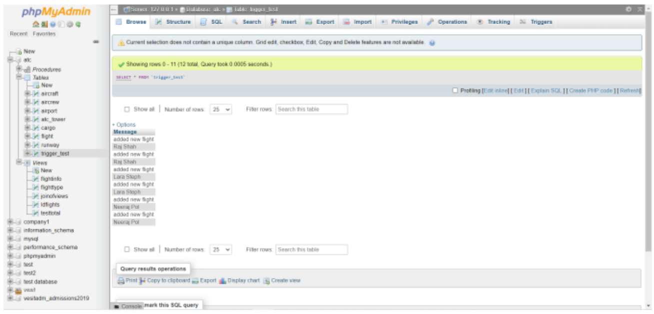

Fig -6: Trigger for Updating the database

This trigger helps the air traffic controller to get updated on the newest additions to the airport. The message section of the database gets updated when a flight lands into the airport. The message reads “added new flight” and mentions the name of the pilot handling the aircraft. This trigger helps in ensuring that all of the flights in the airport are well accounted for by one of the air traffic controllers.

4. Conclusion

In this paper, we have taken into consideration air traffic control systems and the shortcomings in the model. An air traffic control system is the foundational element of an airport. With an increase in the number of passengers using airplanes as their preffered mode of transportation, the need to minimise delays and make the experience hassle free is increasing with every passing day. With the aviation industry emerging as one of the fastest growing industries in the world, there needs to be a better alternative of managing aircrafts. We have formulated an air traffic control database management system that automates the process of storing essential data and increases the access to information for a controller. This would help in efficient scheduling of aircrafts and minimisation of delays which would inturn lead to saving money for both airports and airlines.

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