Exploring Aircraft Flying Data for Improved Air Operations in Pakistan using MobilityDB

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3. Wherever I have quoted from the work of others, the source has been always cited. With the exception of such quotations, this thesis is entirely my own work.

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DEDICATION

"To my loving mother and father who always prayed for my success, emphasized to work hard and learn"

"To my wife who supported me in every walk of life"

"To my affectionate children who always used to ask … Baba …. Aap Har Waqt Kia Karte Rehte Hein?"

May Allah bless them all and make them successful in both of the worlds!

Aameen…!

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My gratitude to my dear parents, who always prayed for my success everywhere and my wife who stood side by side with her silent prayers keeping me determined to complete this journey. I acknowledge all the sacrifices they offered in terms of time and bearing my partial availability on most of gatherings conducted at home. My special appreciation to my mentor, Dr. Muhammad Ali Tahir, who always took interest and solved my problems. He has been so kind during supervision, extending his support and paying great attention to every concern. Without any hesitation, I would accept that his encouraging approach made me comfortable to complete my research. May Allah reward him in return. My thanks to Dr. Salman Atif and Dr. Muhammad Tariq Saeed for guiding and helping me to fulfill thesis requirements. I would not forget to name Dr. Ejaz Hussain (Associate Dean – IGIS) and Dr. Javed Iqbal (Head of Department – IGIS) for their continuous support and guidance in completing my research. Their support, courtesy and availability are really recognized. May Allah bless them for their kindness.

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ABSTRACT

The incessant advancements in location tracking technologies have brought up spatiotemporal datasets being vital in real time usage (e.g., tracking, monitoring, and decision making etc.). In addition, spatiotemporal datasets can be used to extract certain patterns, configuration of routes and different scenarios depending upon different temporal behaviors found in the datasets. To fulfil the need of achieving spatiotemporal database management systems, several platforms like Hadoop, SECONDO and the most recent MobilityDB have been developed by researchers to resolve this challenge of information extraction. Apart from the rest, MobilityDB an extension of PostGIS, is the first ever commercially available moving objects' database having the capability to incorporate mobility datasets and perform complex pattern extraction using spatiotemporal queries. Building trajectories is one of the important features of MobilityDB. This study has got its uniqueness on the basis that no research has yet been carried out on flights dataset, to the best of our knowledge. In this study, we have used Pakistan International Airlines (PIA) flights dataset to build aircraft trajectories using MobilityDB with the objective to explore the trajectories for optimizing air operations based upon different parameters including aircraft taxiing time, flight diversion, monitoring flight routes and distance among different flights in the air etc. The methodology used in the study is simple and adaptable for the new researchers for future enhancements in the research area. The results produced by the study have highlighted different areas of improvements in air operations. We found that minimizing taxiing time at Islamabad and Lahore International airports will have a good impact on air operations. The policy / decision maker would be getting more informed and well intime decisions based upon the statistics and facts to improve air operations of PIA and Pakistan.

Chapter 1

INTRODUCTION

1.1 Background

Human being is always in search of new opportunities and accepting challenges at the same time. These challenges are sometimes so demanding, and people go beyond their limits. The current century came up with a variety of new concepts and lifestyles in addition to abundance of digital gadgets. Time is money is a well mentioned statement that shows the importance of time resembling with the current trends of life. The latest gadgets and technology are always better than the older in terms of performance and efficiency. With the advent of tracking of moving items and now becoming part of our daily use in routine life. We are least bothered about movement tracking of people, vehicles, ships and even the aircraft. Moving Objects like humans (Wang et al., 2019), vehicles, trains, ships, and aircraft etc. can be tracked, monitored, and anticipated (Alessandretti et al., 2017). Every moving object such as car, vessel, aircraft, or pedestrians do not move at random, but collectively form patterns (Christophe et al., 2016). The movements form spatiotemporal datasets and can be used to extract patterns, configurations and different scenarios depending upon different temporal behaviors found in the datasets. There is no doubt in usefulness of tracking technologies, however they produce their risk factor involved with each type these tracking. Social media platforms in addition to cellular phone are also doing different types of tracking e.g., pattern analysis through usage of these social media platforms. These tools are becoming so powerful that they can predict the human behavior using machine learning algorithms and deep analysis techniques. Our study orbits around already tracked aircraft movements i.e., flight history data. Every movement of an aircraft can be tracked starting from switching on/off its engine, speed, direction, altitude, latitude, and longitude etc. We will be using flights data to perform diverse types of analysis and produce results based on these analyses (Güting et al., 2000).

1.2 Motivation

Moving objects (MOs) are the objects that change their location or value with time. The plenty of tracking devices and technologies has been resulted in collecting the massive amounts of useful data that describes temporal evolution of moving objects and their values. The flights' data has greater importance on the basis life (humans), cost (aircraft, fuel, maintenance, parking etc.) thus creating opportunities to get familiar with the tools, techniques and database inventions that support efficient usage of this asset and to utilize these technologies in our national needs. With the help of spatiotemporal database management systems, we can answer the complicated questions like:

(a). How many PIA flights passed through a specific point in the air? How many PIA flights are within a specific region during a specific point of time? Scenario may be understood by recalling 'No Flying Zone' concept.

(b). How close any two PIA flights came to each other during operations? Measuring the chances of Collision between two flights.

(c). How many touch-and-go, missed approaches were took place?

(d). What is the percentage of flight diversion?

(e). What is the airport wise average taxi-out and taxi-in timings of flights?

1.3 Relevance to National Needs

To cope up with technology speed, every department in the country is struggling towards the automation of their systems including public and private organizations. Transportation industry including both ground and air are investing millions of rupees in the race. To get maximum benefits of automation with the latest technology of MobilityDB, the departments dealing with spatial and temporal data must upgrade their systems to PostgreSQL database management system, as MobilityDB functionality is equipped as extension to PostgreSQL only. Using this platform, they can utilize the spatiotemporal

query management functionality of MobilityDB. Moreover, this will initiate the future research by efforts to bring this high-impact technology (MobilityDB to cloud level as Platform as a Service) to commercial geospatial applications. This can open a new horizon in Pakistan with the latest research in Mobility Analytics and its implementation in Pakistan.

1.4 Literature Review

Godfrid et al., (2022) state that moving objects (e.g., bikes, cars, trucks, pedestrians) change their spatial features incessantly over time. MOs are represented as series of spatiotemporal points, of the form (x, y, t). MO data are typically distributed into parts, called trajectories. We can perform different types of analyses over these trajectories, e.g., pattern matching, semantic analysis. The raw data is found in form of discrete points, however, in most of the cases we need a continuous representation of trajectory, and this requires appropriate interpolation functions. After implementing these functions, the trajectories are called continuous, otherwise they remain discrete.

Moving Object Databases (MODs) are databases that store the positions of MOs at any point in time, in other words, to represent a continuous function from an instant to a point with signature. For instance, temporal floats may be used to represent how the utility bill of a house changes across the time. On the similar lines, a temporal point may represent the evolution in time of the position of a moving object like a vehicle or a pedestrian, reported by a GPS device, resulting in a temporal geometry of point type. On the same lines, a route denotes a certain spatial trajectory that a moving object can take, without specifying date and/or time with it (Zimányi et al. 2020).

MOs such as cars, vessels, aircraft, or pedestrians collectively form patterns while moving. These patterns may be formed in two ways: by groups that share some functional relationship, such as groups of animals moving together, or by cohorts, which have some

other factor in common, such as trains that have the same destination. They are interested in analyzing the latter patterns, which we call traffic flows. A traffic flow is represented by a set of trajectories. This gives rise to several challenges including visualizing of all trajectories such that a user can easily find traffic flows of interest; how to select these traffic flows; how to analyze their dynamics, i.e., their behavior etc. (Christophe et al., 2016). They studied that traffic flows have intrinsic properties that can be displayed and analyzed even in complex visualizations (Scheepens et al., 2015). In addition, traffic flows can have other dimensions, such as altitude, speed, type of moving object, etc., which can evolve over time (Christophe et al., 2016).

Initially, research in spatiotemporal datasets have been separately studied, i.e., the temporal and the spatial aspects separately. The main idea is to cross the systems and database managements of spatial and temporal data separately and establish the spatiotemporal data management system. Most of the research carried out with the aim to extend the spatial databases with the integration of temporal evolution and some studies were carried out by extending temporal databases with the integration of spatial evolution (Newell et al., 1992).

There are two main research prototypes for moving object database that are available in literature. These are SECONDO (Guting et al., 2005) and HERMES (Pelekis et al., 2015). The first one is an open-source database system, all the functionality is implemented from the scratch, but it reuses the file systems of Cassandra and Berkeley DB. SECONDO consists of three modules naming the kernel, the optimizer, and the GUI. Like Mobility-DB, HERMES, also follows abstract data type (ADT) approach. ADT approach implements operations and types for the spatiotemporal data in an extensible database. HERMES integrates with Object-Relational Database Management System (ORDBMS). It also has type systems which have base type, interval type and time point and geometry

types like point, line, rectangle, and segment. The sliced representation of is adopted for spatiotemporal types used in HERMES. Query language is like SQL but have different syntax of Oracle and PostgreSQL (Guting, et al., 2005).

There are three different trajectory analysis techniques. These techniques include direct manipulation, visual analytics, and MOD queries. Direct manipulation visually represents the raw trajectories and allows the user to efficiently explore them and highlight interesting subsets using convenient views and simple mouse interaction. This technique purely requires manual work. However, the visual analytics provide a rich toolbox of data transformations and visualizations that help a human analyst studying and exploring complex movement events present in the dataset. The MOD defines query operators accessible to the user through textual query languages. They can perform complex computations over large data sets efficiently with a little amount of manual work required (Srinivasan et al., 1993).

Jung et al., (2011) is of the view that delays in air operations negatively impact other areas in the air traffic system, even those far from the airport. Such delays not only add uncertainty and complexity in controlling aircraft, but also affect the ability of flights to meet scheduled arrival times at destination airports, resulting in economic and environmental cost due to increased fuel usage and emissions. They presented the concept and evaluation of the “Spot and Runway Departure Advisor (SARDA), where real-time optimized advisories for managing surface traffic were tested in a human-in-the-loop (HITL) environment”. The experimental trial of surface optimization algorithms in HITL environment showed promising results in taxi delays and fuel/emissions in heavy traffic situations. Both estimated fuel consumption and engine emissions generated by taxiing aircraft in the movement area were also reduced with a good percentage.

To the best of our knowledge, MobilityDB has never been used to analyze flights dataset till date as for as the work presented in this thesis is concerned.

1.5 Objectives

This study aims to achieve the following objectives:

- To build aircraft trajectories using MobilityDB
- To explore and analyze aircraft trajectory data for improvement in air operations based upon different parameters like monitoring ‘No Flying Zones’, evaluating collision chances of flights, assessing landing approach/Touch-and-Go, evaluating aircraft taxiing timings and assessment of flight diversion at different airports of Pakistan.

Chapter 2

MATERIALS AND METHODS

2.1 Study Area

The study area for this research includes almost all airports of Pakistan; here we have mentioned sixteen airports for which we found the flights data. All these airports have been shown on the map of Pakistan in Figure 2.1, spreading over all area of Pakistan. Province wise distribution of study area is given in Table 2.1. It is displayed in the table that there is one airport in Islamabad Capital Territory (ICT), two airports in each Gilgit-Baltistan, Khyber Pakhtunkhwa, and Sindh, three in Balochistan and six airports are in Punjab.

The dataset contains flights for all airports mentioned in the study area. However, later we came to know that there are certain areas / airports in Pakistan for which 100% flight path coverage is not available as we encountered loss of data issue due to less coverage in these areas during subsequent data processing steps. These airports include Bahawalpur (BHV), Chitral (CJL), Gwadar (GWD), Gilgit (GIL), Quetta (UET), Rahim Yar Khan (RYK), Skardu (KDU), Sukkur (SKZ) and Turbat (TUK). Therefore, flights with missing Take-off and/or landing information have been filtered for these low coverage airports. In general, we can say that airports in Northern and South-Western parts of the country lack complete coverage of flight tracking by FR24. For better monitoring and assessment of flight behaviors as these airports, efforts are in hand at the data source to minimize the coverage issues.

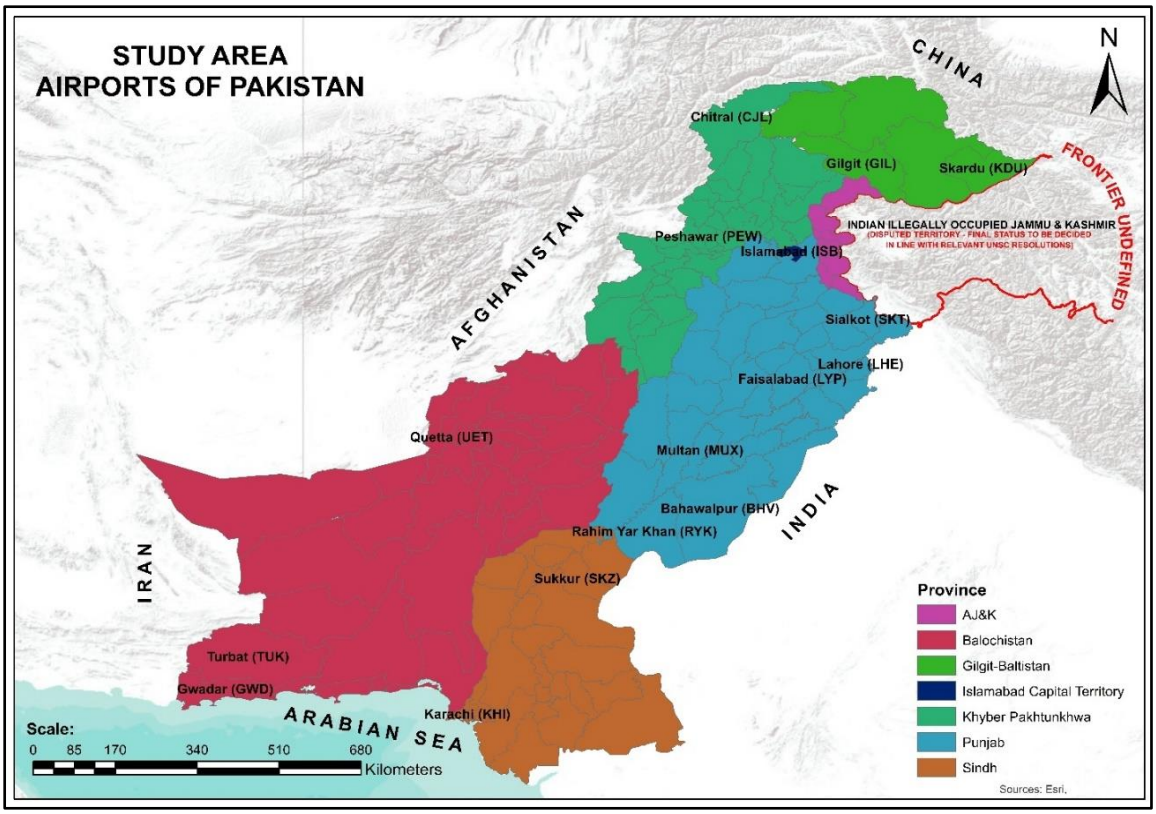

Figure 2.1. Study area map.

Table 2.1. Pakistani airports (province wise).

S No	Airport Name	Province	S No	Airport Name	Province
1	Gwadar (GWD)	Balochistan	9	Bahawalpur (BHV)	Punjab
2	Quetta (UET)		10	Faisalabad (LYP)	
3	Turbat (TUK)		11	Lahore (LHE)	
4	Gilgit (GIL)	Gilgit-Baltistan	12	Multan (MUX),	
5	Skardu (KDU)		13	Rahim Yar Khan (RYK)	
6	Islamabad (ISB)	Islamabad Capital Territory	14	Sialkot (SKT)	
7	Chitral (CJL)	Khyber Pakhtunkhwa	15	Sukkur (SKZ)	Sindh
8	Peshawar (PEW)		16	Karachi (KHI)	

2.2 Dataset

Flying information (flights' dataset) of Pakistan International Airlines (PIA) has been used for this study. It is sourced from a commercial website FlightRadar24. Initially, we contacted concerned offices of PIA and Civil Aviation Authority (CAA), Pakistan for provisioning of data. But due to procedural delays and formalities we anticipated and preferred to get the required dataset from other sources. Subsequently, we decided to contact FligthRadar24. The dataset includes all PIA Fleet / Aircraft held on PIA inventory and domestic/local flights operated within Pakistan from 01 January 2022 to 30 June 2022 (6 months – 181 days).

2.3 FlightRadar24

Flightradar24 (FR24) is a global flight tracking service that provides with real-time information about thousands of aircraft around the world. It is currently available online, iOS (iPhone, iPad, iPod Touch) and Android devices. FR24 started as a hobby project in 2006 when two Swedish aviation geeks decided to build a network of Automatic Dependent Surveillance – Broadcast (ADS-B) receivers in Northern and Central Europe. Using the ADS-B technology, an aircraft gets its location from a GPS navigation source (satellite), the ADS-B transponder on aircraft transmits signal containing the location and much more. ADS-B signal is picked up by a receiver connected to FR24 feeding data to FR24. In 2009, FR24 opened the network and made it possible for anyone with an ADS-B equipment. Many parts of the world were quickly covered, but the quest to provide global ADS-B coverage is still ongoing. The website holds dataset of almost all airlines of the world. On cruising altitude (above 30,000 feet) FR24 covers 100% of Europe and of the USA. There is also good coverage in Africa, Australia, Brazil, Canada, Caribbean, China, Colombia, Ecuador, India, Indonesia, Japan, Malaysia, Mexico, Middle East, New Zealand, Pakistan, Peru, Russia, South Taiwan, Thailand, and Venezuela.

The overall access/coverage of the world is already undertaken. It is important to highlight that the ADS-B coverage in Northern and South-western parts of Pakistan is not completely available. The airports in these areas include Bahawalpur (BHV), Chitral (CJL), Gilgit (GIL), Quetta (UET), Rahim Yar Khan (RYK), Skardu (KDU), Sukkur (SKZ) and Turbat (TUK).

2.4 Data Acquisition

The dataset can be accessed through subscription of the website as there are limited features which are available for free. The data downloading is also one of the features available on payment. The website offers four different subscription plans. The first of them is the 'Basic' which is by default selected for and every visitor of FR24. Remaining three plans offer different charges and features for data accessibility options. The complete details of these subscription plans are available on FR24 website. This study requires datafiles of flight history therefore only that part of subscription is given in Table 2.2. We have used Business subscription plan to speed up data downloading process.

Table 2.2. Subscription plans of FR24.

S No	**Plan**	**Subscription (USD)**		**Features / Details**
		Monthly	**Annually**	
1.	Basic	No charges		No downloading (History of last 7 days)
2.	Silver	1.49	9.99	10 files per day (History of last 90 days)
3.	Gold	3.99	34.99	25 files per day (History of last 365 days)
4.	Business	49.99	499.99	60 files per day (History of last 3 years)

The dataset has three categories:

1. PIA Fleet Information.
2. Flight Basic Information.
3. Flight Details Segment.

2.4.1 PIA Fleet Information:

As per the mentioned data source (FR24), from 01 January to 30 June 2022, PIA held with 34 aircraft on its inventory. They include different aircraft types including Airbus A320, Boeing 777, and ATR 42. The details of PIA fleet and summary of domestic flights is given in Table 2.3. We have shown the aircraft details for which domestic flights data exists during said period. The count of these aircraft is 20, the flights of rest of 14 aircraft are either international or it is beyond the period (January – June 2022). We have downloaded the dataset in two phases i.e., initially from January to March 2022 (Phase I) and later April to June 2022 (Phase II) was also included in the dataset to have a good volume of data.

It is pertinent to mention that the successful flights have only been considered here which have the status of either Landed or Diverted to some other location. Flights with status other than Landed/Diverted are not included. The main reason for filtering these flights is that most of them have coverage issues or some of them were scheduled but not operated.

The list of aircraft inventory shown in Table 2.3 is produced as per the data source website. The downloading process has been completed with one aircraft tail number at a time. Once it is over, i.e., all its flights were downloaded successfully and its record keep was done, the next aircraft tail number was selected for data downloading process. Figure 2.2 shows the summary of downloaded flights' data.

Table 2.3. PIA flights data summary.

S No	Aircraft Type	Reg. No	Tail No	No of Flights		
				Phase I	Phase II	Total
1	PIA Airbus A320-214	AP-BLA	3031	118	128	246
2	PIA Airbus A320-214	AP-BLB	2155	244	179	423
3	PIA Airbus A320-214	AP-BLS	3060	186	210	396
4	PIA Airbus A320-214	AP-BLU	2719	135	141	276
5	PIA Airbus A320-214	AP-BLV	2758	192	158	350
6	PIA Airbus A320-214	AP-BLW	2789	177	210	387
7	PIA Airbus A320-214	AP-BMX	4392	181	167	348
8	PIA Airbus A320-214	AP-BOK	7784	189	162	351
9	PIA Airbus A320-214	AP-BOL	7792	187	173	360
10	PIA ATR 42-500	AP-BHH	0645	46	69	115
11	PIA ATR 42-500	AP-BHI	0653	38	33	71
12	PIA ATR 42-500	AP-BHM	0659	25	136	161
13	PIA ATR 72-500	AP-BKX	1037	0	17	17
14	PIA Boeing 777-240(ER)	AP-BGJ	33775	8	5	13
15	PIA Boeing 777-240(ER)	AP-BGK	33776	15	0	15
16	PIA Boeing 777-240(ER)	AP-BHX	35296	8	0	8
17	PIA Boeing 777-2Q8(ER)	AP-BMH	32717	8	0	8
18	PIA Boeing 777-240(LR)	AP-BGY	33781	6	4	10
19	PIA Boeing 777-240(LR)	AP-BGZ	33782	5	2	7
20	PIA Boeing 777-340(ER)	AP-BHV	33778	4	0	4
Total PIA flights:				**1772**	**1794**	**3566**

2.4.2 Flight Basic Info:

This dataset contains basic information about a flight including flight date, flight No, source airport, destination airport, scheduled time and total flight time etc. Figure 2.3 shows its depiction on data source. The same has been downloaded and recorded with its Flight Detail CSV file name. We must highlight that majority of PIA aircraft, especially Airbus and Boeing, do fly for both domestic and international flights as shown in Figure 2.3. Therefore, it remained a challenging task to filter all international flights and downloading only domestic flights. The record of each flight and its details in CSV format have been maintained; To see an example of this record keeping, Appendix 'A' is given that shows all flights of Tail No 3031 of PIA Airbus A320-214 aircraft. We can see that this Tail No has completed 246 domestic flights within six months (January to June 2022). This kind of record keeping has been maintained for each aircraft. The details of fields in Flight Basic Info segment are given in Table 2.4.

2.4.3 Flight Details:

This segment contains the detailed information about path/route information followed by the flight during its operation. In this data segment the latitude, longitude and altitude values exist which helped to generate flight trips. Moreover, this segment also used to remove the anomalies of source and destination airports (we found different source/destination airports in Basic Flight Information and Flight Details segment). We used the latitude and longitude points (Flight Details data segment) to ensure the source and destination airports for the flights. Fields of this data segment have been explained in Table 2.5.

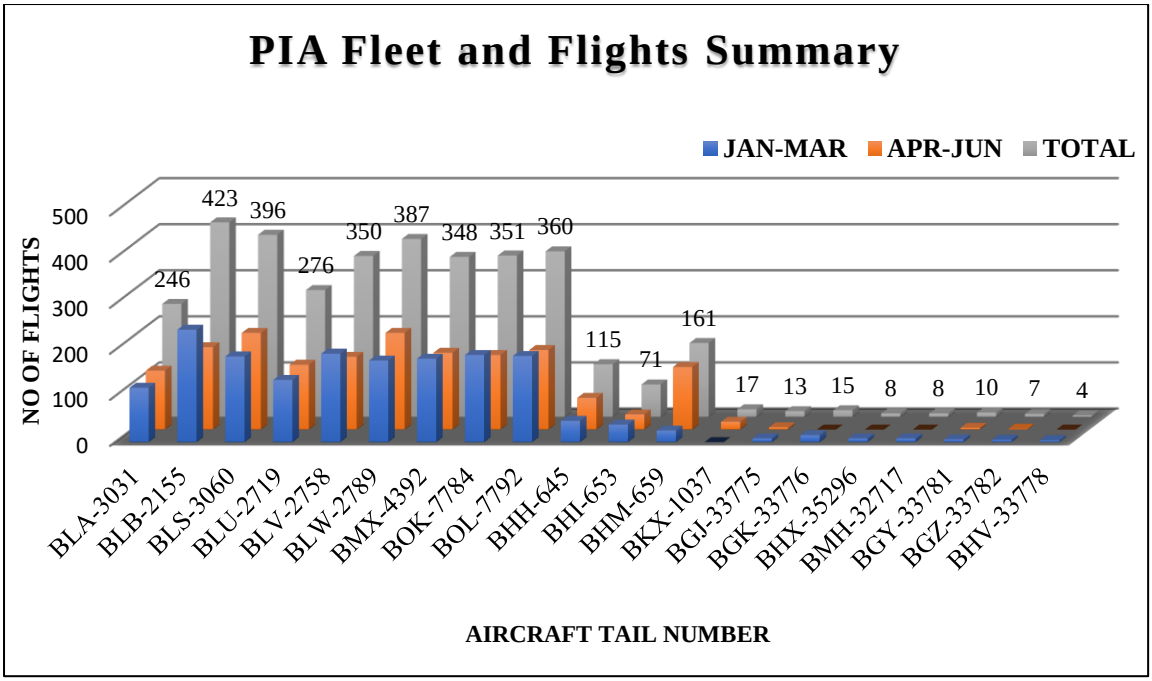

Figure 2.2. PIA flights data summary.

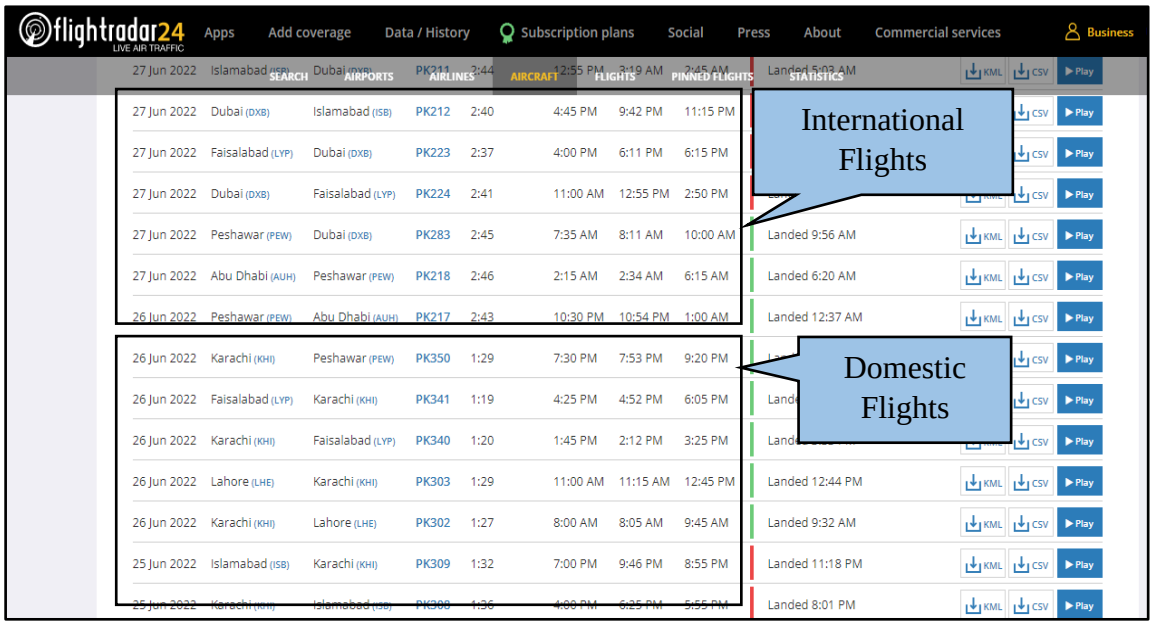

Figure 2.3. Flight basic information.

Table 2.4. Flight basic information data.

S No	Field Name	Field Description
1.	Flight Date	Date of the flight
2.	Flight No	Flight Number assigned to the flight for identification of each flight record uniquely
3.	From / To	The location/airport from where the flight took off and where it would be landing
4.	Flight Time	Total time which a flight took from source airport to the destination airport. Values are in HHMM format.
5.	Sch. Dep. Time	Scheduled Departure Time – Time at which the flight was scheduled to fly
6.	Act. Dep. Time	Actual Time at which the flight took off
7.	Sch Arr. Time	Scheduled Arrival Time – Time on which the flight was supposed to land on the destination airport
8.	Act. Arr. Time	Actual Arrival Time – Time at which the flight landed at the destination airport
9.	Status	Landing information about the flight whether it landed, cancelled and/or diverted. This field also contains landing time if it lands its actual destination

Table 2.5. Flight details dataset.

S No	Field Name	Description
1.	Date/Time Stamp	A Date/Time value with a difference of about 3-5 seconds in each succeeding record. Its format is “YYYY-MM-DD HH:MM:SSS” (For e.g., "2022-03-20 05:39:39+00")
2.	Position	This field includes comma separated latitude/longitude points of air path/route of the flight followed by the aircraft
3.	Altitude	The height of the aircraft (in feet) during the flight as per the Date/Time stamp value. Its value remains zero (‘0’) before take-off (taxi-out) and after landing (taxi-in)
4.	Speed	Aircraft speed in air calculated in nautical miles per hour (1 Knot = 1.852 km/h)
5.	Direction	It is direction of the flight being followed by the aircraft.

2.5 Creating Database in MobilityDB

Once we have complete picture of our dataset and fields with their datatypes, we created the database in PostgreSQL. We named it 'pia_db' see Figure 2.4 and Figure 2.5. We have merged fleet information and basic flight information segments into one. After merging of these segments, we can say that there are two main types of datasets, i.e., Flight Basic and Flight Details. Therefore, we must create two tables for each of the datasets (i.e., one for flight basic info and one for flight details data segment). We performed the following steps to accomplish this task of table creation:

(a). Flight Basic Information along with aircraft details (Type, Model, Tail No) used for the flight to be stored in **flt_info** table. Primary key of this table includes **flt_date, flt_no** and **from_apt** fields. We used algorithm 1 (Appendix 'C') to create this table.

(b). Flight Details segment to be stored **flt_details** table. Primary key of this table includes **flt_date, flt_no, from_apt** and **date_time_stamp** fields. We used algorithm 2 (Appendix 'D') to generate this table in the database.

(c). After execution of these algorithms in PostgreSQL database, we now have both tables 'flt_info' and 'flt_details' available with us for data loading and further processing. Field to field mapping between datasets and database tables along with structure of both tables are explained in Table 2.6 and Table 2.7 respectively.

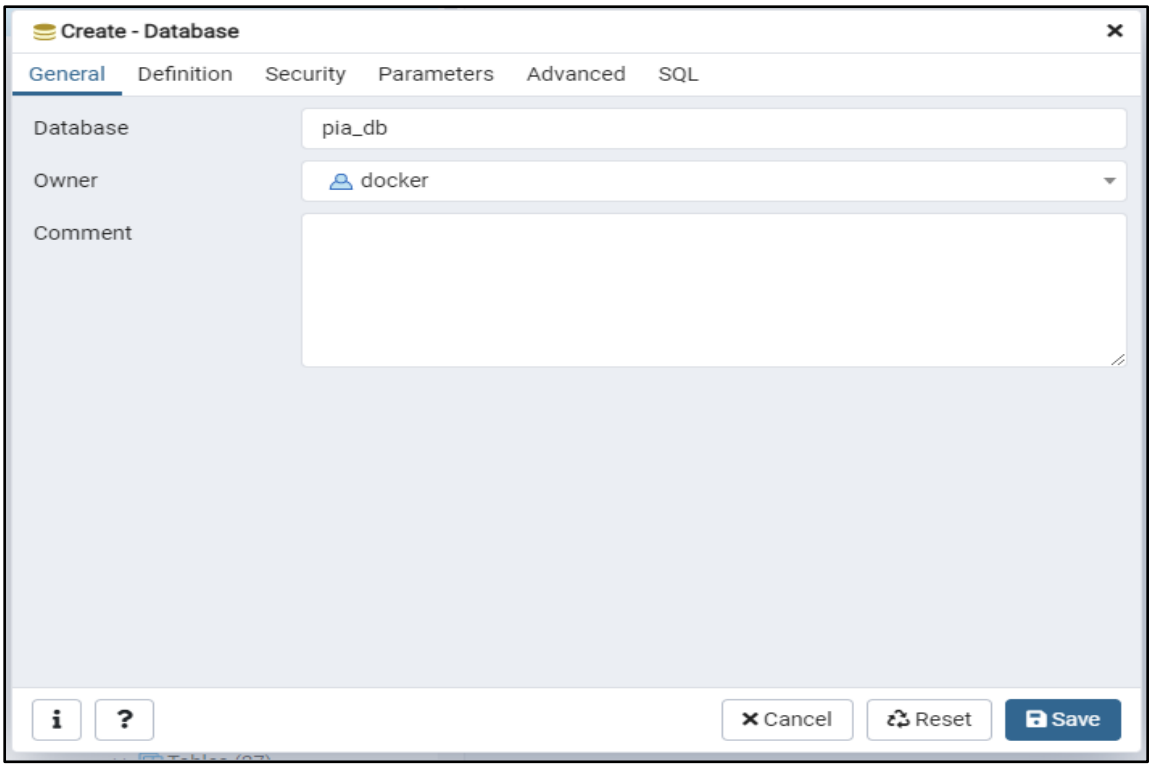

Figure 2.4. Creating database in PostgreSQL (name).

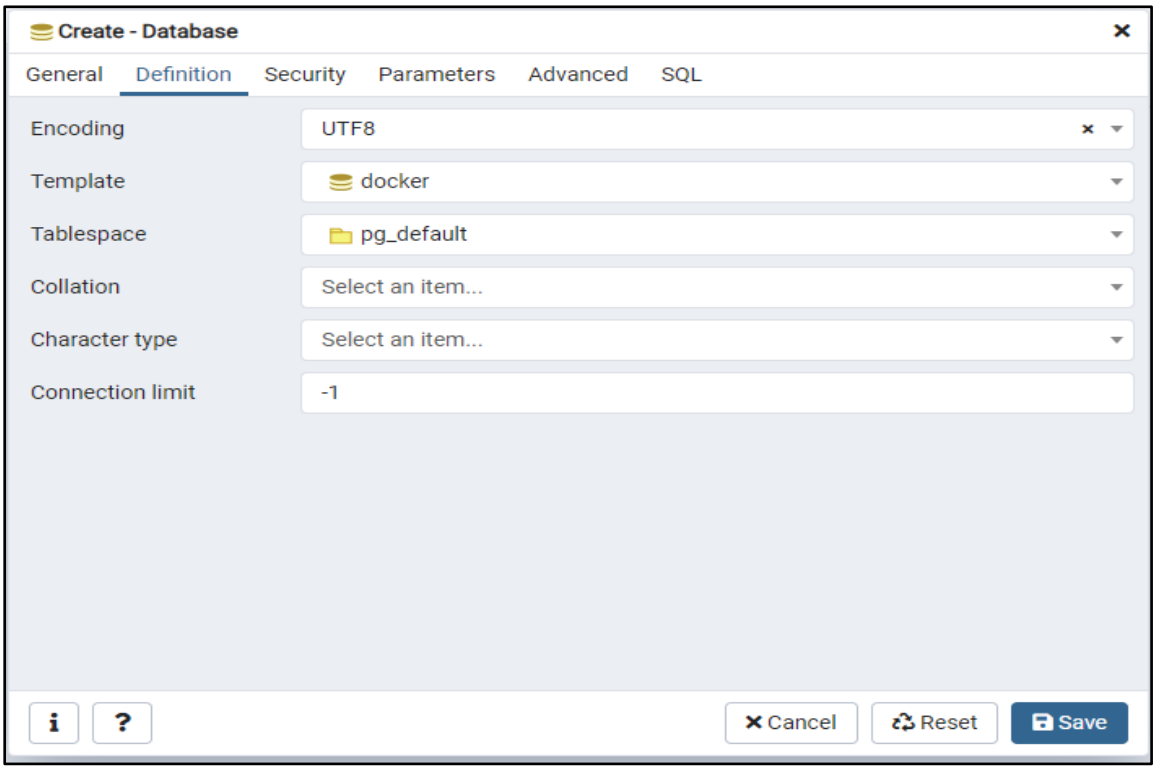

Figure 2.5. Creating database in PostgreSQL (definition).

Table 2.6. Field to field mapping (Basic flight information segment).

S No	Dataset Field	Table Name	Field in DB	Data Type
1.	Flight Date	flt_info	flt_date	Date
2.	Flight No	flt_info	flt_no	Char (10)
3.	From	flt_info	from_apt	Char (20)
4.	To	flt_info	to_apt	Char (20)
5.	Flight Time	flt_info	flt_time	Time
6.	Sch. Dep. Time	flt_info	sch_dep_time	Time
7.	Act. Dep. Time	flt_info	act_dep_time	Time
8.	Sch Arr. Time	flt_info	sch_arr_time	Time
9.	Act. Arr. Time	flt_info	act_arr_time	Time
10.	Status	flt_info	status	Char (20)
11.	Aircraft Type	flt_info	acft_type	Char (15)
12.	Aircraft Name	flt_info	aircraft	Char (50)
13.	Model	flt_info	acft_model	Char (10)
14.	Serial No	flt_info	acft_ser_no	Char (10)
15.	Call Sign	flt_info	call_sign	Char (10)

Table 2.7. Field to field mapping (Flight details segment).

S No	Dataset Field	Table Name	Field in DB	Data Type
1.	Flight Date	flt_details	flt_date	Date
2.	Flight No	flt_details	flt_no	Char (10)
3.	From	flt_details	from_apt	Char (20)
4.	Date/Time Stamp	flt_details	date_time_stamp	Date/Time
5.	Latitude	flt_details	Lat	Numeric
6.	Longitude	flt_details	Lon	Numeric
7.	Altitude	flt_details	altitude_ft	Bigint
8.	Speed	flt_details	speed	Bigint
9.	Direction	flt_details	direction	Bigint
10.	Call Sign	flt_details	call_sign	Char (10)

2.6 Methodology

In this study, we would be getting data downloaded pertaining to PIA flights, operated during 01 January to 30 June 2022, from FR24 after having its suitable subscription plan. Once dataset is completed, we will perform preprocessing, data loading and analysis phases will follow. Our results would include aircraft trajectories augmented with analysis of these trajectories based on different evaluation parameters including aircraft taxiing time, airport wise flight diversion percentage, landing approach, touch-and-go scenario, monitoring no-fly zones, distance among different flights in the air (evaluation collision chances within flights etc). Details of how we have gone through each evaluation parameters would be given in the methodology area. Once all evaluations parameters have been worked upon, all results would be produced and discussed in the Results and Discussion chapter. At the end of the analysis, we will be concluding the complete work done during the study and produce our recommendations to improve the flying operations of PIA. We would be considering all airports of Pakistan unless it is filtered during preprocessing or some later stage during the study. The flowchart of methodology is given in Figure 2.6.

2.7 Hardware and Software platform

It is better to have an insight about platform (hardware and software) used for the research work. We have used 10^{th} Generation DELL Latitude 3510 laptop machine with the specifications given in Table 2.8.

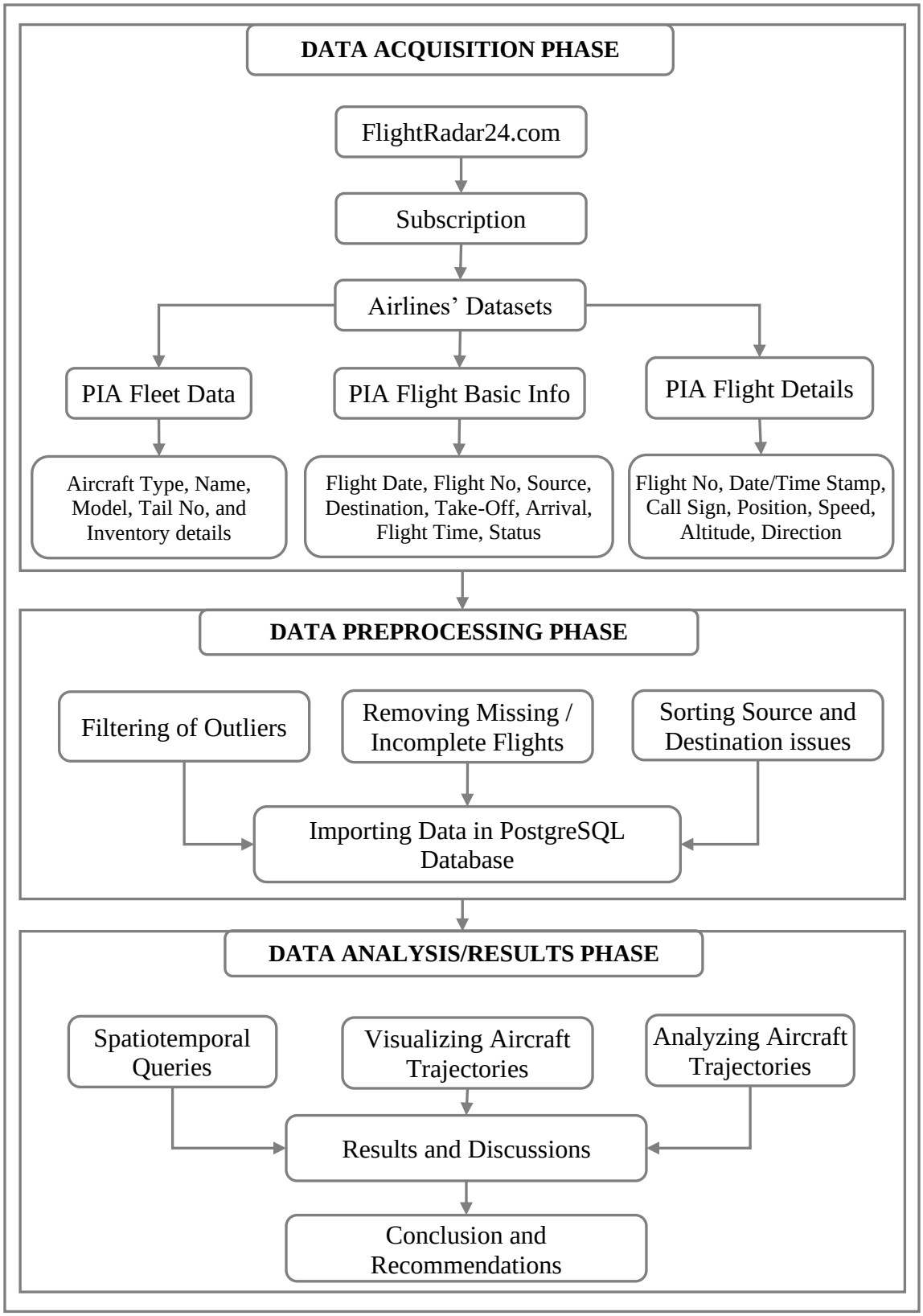

Figure 2.6. Methodology flowchart.

Table 2.8. Hardware / software products.

S No	Category	Product	Specification / Version
1.	Hardware	Processor	Intel ® Core ™ i5 – 10210U CPU @ 1.60 GHz 2.11 GHz (64-bit)
2.		RAM	16.0 Gigabyte (GB)
3.		Graphic Card	NVIDIA GeForce MX230 2.0 GB
4.	Software	OS	Microsoft Windows 10 Professional Ver 21H2 (OS Build 19044.1889)
5.		DBMS	PostgreSQL Ver 13.0 with PostGIS Ver 3.2 and pgAdmin4 Ver 5.2 configured for MobilityDB using Docker Desktop Ver 4.11.1
6.		Mapping	ArcMap / ArcGIS Ver 10.8.1
7.			QGIS Desktop Ver 3.22
8.		IDE	Microsoft Visual Studio 2022 (To develop CSV Files Merging utility)
9.		Editor	Notepad++ Ver 8.4.4 (64-bit)
10.		Documentation	Microsoft Word 365
11.			Microsoft Excel 365
12.		External Utility	OSM2PGSQL Ver 1.6.0 (for importing OSM planet dataset into the database)
13.		BI Tool	Microsoft Power BI Desktop application Version: 2.109.1021.0 64-bit (To generate and verify different maps)

2.8 Data Preprocessing

Data preprocessing is a pre-requisite step to be taken before working on any dataset. Pre-processing steps may vary depending upon the type and nature of data. During this study, the dataset of flying information was apparently error free but as we go through it, we found different issues to be addressed during preprocessing. It includes the following:

2.8.1 Preprocessing Before Data Loading to Database

It is pertinent to mention here that some of the flights details was not completely available in the dataset, like source airport was Unknown, sometimes the destination airport was not mentioned or Unknown. Such types of flights were filtered as first step of data preprocessing. During outlier filtering, flights operated beyond Pakistani airspace were discarded. Before going to further details, we must mention here that due a lot of files of same type and data, it was prudent to merge these files before loading them into that database. Therefore, to make this merging task efficient and error free, 'CSV Files Merging Utility' (Details given at Appendix 'B'.) was developed and used. However, verification of record count has been accomplished using *Power Query* option of Microsoft Excel. Before data uploading to the database, Flight Basic Info data segment was updated with the following additional fields:

- 'Aircraft Type', 'Aircraft Name', 'Aircraft Model' and 'Tail No' fields were updated from PIA fleet information. Actual Time of Arrival (ATA) was deducted from Status field.
- The format of Scheduled Time of Departure (STD), Actual Time of Departure (ATD), Scheduled Time of Arrival (STA) and ATA was converted into 24 Hours (i.e., HHMM) from 12 Hours (AM/PM) format.

- ‘Call Sign’ field has been created from Flight No field using *Replace* function of Microsoft Excel, i.e., *=Replace (‘FlightNo’,1,2, ‘PIA’)*. This will create Call Sign: ‘PIA301’ from Flight No: ‘PK301’.
- The last field of Flight Basic Info segment was prepared with the name as per flight details CSV file to ensure smooth and accurate data migration process of each flight.
- The complete dataset was transformed into CSV format and merged to have single large file for data loading to the database.

The following actions have been performed on Flight Details dataset:

- ‘Flight Date’ field was not originally available with Flight Details data segment. Therefore, it has been extracted from Date/Time Stamp value. It is created using *left* function of Microsoft Excel as “*=left (date_time_stamp, 10)”*.
- ‘Latitude’ and ‘Longitude’ fields have been generated from position column in the file using *Text to Column* feature of Microsoft Excel.
- ‘Flight Number’ / ‘Call Sign’ field was found empty for some of the records, these records were also filtered.
- The complete dataset (CSV format files) was merged to have single large file for data loading to the database.

2.8.2 Preprocessing During Data Loading to Database

The resultant CSV files of both data segments were finally imported to PostgreSQL database using its built-in utility. This process performed twice, once for each data segment:

(a). For importing Flight Basic Information data segment, refer to Figure 2.7 and Figure 2.8. respectively.

(b). While importing Flight Details data segment, we used the same procedure as for Flight Basic Information data segment. Figure 2.9 and Figure 2.10 elaborate these steps.

(c). On successful completion of data import for both data segments, we are now able to proceed further with our next step in the study.

During this data migration process, some flights found with more than one Aircraft Tail Number mentioned with them. For example, Flight No PK325 used aircraft tail number 2155 and same Flight i.e., PK325 also used aircraft tail number 3060 on same day. In this case, we considered the first occurrence of flight in chronological order as a valid record, and we disregarded all flights after that. The argument to justify this action is that it is impossible that a flight would be using multiple aircraft tail number at the same date/time, that's why we filtered out the subsequent flight records with same aircraft tail number.

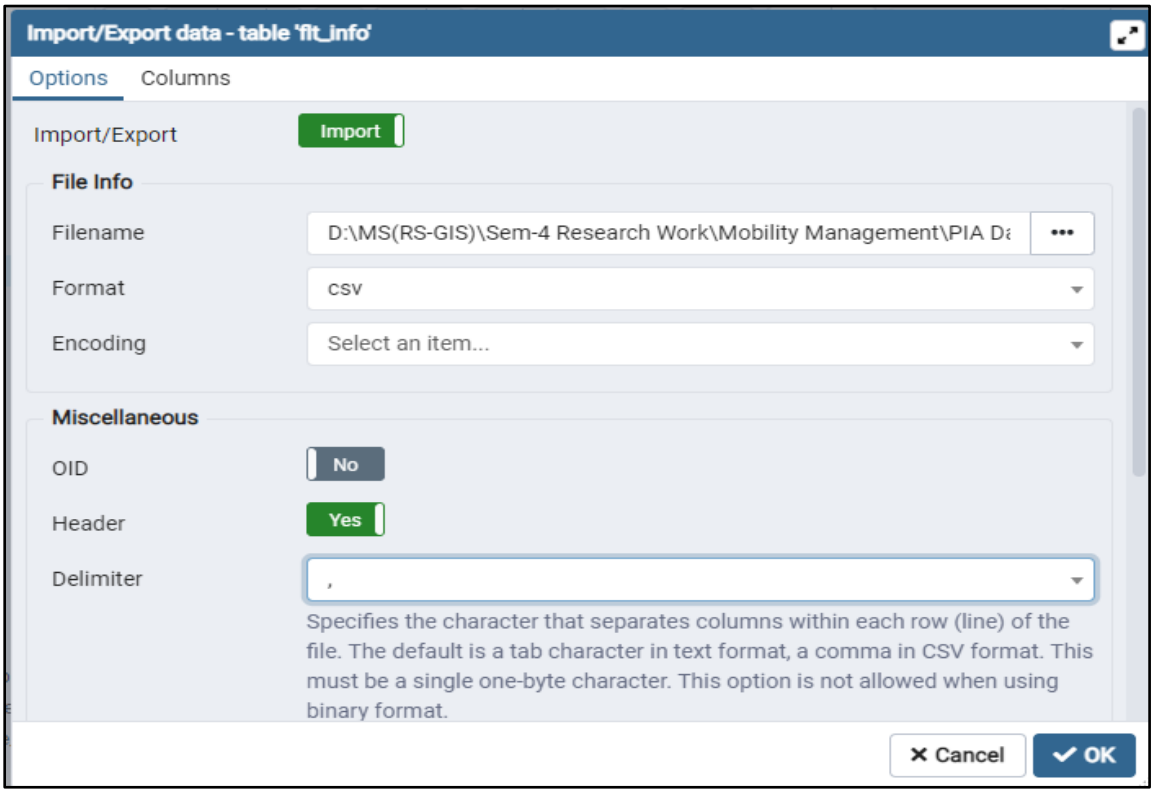

Figure 2.7. Importing 'Flight Basic Info' segment (selecting source CSV file)

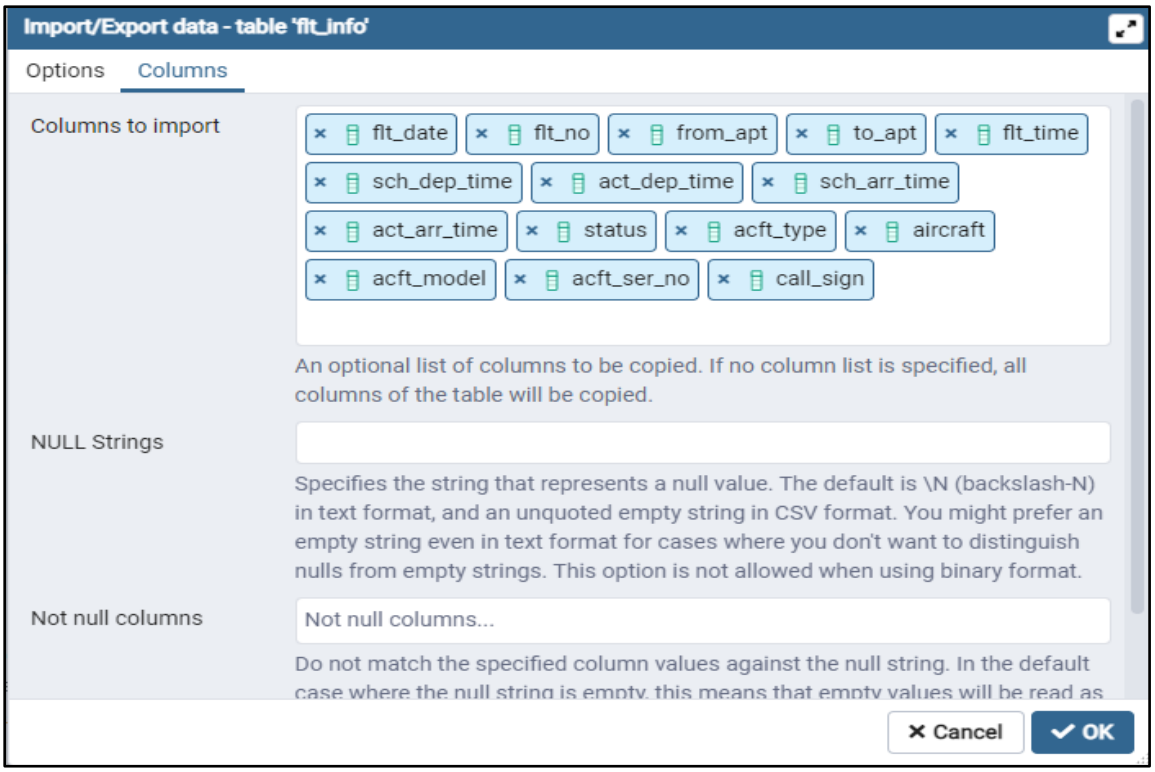

Figure 2.8. Importing ‘Flight Basic Info’ segment (selecting columns to import)

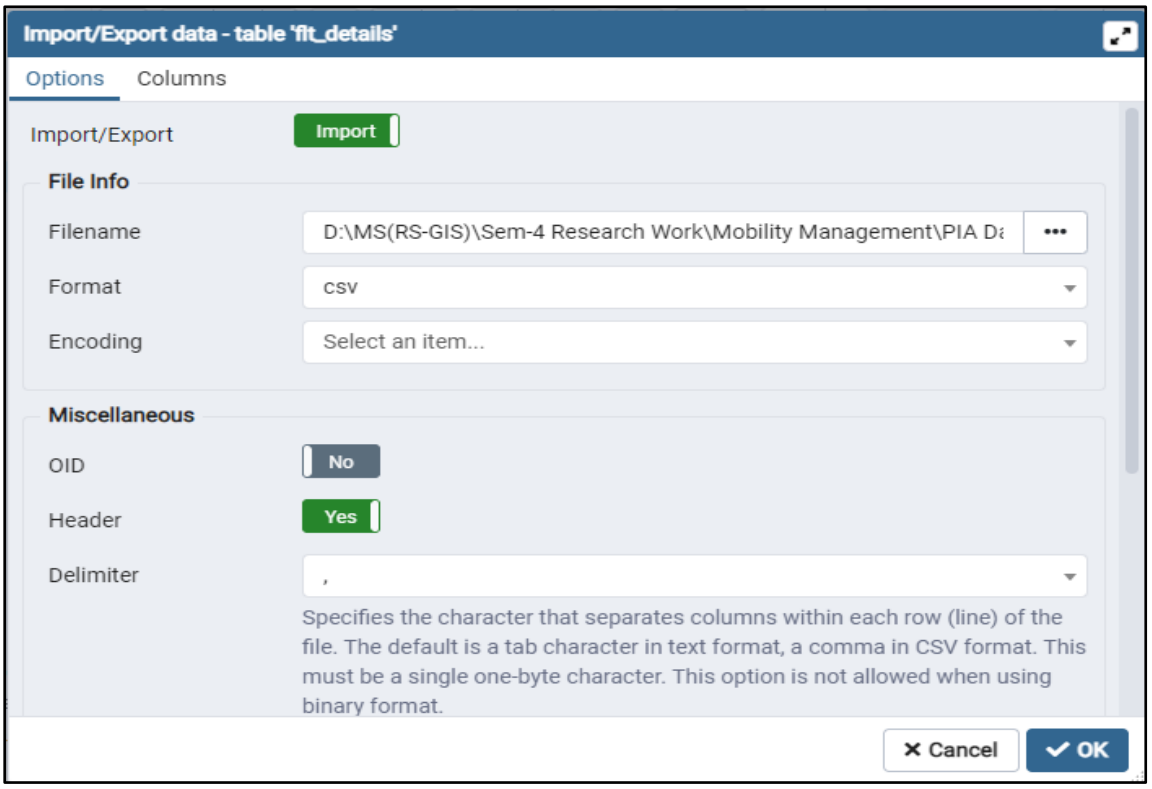

Figure 2.9. Importing ‘Flight Details’ segment (selecting source CSV file)

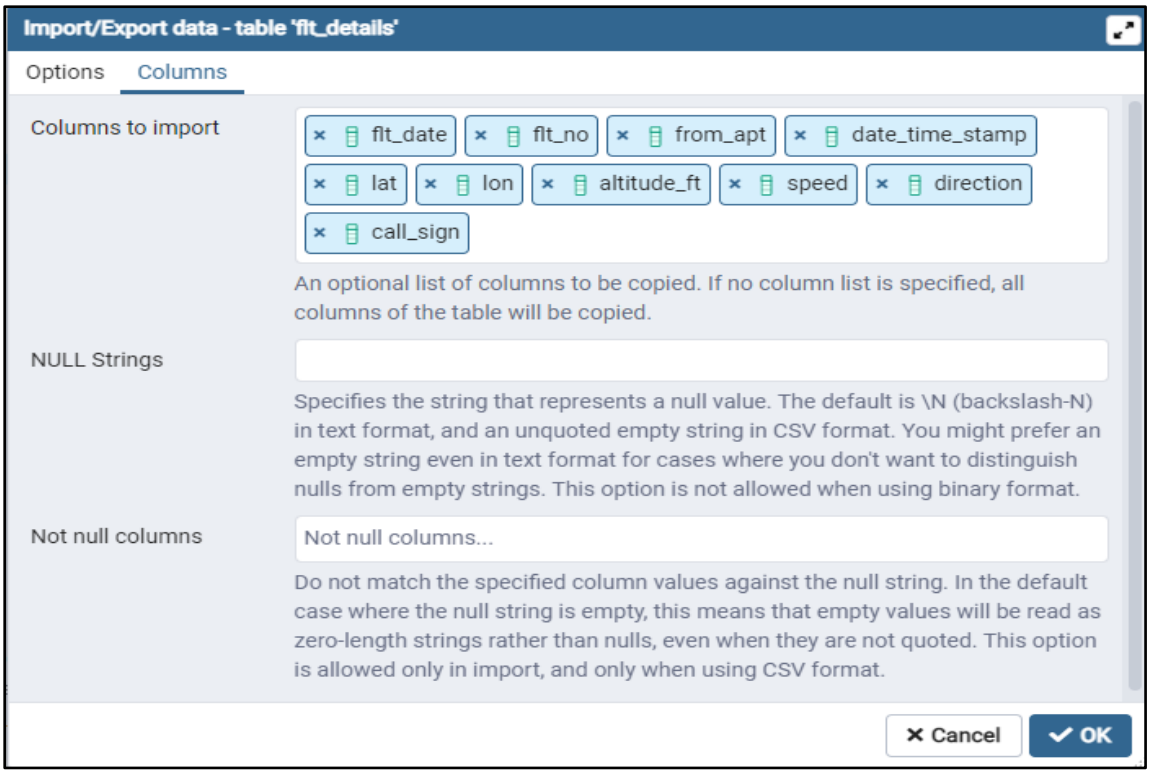

Figure 2.10. Importing ‘Flight Details’ segment (selecting columns to import)

2.8.3 Preprocessing After Data Loading to Database

After data migration, some of issue pertaining to data inconsistency/completeness were resolved that include:

- Flights details / flight paths were found to be different from Flight Basic data. For example, if a flight is scheduled (as per Flight Basic Info data) from Islamabad to Karachi, its flight details (flight path) were in a reverse order i.e., from Karachi to Islamabad. This issue was addressed, and the database was updated according to the Flight Details (Latitude / Longitude) data.
- **Flights with Coverage Loss (Outlier Filtering):** After solving source and destination airports issues, the flight paths / trips were generated to have a better understanding of flights dataset, see Figure 2.11 where we have shown all 893,120 flight trips without filtering outliers. We can see in the map that there are flights which have missing / incomplete routing information (i.e., flight paths/trips are not

completely covered by Latitude / Longitude points given in the downloaded datafiles) as they are not ending on some airport location. For example, flights travelling towards Skardu (KDU) are not being shown completely, i.e., trips are not ending on Skardu (KDU) airport, which means no tracking / monitoring of flights is available in Skardu area. The same case is with Chitral (CJL), Turbat (TUK) and Gwadar (GWD) etc. The flights shown in the Figure 2.11 fall into two categories:

- **Flights with Missing Landing Info** – These flights were found with zero values of altitude initially and increasing with the flight path (Taking-Off scenario). Suddenly, flight loses its track without coming its altitude to zero, meaning that landing of the flight has not been recorded. All flights with missing landing information were filtered.
- **Flights with Missing Taking-Off Info** – These flights were found with non-zero values of altitude and end with a zero value (Landing scenario), meaning that the initial tracking of the flight got missed. These flights were also disregarded to maintain a health state of data.

o Time values present in the dataset including ATD, STD, STA, ATA were in Universal Coordinated Time (UTC) format. This was converted to Pakistan Standard Time (PST) i.e., UTC+5.00 using 'UPDATE flt_details SET date_time_stamp = date_time_stamp + INTERVAL;**'5'**' query.

o After consolidation and removal of data inconsistency issues, the record count of the datasets is given in Table 2.6. The graphical form of flights count is given in Figure 2.12 where x-axis is showing different airports of the country and y-axis is displaying outgoing flights from each airport. Comparison of before and after pre-processing steps is shown in the figure.

- Table 2.9 presents that around 41% flights and 28% flight details have been filtered out during the preprocessing steps. This is quite high percentage and major portion of this percentage encompasses those flights which have been filtered due to loss of coverage at different airports of Pakistan as previously discussed in Section 2.1.
- Figures 2.13 and 2.14 are screenshots of dataset from PostgreSQL *pia_db* database after successful data migration from CSV files to database tables.

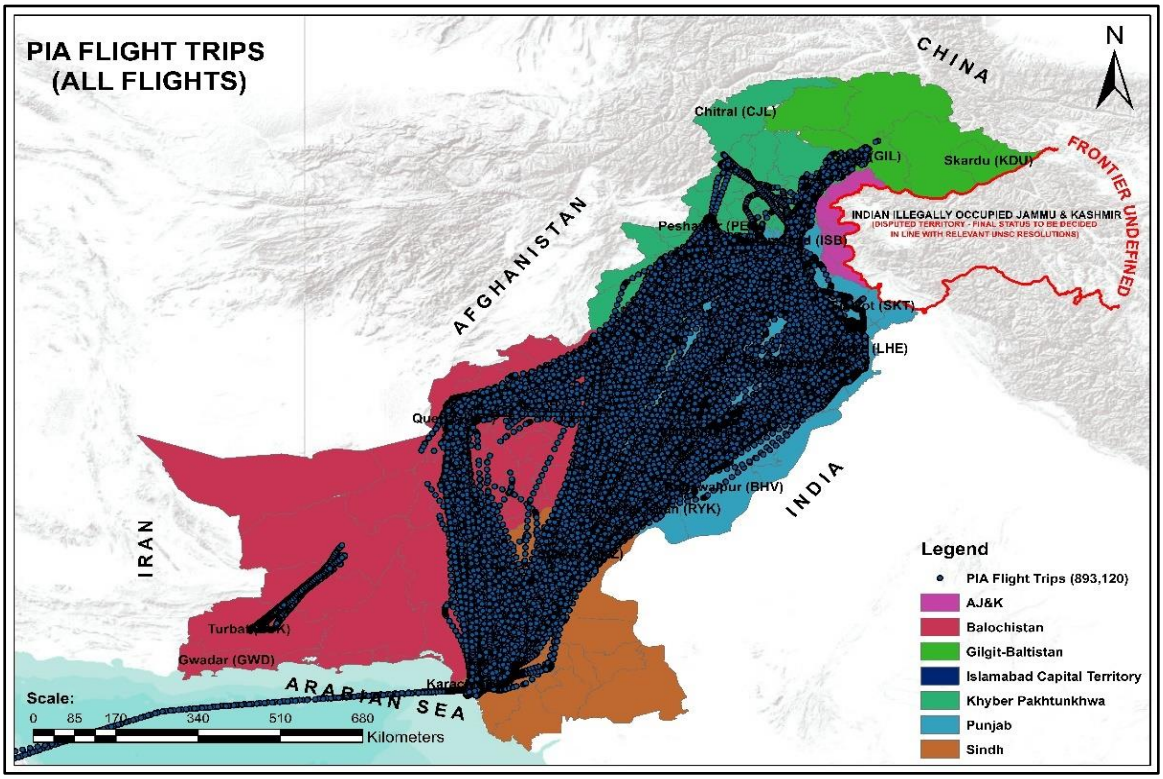

Figure 2.11. PIA flights trips.

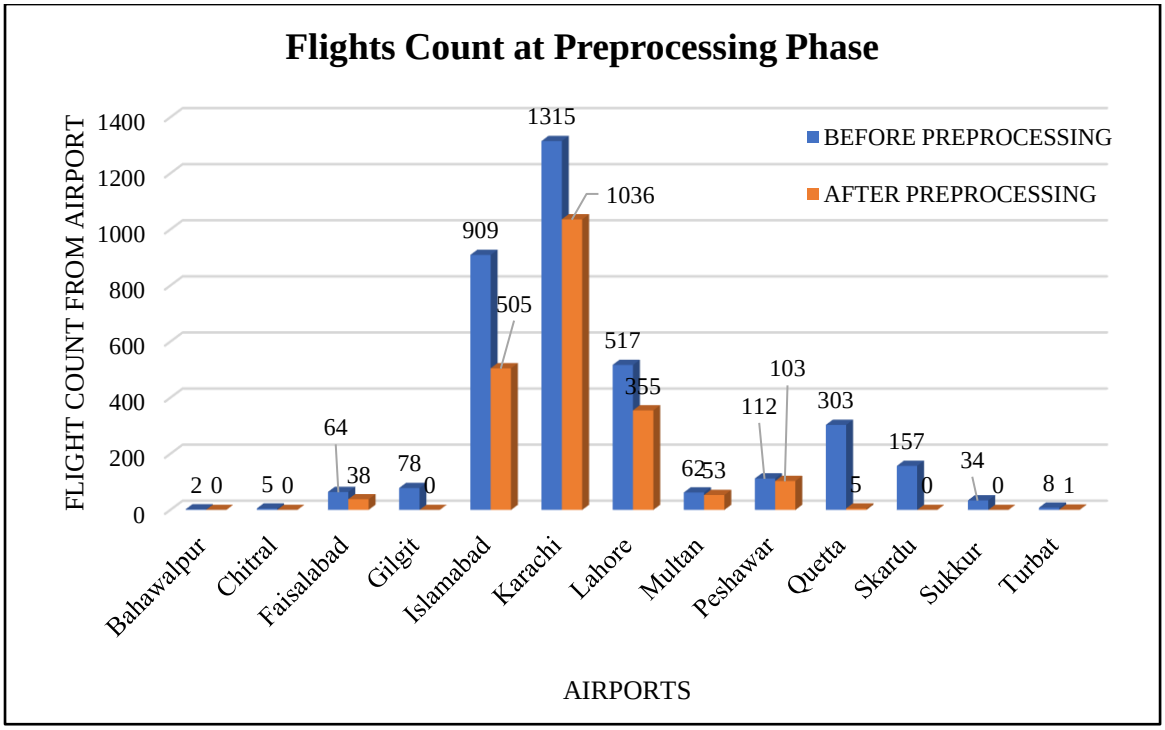

Figure 2.12. Flights count before and after preprocessing steps.

Table 2.9. Record count of PIA dataset.

Dataset	**Initial Total**	**Filtered During Preprocessing**	**Remaining**	**Percentage of filtered data**
Flight Basic Info	3,566	1,470	2,096	41.22%
Flight Details	893,120	253,308	639,812	28.36%

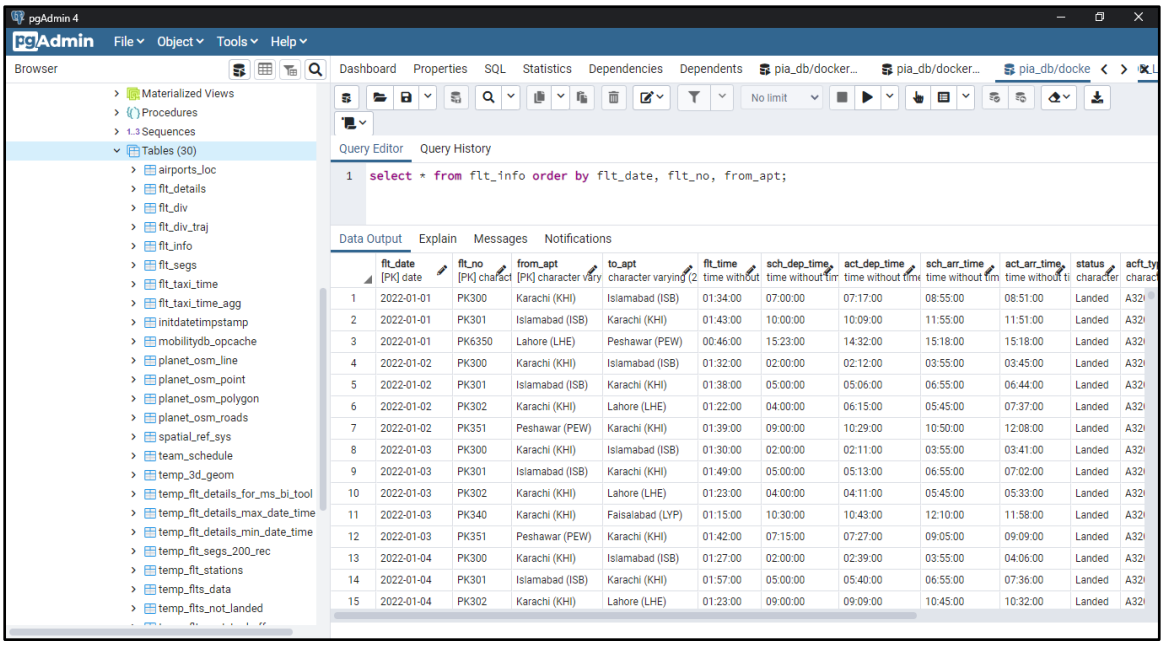

Figure 2.13. Flight Basic Info data segment.

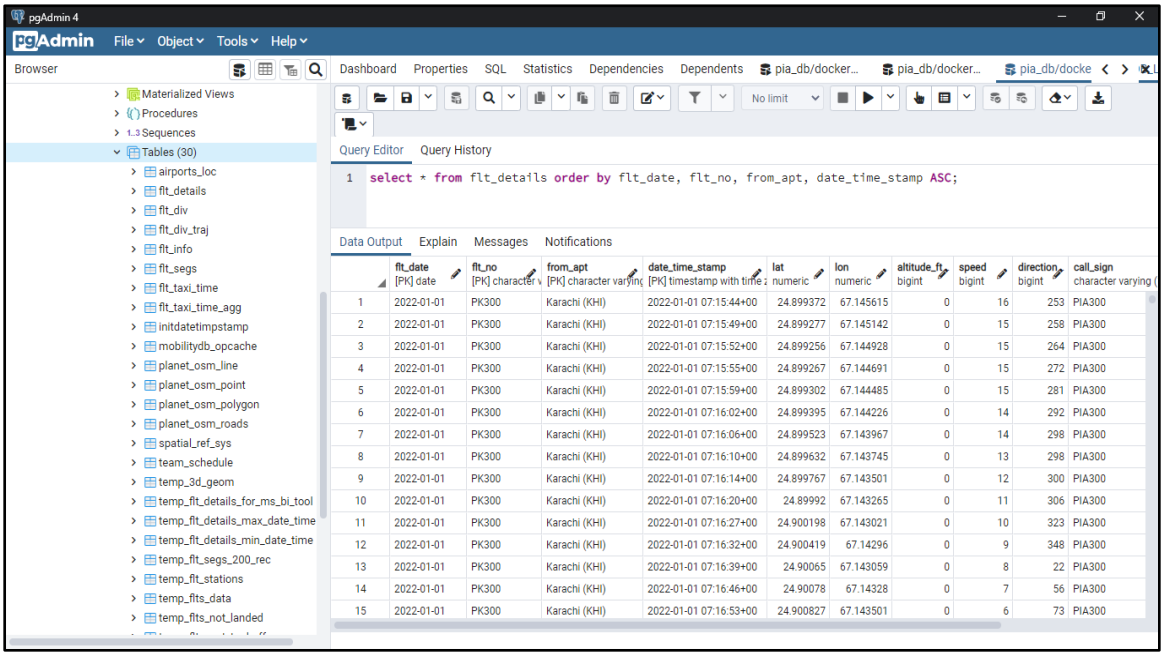

Figure 2.14. Flight Details data segment.

- As a last step of data preprocessing, we added Open Street Map (OSM) dataset from Geofabrik server. The OSM dataset contains the following tables:
  - planet_osm_line
  - planet_osm_point
  - planet_osm_polygon

- planet_osm_roads

- The OSM data would be used for finding and comparing different geometries of aircraft trajectories to address our different scenarios like finding whether a flight is passing over the Centaurus Mall Islamabad or not?

2.9 Building Aircraft Trajectories

The first objective of our study is to build aircraft trajectory using MobilityDB. We have built aircraft trajectories using the following steps:

(a). First, we have generated a table to store geometry fields within the dataset. We call it flight segments ('flg_segs'). Purpose of this table is to filter out other fields of data that are not required to generate aircraft trajectories. We used Algorithm 3 (Appendix 'E') to create this table.

(b). As a next step, we populated this table with the flight trips.

(c). The trajectories were generated, and destination airport and status of each flight updated for better understanding of trajectories. We used Algorithm 4 (Appendix 'F') to perform Steps (b) and (c).

2.10 Flight Diversion

A flight diversion takes place when an aircraft is unable to arrive at its pre-decided destination. All diversions are unexpected; otherwise, it is termed as an alternate prior to departure. Factors that may cause a diversion include medical emergency, mechanical malfunction, and poor weather conditions/visibility. We used Algorithm 5 (Appendix 'G') to get the details of PIA diverted flights.

2.11 Aircraft Taxiing-out and Taxiing-in Timing

When an aircraft starts its engine for flight and takes-off (leaves ground), this difference of time in minutes is termed as Taxiing Out (TXO), however the time between landing of aircraft and coming to stop position when its engine is stopped, is termed as

Taxiing In (TXI). Aircraft taxiing timing depend upon design & architecture of the airport as well as number of flights being operated / handled at the airport. We have calculated the aircraft taxi timings based on 'altitude' field from Flight Details data segment. We know that initially, the altitude is zero and remains zero until the aircraft takes-off where it instantly increases and becomes greater than zero, we calculate the difference of data/time stamp values when it was at zero and when it jumped to greater than zero. This is how TXO is calculated.

For TXI, we know when an aircraft lands, its altitude descends to zero and remains zero until the aircraft is switched off for passengers offloading. The difference of date/time stamp values when aircraft descended to ground and when it was switched off, is calculated as TXI. We have used Algorithm 6 (Appendix 'H'), Algorithm 7 (Appendix 'I') and Algorithm 8 (Appendix 'J') to calculate aircraft taxiing timings.

2.12 Monitoring 'No Fly Zone'

Monitoring NFZ implements spatiotemporal queries of MobilityDB. In this step we verify path / trajectory of each flight whether it intersects the geometry of any ground object (Point, Line, Polygon) during its operation. To accomplish this objective, we have employed Open Street Map dataset with all features of Pakistan including Point data (e.g., Buildings, Parks, Hospitals, Schools, Colleges, Universities etc), Line data (e.g., Roads, Rivers, Lakes etc) and Polygons (e.g., Town, Municipality, Cities, Provinces etc). Using spatiotemporal query of MobilityDB, we can find the points of interest (Roads, Lines, Points and Polygons) from where flight path/trajectory intersect or passes through. In the following paragraph, we have explored all three NFZs of Pakistan.

(a). First, we have monitored Red Zone Islamabad; whether it has been violated by PIA flights available in our dataset, Algorithm 2.1 served the purpose:

```
-- Selecting all records with 'Islamabad' in its name:
SELECT DISTINCT flt_date, flt_no, from_apt, to_apt, traj_2d, way, name AS NFZ FROM flt_segs t, planet_osm_polygon p WHERE p.name LIKE '%Islamabad%' AND INTERSECTS (t.trip_2d, p.way) AND building != ''
UNION
SELECT DISTINCT flt_date, flt_no, from_apt, to_apt, traj_2d, name AS NFZ FROM flt_segs t, planet_osm_roads p WHERE p.name LIKE '%Islamabad%' AND INTERSECTS (t.trip_2d, p.way)
ORDER BY flt_date, flt_no, from_apt;
```

Algorithm 2.1 - Selecting all flights passing through Islamabad airspace.

(b). The second NFZ is Nuclear Complex Khushab, we used Algorithm 2.2 to find the flight passing over this NFZ:

```
SELECT DISTINCT flt_date, flt_no, from_apt, to_apt, traj_2d, name AS NFZ FROM flt_segs t, planet_osm_polygon p WHERE p.name LIKE '%Khushab Nuclear Complex%' AND intersects (t.trip_2d, p.way)
ORDER BY flt_date, flt_no, from_apt;
```

Algorithm 2.2 - Selecting all flights passing over Khushab Nuclear Complex

(c). The third and last NFZ is Kahuta Research Laboratories for which we used Algorithm 2.3.

```
SELECT DISTINCT flt_date, flt_no, from_apt, to_apt, traj_2d, name AS NFZ FROM flt_segs t, planet_osm_polygon p WHERE p.name LIKE '%Kahuta%' AND intersects (t.trip_2d, p.way) ORDER BY flt_date, flt_no, from_apt;
```

Algorithm 2.3 - Selecting all flights passing over Kahuta

2.13 Avoiding Flight Collision

We used spatiotemporal query to find out the minimum distance between any two flights / trajectories, we used Algorithm 2.4 to check the flights which came within 100 meters apart from each other:

```
SELECT T1.flt_date, T1.flt_no, T1.from_apt, T1.to_apt, T1.trip_2d, T1.traj_2d,
(T1.trip_3d |=| T2.trip_3d) AS distance  FROM flt_segs T1, temp_flt_segs T2
WHERE t1.flt_date = t2.flt_date and t1.flt_no != t2.flt_no AND T1.flt_date='2022-
01-01'  AND (T1.trip_3d |=| T2.trip_3d) < 100 ORDER BY T1.flt_date, T1.flt_no,
T1.from_apt;
```

Algorithm 2.4 - Calculating minimum distance between flights.

Chapter 3

RESULTS AND DISCUSSIONS

3.1 Building Aircraft Trajectories

The first objective of our study is to build aircraft trajectory using MobilityDB. To accomplish this objective, we have worked on the Flight Details data segment where the geometry points (Latitude, Longitude and Altitude) are present. Figure 3.1 depicts a view of aircraft trajectories for outgoing flights from different airports of Pakistan. We can see the aircraft trajectories on map in form of lines drawn among different airports.

It is also visible from Figure 3.1 that some of the airports present on the map do not have any flight trajectory starting or ending from. These airports include Bahawalpur (BHV), Chitral (CJL), Gwadar (GWD), Gilgit (GIL), Quetta (UET), Rahim Yar Khan (RYK), Skardu (KDU) and Sukkur (SKZ). The reason behind the missing flights for these airports are the flights which were filtered at preprocessing phase due to low coverage of flight path / missing path tracking points.

3.2 Analysis of Aircraft Trajectories

The second objective of the study is to analyze aircraft trajectories to extract information about different scenarios like Assessing flying within No Flying Zones, Measuring Collision Occurrences, Touch-and-Go, Approach, Flight Diversion and Taxi Timing for each flight on each airport separately.

3.2.1 Flight Diversion

A flight diversion takes place when an aircraft is unable to arrive at its pre-decided destination. All diversions are unexpected; otherwise, it is termed as an alternate prior to departure. Factors that may cause a diversion include medical emergency, mechanical malfunction, and poor weather conditions/visibility. Flights may also be diverted due to strikes, armed conflict, and natural disasters. We have investigated the flight diversion

cases in PIA flights based on ‘Status’ field from Flight Basic Info data segment. We used Algorithm 3.5 to get the details of PIA diverted flights. Figure 3.2 shows all diverted PIA flights with its actual itinerary mentioned against each.

We can see a total of ten flights have been diverted from their destination airports. Out of these ten flights, six flights have been diverted from Quetta International Airport (shown in Yellow), two from Chitral Domestic Airport (shown as Brown) and one from each Allam Iqbal International Airport Lahore and Faisalabad International Airport (shown in Red and Blue colors respectively). The analysis and chart of diverted flights are presented in Table 3.1 and Figure 3.3 respectively.

3.2.2 Aircraft Taxiing-out and Taxiing-in Timing

The difference of time in minutes between Actual Wheels Off time and Actual Gate Out time, is called as Taxi-out (TXO). TXO is examined for flights for which Gate **Out**, Wheels **Off**, Wheels **On**, and Gate **In** (OOOI) data are available, estimated for otherwise cases. On the other hand, difference of time in minutes between Actual Gate In time and Actual Wheels On time, is called as Taxi-in (TXI). TXI is examined for flights for which OOOI data are available, otherwise it is estimated. Aircraft taxiing is also called as the movement of an aircraft on the ground in its own capacity/power, not being dragged by towing or pushback. Figure 3.4 shows airport wise average taxi-out and taxi-in timings.

While looking at Figure 3.4 where x-axis is depicting airports and y-axis is showing time in minutes. It is presented that all airports have TXO and TXI shown against each except for Quetta (UET), Chitral (CJL) and Sialkot (SKT) airports. Outgoing flights for these airports had coverage issues and were filtered during preprocessing steps. We can see that Allama Iqbal International Airport Lahore (LHE) having the maximum TXO while Islamabad International Airport has the maximum TXI timings among all airports shown in the Figure 3.4.

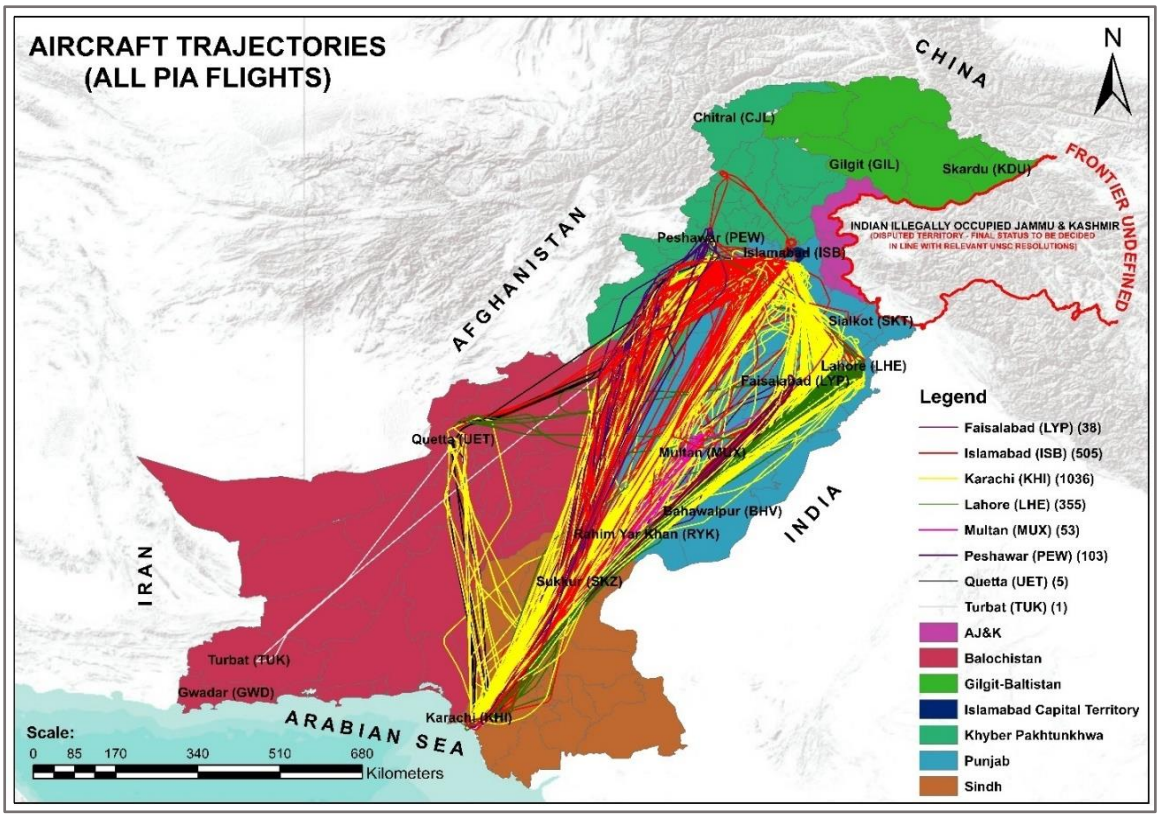

Figure 3.1. Aircraft trajectories (all flights)

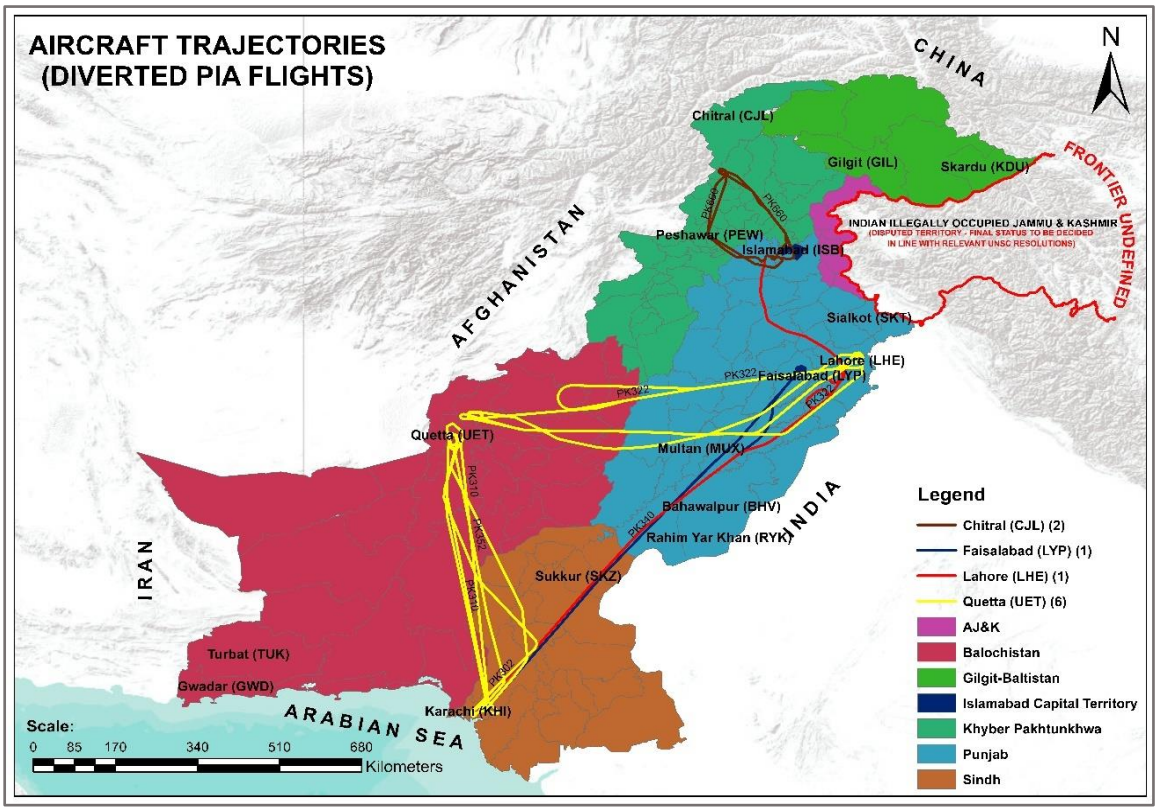

Figure 3.2. Diverted flights.

Table 3.1. Analysis of diverted flights.

S No	Flt Date	Flt No	From	To	Diverted To	Analysis
1	17-06-2022	PK660	ISB	CJL	ISB	All 02 flights destined to Chitral (CJL) diverted back to their source airports.
2	30-05-2022	PK660	ISB	CJL	ISB	
3	05-01-2022	PK340	KHI	LYP	KHI	Normal / routine diversion
4	07-01-2022	PK302	KHI	LHE	ISB	
5	21-06-2022	PK310	KHI	UET	KHI	There were 28 flights destined for Quetta (UET), out of which 06 flights have been diverted and all of them are sent back to their source airports.
6	02-02-2022	PK352	KHI	UET	KHI	
7	22-05-2022	PK310	KHI	UET	KHI	
8	17-06-2022	PK322	LHE	UET	LHE	
9	22-05-2022	PK322	LHE	UET	LHE	
10	08-02-2022	PK322	LHE	UET	LHE	

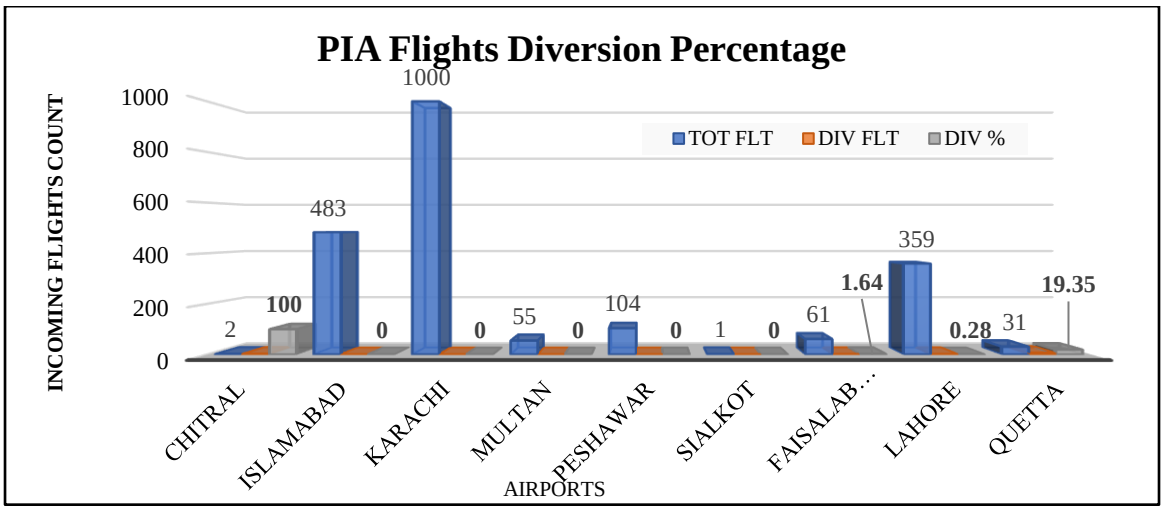

Figure 3.3. Diverted flights (percentage).

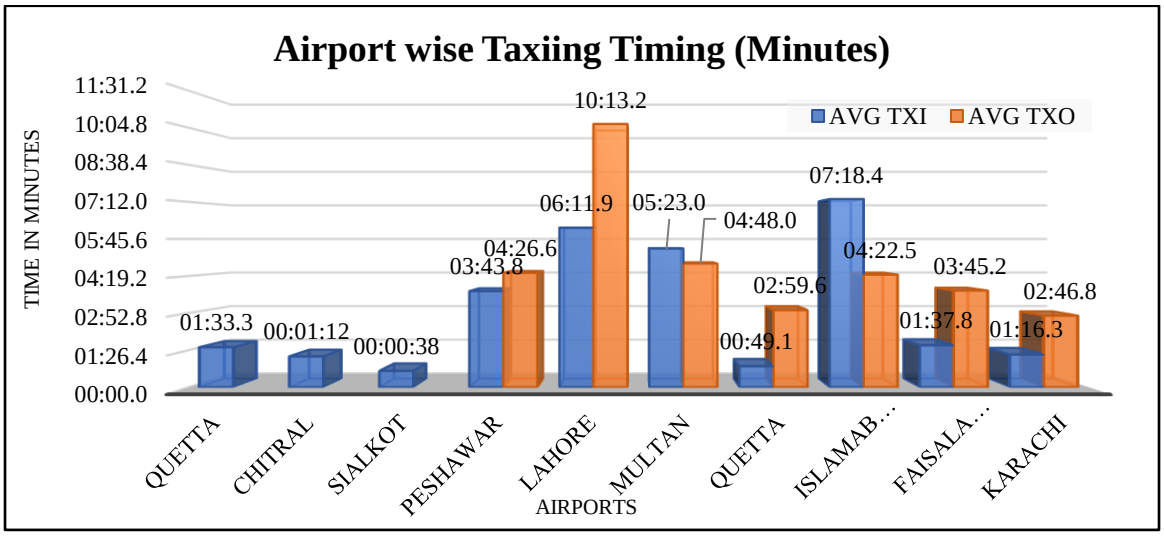

Figure 3.4. Airport wise average TXO and TXI timings.

It is always desirable to minimize the Taxiing Time because it is one of the major expenses in airline operations due to fuel consumption (Mofokeng et al., 2020). The amount of fuel consumed during the taxi period is also quite high. In this regard, it is necessary to emphasize the utilization of effective techniques that minimize taxi times in airport design, considering the financial load on airlines and environmental impact of the fuel burned during aircraft taxiing.

3.2.3 Touch-and-Go (T/G) and Landing Approach

During touch-and-go, an aircraft lands and leaves the runway without stop off. This operation fundamentally joins two maneuvers into one - the aircraft lands on the runway, then speeds up and takes off again, Figure 3.5. This maneuvering is normally part of flight training but sometimes used as a form of aborted landing after touchdown.

The touch-and-go procedure is a series of challenging tasks that need to be considered when deciding whether it is appropriate to perform, as the procedure is more challenging and can be dangerous in case.

(a). There may not be enough runway available. For various reasons (runway length, wind, landing technique etc.) it is possible that the remaining runway is insufficient for a safe take off. The decision whether to continue as planned or abort the take off part may need to be done very quickly, and in combination with switching the aircraft from one configuration to the other.

(b). The main objective of a touch-and-go is to perform the two main maneuvers. That means the takeoff part is only supposed to be initiated when the aircraft is firmly on the ground and has decelerated. Sometimes, having a shorter runway, a delayed touchdown, etc, the landing part is performed differently compared to the full-stop scenario, e.g., almost simultaneous touchdown of all wheels (to save time), no deceleration etc.

(c). There is more stress on the engine as it must quickly go from a relatively cold condition (typical for landing) to a full power state (expected for take-off).

(d). The performance of touch-and-go instead of a landing must be communicated to air traffic control so that they may plan the traffic flow accordingly. Sometimes it would not be safe to approve a touch-and-go and the controller would clear the pilot for a full stop landing.

There are some maneuvers that can be viewed as an alternative to touch-and-go and are also used in flight training.

(a). **Stop and Go:** In this scenario, the aircraft comes to a complete stop and then starts a takeoff roll without switching-off its engine. This procedure is often preferred over touch-and-go as it is less stressful for the pilot, because the two actions are split - the pilots first focus on the landing and only when this task is completed, they turn their attention to take-off. In addition, there is some timespan available for pilots to switch between the tasks which is not the case with touch-and-go.

(b). **Low Approach:** This maneuver is a combination of an approach (lowering down the aircraft for landing) and a go-around. The aircraft does not touch the runway (unlike touch-and-go/stop-and-go). Unlike missed approach, the aircraft does not start climbing at the missed approach point but continues to fly at this height instead. The climb starts at a later point, e.g., after overflying the runway end. In other words, the aircraft performs low flying in this scenario.

(c). **Full Stop:** In this case landing is followed by a taxi-back take-off. The aircraft exits the runway (as if this were the end of the flight) and then taxies to the holding point. Sometimes (wind and traffic permitting) a backtrack can be used to take off from the opposite direction. The advantage of this approach is that it fully

represents both parts of the flight. The downside is that it is the most time consuming and could not be possible in case when number of flights are already lined up to fly.

It is pertinent to mention that these procedures are followed in the United States of America and United Kingdom and other countries, but they are not universally adopted International Civil Aviation Organization (ICAO) procedures. The Assessment criteria for touch-and-go includes approach – decelerating altitude (< 1000 feet), Altitude = 0 for just 2-3 seconds and abrupt acceleration in speed and altitude. However, the bad landing approach occurs when there is decelerating altitude (< 1000 feet) but remains > 0 and abrupt acceleration in speed and altitude within a time of 2-3 seconds. This is shown in Figure 3.6.

In our dataset, we do not find any flight with touch-and-go and /or other scenarios discussed in preceding paragraphs. However, we do have an example of PIA Flight PK8303 traveling from Lahore (LHE) to Karachi (KHI) on 22 May 2020. This unfortunate PIA Airbus A320-214 (Tail No: 2274) could not land at Karachi airport and crashed in the vicinity of the airport in Model Colony Karachi killing 97 people. This flight was known to have performed touch-and-go maneuver, that was not successful. Figure 3.7 shows the record of this flight on FR24.

As per its tracking record on FR24, it has just completed its flying from Lahore (LHE) airport to Phool Nagar, a town at about 60 kilometers ahead of Lahore on its track to Karachi. The pictures got from preliminary investigation report issued by Aircraft Accidents Investigation Board (AAIB), Pakistan dated 19 June 2020 are given as Figure 3.8, Figure 3.9, Figure 3.10, and Figure 3.11. While looking at these figures published by the AAIB board we can have a better idea of the nature of the air accident and can estimate the cost of damage incurred because of this unfortune.

3.2.4 Monitoring 'No Flying Zones'

No Flying Zone (NFZ) or Air Exclusion Zone (AEZ) is a territory or area established by Govt / Military on which specific air vehicles are forbidden to fly. A forceful action is employed by the enforcing state depending on the terms of the NFZ. Violation of NFZs might result in military interception. NFZs in Pakistan include:

- Islamabad Capital Territory: In capital city of Islamabad, the no-fly zone is the constitution avenue where certain government buildings of vital importance are located.
- Khushab Nuclear Complex
- Kahuta Research Laboratories

(a). The result set obtained for Islamabad Capital Territory contained a total of 118 records but after filtering we concluded with 05 flights (02 for Islamabad, 02 for Chitral and 01 for Karachi) flying over Islamabad Capital Territory. Table 3.2 and Figure 3.12 show the information and trajectories of these flights respectively. We can see that all 05 flights, though passing over Islamabad city, but no one is violating Islamabad Red Zone area.

(b). The second NFZ is Nuclear Complex Khushab which is a plutonium production nuclear reactor and heavy water complex situated 30 km south of the town of Jauharabad in Khushab District, Punjab, Pakistan. As a resultant record set, we got 07 flights. Information about these flights is given in Table 3.3 and its trajectories are shown in Figure 3.13.

(c). We could not find any result for Kahuta Research Laboratories, that means no PIA flight is violating Kahuta Research Laboratories as per the flights records available in our dataset.

3.2.5 Avoiding Flight Collision

A collision is an accident in which an aircraft comes into unplanned contact with other aircraft and/or obstacle. Flight collision may occur on the runway (also called Runway Incursion), one aircraft is on runway and other is in the air close to the ground, taxi / push-back or with parked aircraft (Ground Incursion), collision within terrain, buildings, and other aircraft during flight. The main objective of Air Traffic Control (ATC) is to maximize the safety of both the aircraft and the people flying on it (Hurter et al., 2013).

While working on this aspect of flying data, we monitor the flight trajectory for the distance between any two flights at the same time. There are two scenarios to answer this question. One is about the live flights and other is about the historical dataset. In the first case, when we are monitoring live flights, we would be working within same timeslot and all our queries would automatically execute at the same time for all flights in operation. However, in the second scenario, we must consider the timeslot to be mentioned while querying the historical dataset; otherwise, all the historical flights will be considered in the query by default if we don't mention the timeslot for flights under consideration. In our case, we worked as per the second scenario.

The resultant records for all flights which have gone through within the distance of 100 meters. In our case, this query returned 02 flights on 1st January 2022. The information about the flights and trajectories are given in Table 3.4 and Figure 3.14 respectively.

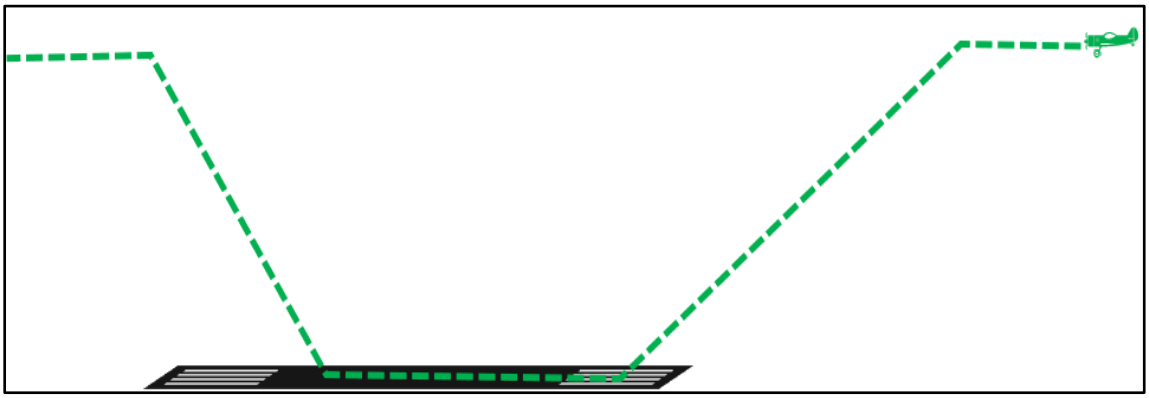

Figure 3.5. Aircraft Touch-and-Go.

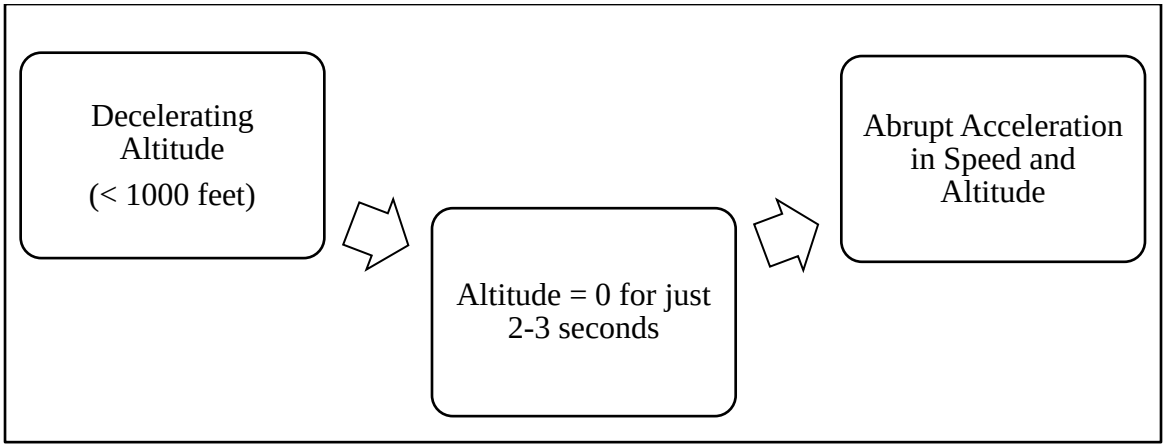

Figure 3.6. Touch-and-Go scenario.

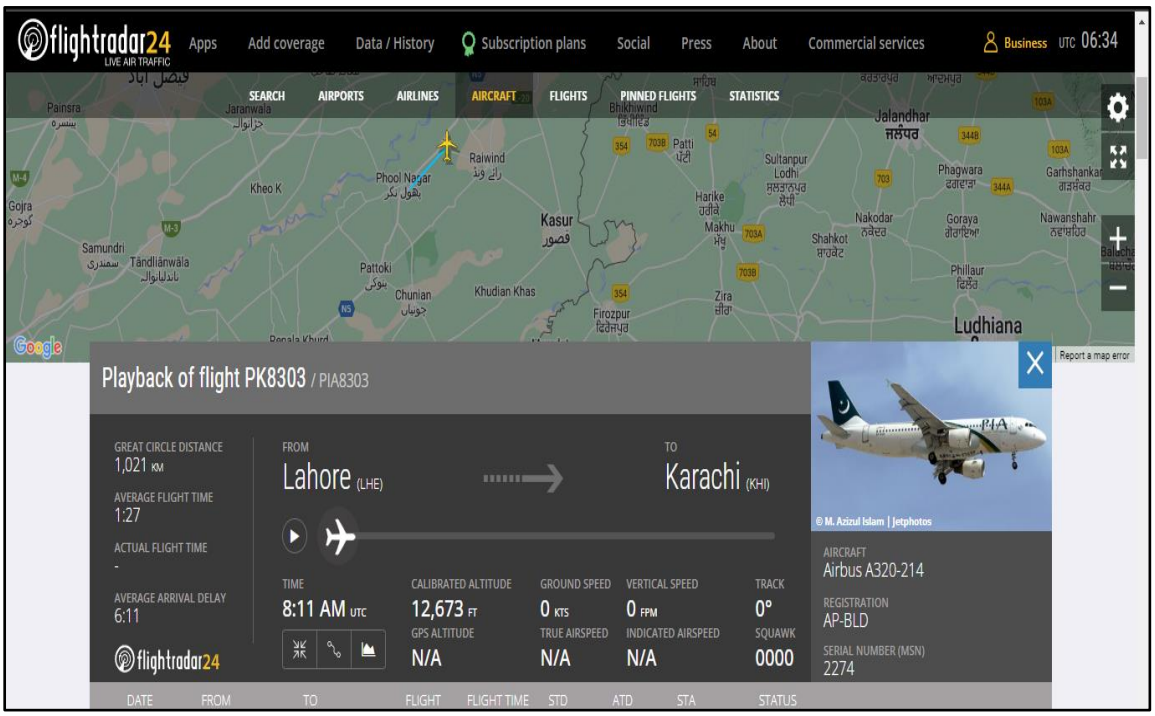

Figure 3.7. PIA flight PK8303 record on FR24.

Figure 3.8. Google Earth crash site location (direction of flight from right to left).

Figure 3.9. Arial view of the crash site street (direction of flight from left to right).

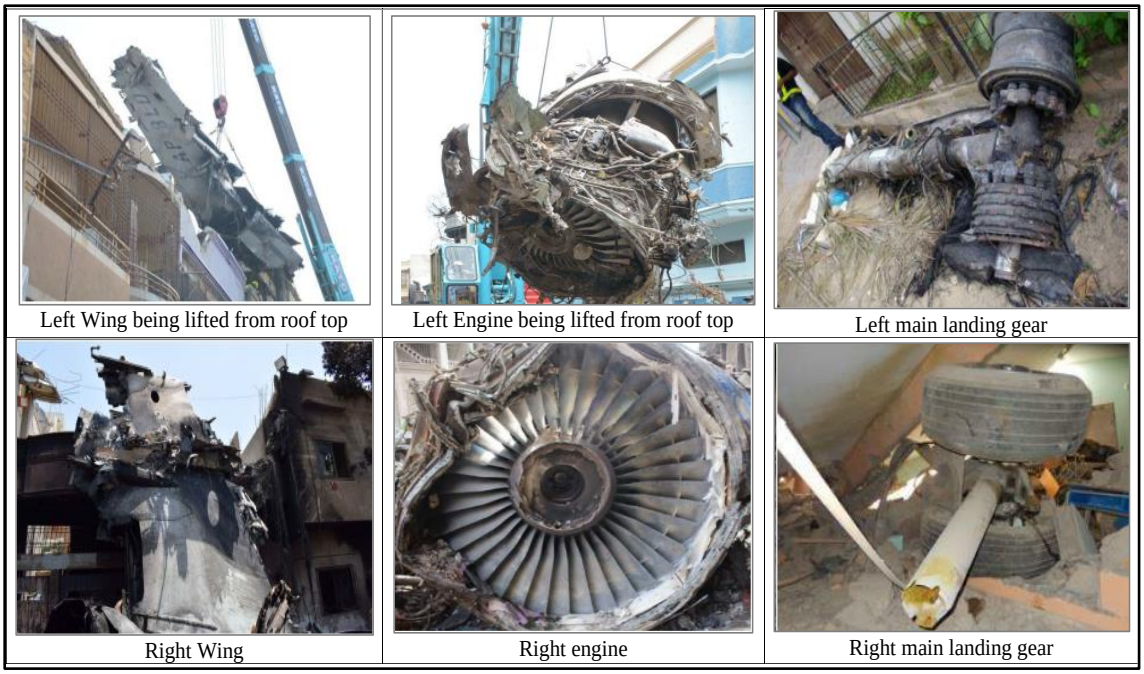

Figure 3.10. Different parts of aircraft.

Figure 3.11. Wreckage at storage site.

Table 3.2. Flights passing over Islamabad Capital Territory.

S No	Flight Date	Flt No	From	To	Passing Through
1	19-01-2022	PK370	KHI	ISB	Border Capital Territory Islamabad - Punjab
2	29-05-2022	PK369	ISB	KHI	Islamabad Capital Territory - Khyber Pakhtunkwa
3	30-05-2022	PK660	ISB	CJL	Islamabad Capital Territory - Khyber Pakhtunkwa
4	30-05-2022	PK660	ISB	CJL	Islamabad Expressway
5	15-06-2022	PK368	KHI	ISB	Border Capital Territory Islamabad - Punjab

Table 3.3. PIA flights passing over Khushab Nuclear Complex.

S No	Flt Date	Flt No	From	To	Passing Through
1	16-01-2022	PK368	KHI	ISB	Khushab Nuclear Complex
2	06-03-2022	PK368	KHI	ISB	Khushab Nuclear Complex
3	13-03-2022	PK309	ISB	KHI	Khushab Nuclear Complex
4	13-06-2022	PK308	KHI	ISB	Khushab Nuclear Complex
5	16-06-2022	PK369	ISB	KHI	Khushab Nuclear Complex
6	17-06-2022	PK369	ISB	KHI	Khushab Nuclear Complex
7	19-06-2022	PK369	ISB	KHI	Khushab Nuclear Complex

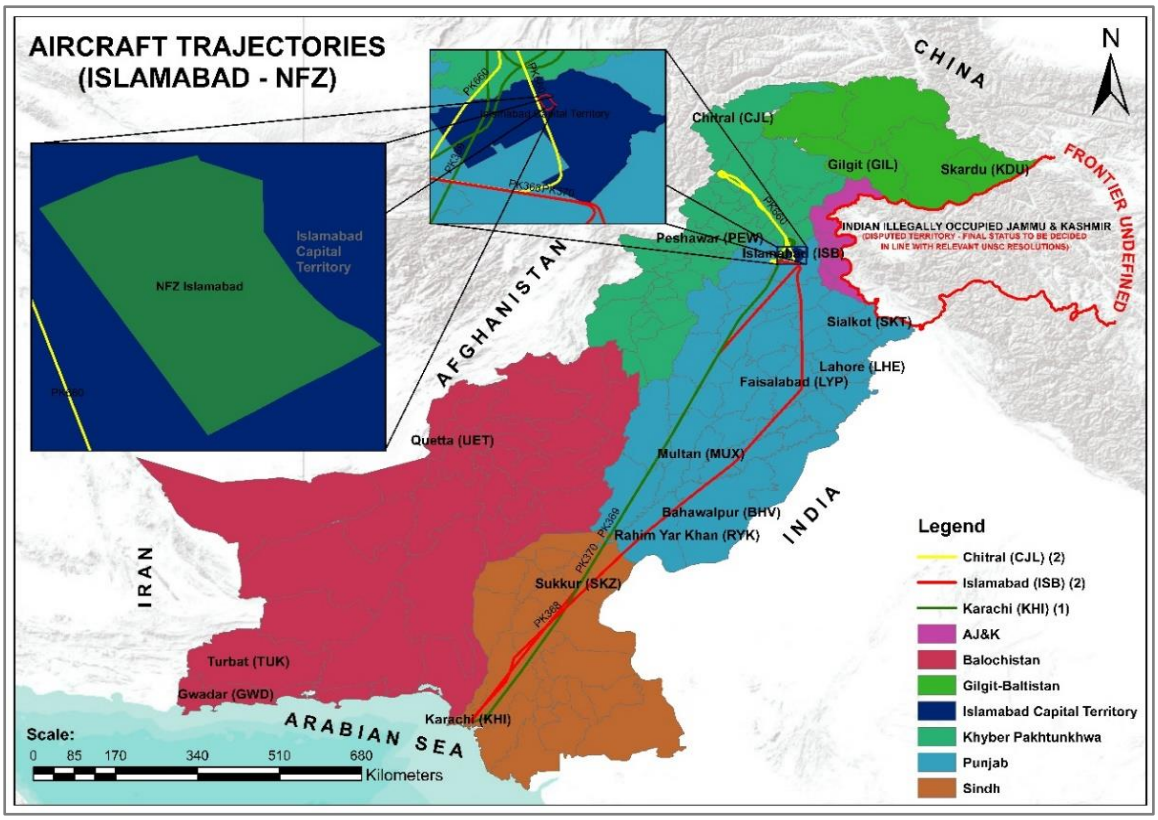

Figure 3.12. No-Fly Zone Islamabad.

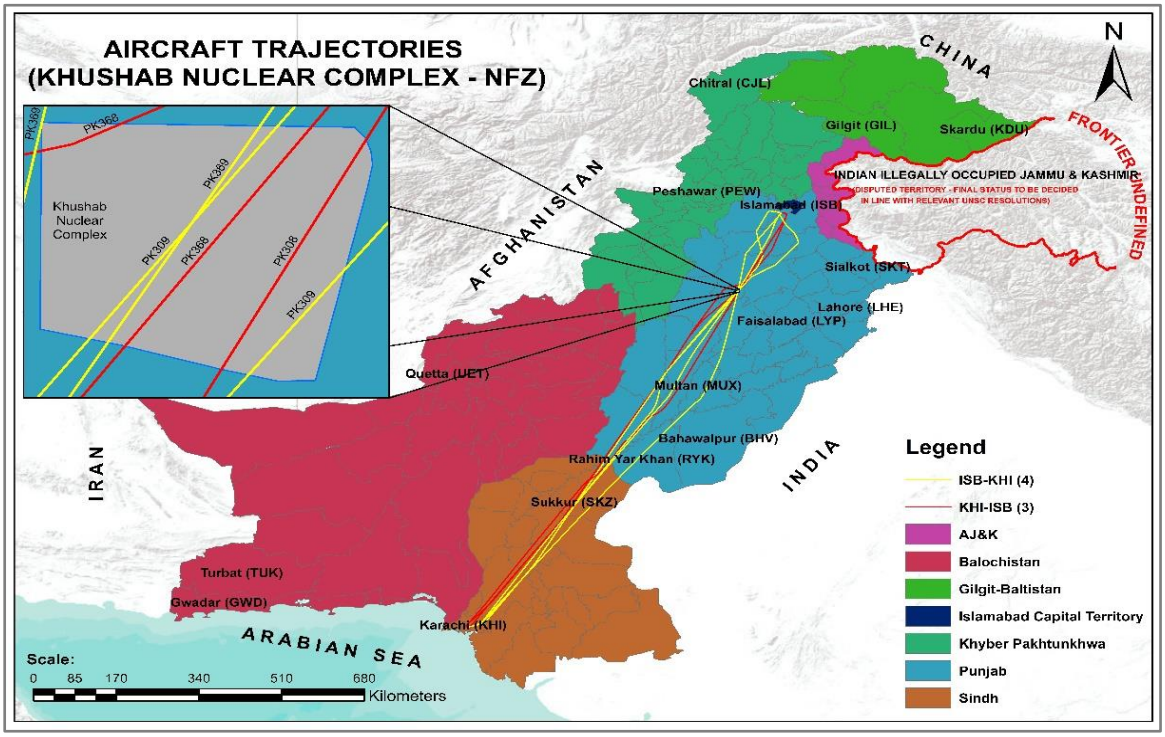

Figure 3.13. PIA flights passing over Khushab Nuclear Complex.

Table 3.4. Nearest PIA flights.

S No	Flt Date	Flt No	From	To	Distance (m)
1	01-01-2022	PK301	ISB	KHI	1.404
2	01-01-2022	PK6350	LHE	PEW	1.404

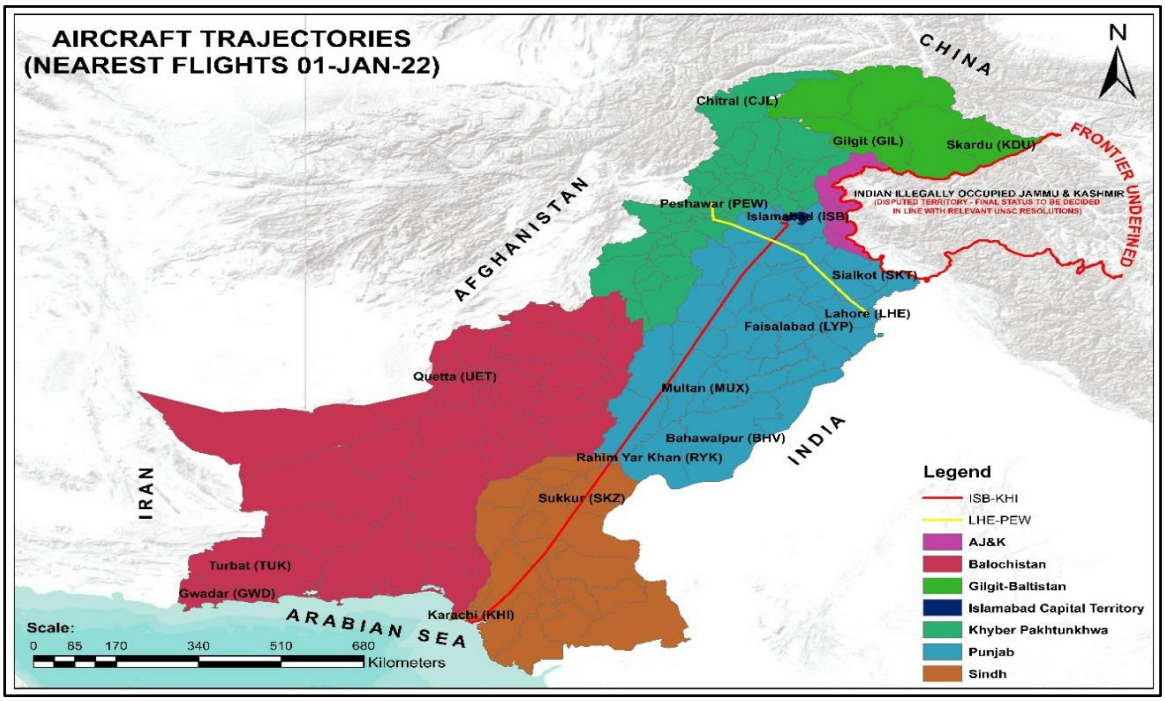

Figure 3.14. Nearest PIA flights.

Chapter 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

This study shows how MobilityDB, an open source moving object database, can be utilized to analyze mobility data. We used Pakistan International Airlines' data to complete this study. These data are downloaded from FR24, preprocessed, and loaded into a PostgreSQL database using its built-in utility. We analyzed different aspects of flights and air operations for improvements in PIA operations. The processes described in this study can be used and generalized for any other commercial airline operating in Pakistan being a significant reference for similar cases. The queries used in the analysis phase illustrate how flights and transit data can be queried in MobilityDB which is constantly evolving in several directions. To be able to process voluminous movement data that are currently being generated by latest tracking technologies, a distributed version of MobilityDB that works in cloud environments such as Azure, AWS, or Google Cloud Platform, is the best option.

During this study we have gone through multiple scenarios of Aircraft Flying data. We presented Aircraft Trajectory for the flights conducted during first half of year 2022 (i.e., from 01 January to 30 June 2022). We investigated flight diversion, aircraft taxiing timings, touch-and-go / landing approach, monitoring of no flying zone and distance between any two flights during their operations. We have concluded the following:

- Aircraft Trajectories are a useful tool to understand flight patterns and behavior.
- Allama Iqbal International Airport Lahore has maximum TXO while Islamabad International Airport has the maximum TXI.

- Chitral Domestic Airport has 100% flight diversion as per the dataset and Quetta International Airport has 2nd highest average of flight diversions (i.e., 19.35%). Apparently, it seems negligible figure, but it becomes more critical once we compare Quetta airport with other International Airports of Pakistan.
- Jinnah International Airport Karachi is the busiest airport of the country while Islamabad International Airport, Islamabad and Allam Iqbal International Airport, Lahore come at 2nd and 3rd positions respectively.
- Sialkot International Airport is the least busy airport of the country.
- Airports in Northern and Southern parts of the country lack optimal ADS-B coverage used by FR24 for flight tracking and record keeping of flights.
- PIA flights don't violate No Flying Zones (NFZ) except Khushab Nuclear Complex.
- Flights with nearest distance of less than 1000 meters found without any occurrence of collision due to direction of the flights.

Aircraft trajectories also show the behavior of different pilots, landing patterns etc. Analyzing such prospects can lead to an understanding world and brings easiness in human society. Knowledge extracted from historic data could be much more valuable than expatiations if used properly. In short, if we are looking at what we are doing and we are of the view to improve the flying culture and environment, we can go for improvements in all areas discussed above.

4.2 Recommendations

In the light of experiments and scenarios addressed during the study, we make the following recommendations:

- Case studies may be carried out at Allama Iqbal International Airport Lahore to minimize TXO and Islamabad International Airport to minimize TXI.
- The Touch-and-Go procedure be avoided, however 'Stop & Go' and 'Full Stop' are good alternatives.
- Case may be initiated to study high average of flight diversion at Quetta International Airport. The issue needs priority to be resolved.
- PIA operates Airbus A320 aircraft, the most for domestic flights in Pakistan. Alternatives may also be used (e.g., Boeing 777 Tail No: 33778, 33779, 33780 etc).
- Procedures for provisioning of data by CAA / Commercial Airlines be revised and made easy for research purposes.

4.3 Future Work

As a future work, we would recommend development of a platform where we can deploy and visualize the 3-Dimensional aircraft trajectory generated from MobilityDB for more better analysis and results. As a reference to this, Figure 4.1 gives view of a flight. This view is required to be generated during flight once it is in the air using MobilityDB platform to take in-time and informed decisions viz-a-viz required actions, if any.

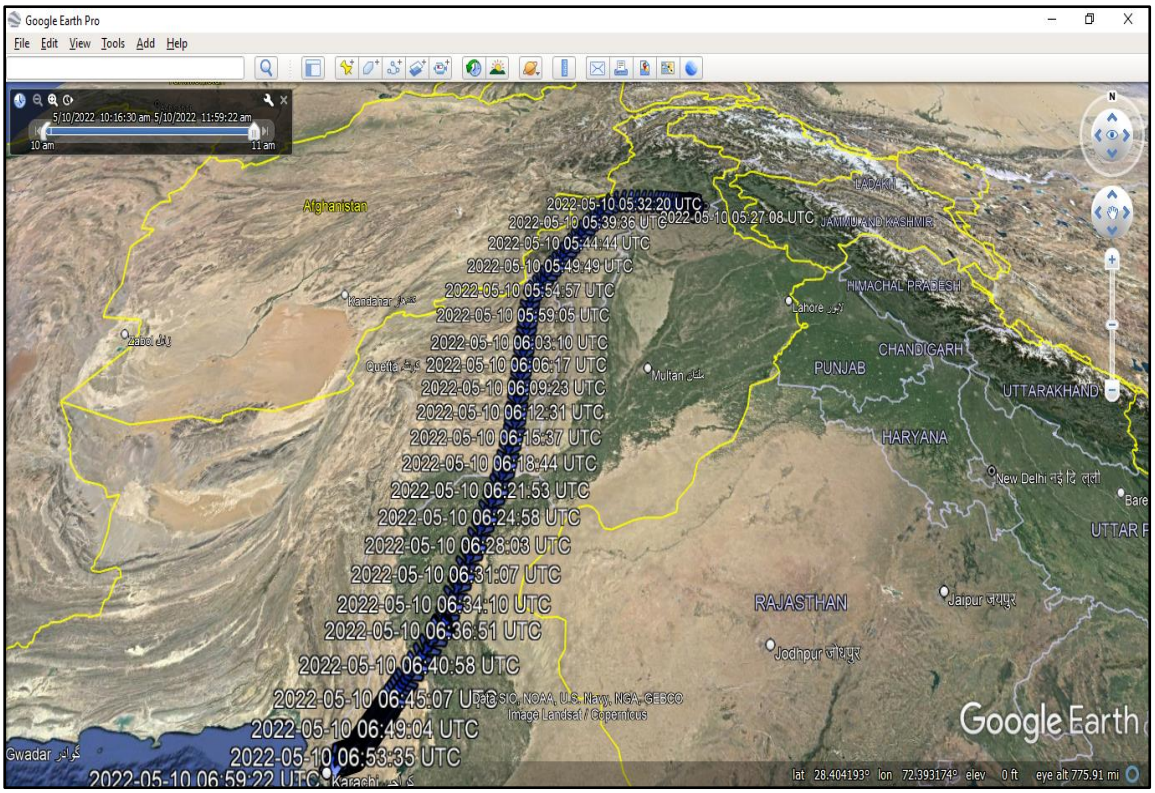

Figure 4.1. 3D view of flight PK301 on Google Earth

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Appendix ‘A’: Flight history for aircraft AP-BLA.

Flight history for Aircraft AP-BLA		
AIRCRAFT Airbus A320-214	**TYPE CODE** A320	
AIRLINE Pakistan Airlines (Retro 1960 Livery)	**Mode S** 760981	
OPERATOR Pakistan International Airlines	**Aircraft S No** 3031	

S NO	DATE	FROM	TO	FLIGHT	FLT TIME	STD	ATD	STA	STATUS	CSV FILE
1	29 Jun 2022	Karachi (KHI)	Lahore (LHE)	PK302	1:26	8:00 AM	8:12 AM	9:45 AM	Landed 9:38 AM	PK302_2c7005e3
2	27 Jun 2022	Lahore (LHE)	Karachi (KHI)	PK303	1:23	11:00 AM	11:08 AM	12:45 PM	Landed 12:31 PM	PK303_2c6971d9
3	27 Jun 2022	Karachi (KHI)	Lahore (LHE)	PK302	1:22	8:00 AM	8:02 AM	9:45 AM	Landed 9:24 AM	PK302_2c692b41
4	26 Jun 2022	Lahore (LHE)	Karachi (KHI)	PK305	1:24	8:15 PM	9:19 PM	10:00 PM	Landed 10:44 PM	PK305_2c67b83d
5	26 Jun 2022	Karachi (KHI)	Lahore (LHE)	PK304	1:25	5:30 PM	6:24 PM	7:15 PM	Landed 7:49 PM	PK304_2c672f76
6	26 Jun 2022	Quetta (UET)	Karachi (KHI)	PK311	1:01	2:40 PM	3:15 PM	4:00 PM	Landed 4:16 PM	PK311_2c66bc4a
7	26 Jun 2022	Karachi (KHI)	Quetta (UET)	PK310	1:14	12:20 PM	12:53 PM	1:40 PM	Landed 2:08 PM	PK310_2c667667
8	26 Jun 2022	Peshawar (PEW)	Karachi (KHI)	PK351	1:32	9:35 AM	9:59 AM	11:25 AM	Landed 11:31 AM	PK351_2c663296
9	24 Jun 2022	Karachi (KHI)	Islamabad (ISB)	PK368	1:40	1:00 PM	1:58 PM	2:55 PM	Landed 3:39 PM	PK368_2c5fe21d
10	24 Jun 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:32	10:00 AM	11:04 AM	11:55 AM	Landed 12:36 PM	PK301_2c5f9446
11	24 Jun 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:42	7:00 AM	7:32 AM	8:55 AM	Landed 9:15 AM	PK300_2c5f3627
12	23 Jun 2022	Lahore (LHE)	Karachi (KHI)	PK305	1:26	6:00 PM	6:44 PM	7:45 PM	Landed 8:10 PM	PK305_2c5cf018
13	23 Jun 2022	Karachi (KHI)	Lahore (LHE)	PK304	1:22	3:00 PM	3:52 PM	4:45 PM	Landed 5:14 PM	PK304_2c5c7aa9
14	23 Jun 2022	Quetta (UET)	Karachi (KHI)	PK311	0:58	12:40 PM	1:14 PM	2:00 PM	Landed 2:12 PM	PK311_2c5c29be
15	23 Jun 2022	Islamabad (ISB)	Quetta (UET)	PK325	1:23	10:20 AM	10:36 AM	11:40 AM	Landed 11:59 AM	PK325_2c5bde34
16	20 Jun 2022	Karachi (KHI)	Lahore (LHE)	PK306	1:43	7:00 PM	8:59 PM	8:45 PM	Landed 10:42 PM	PK306_2c52d10e

S NO	DATE	FROM	TO	FLIGHT	FLT TIME	STD	ATD	STA	STATUS	CSV FILE
17	19 Jun 2022	Karachi (KHI)	Islamabad (ISB)	PK6372	1:42	9:57 PM	10:08 PM	11:57 PM	Landed 11:50 PM	PK6372_2c4fc44c
18	19 Jun 2022	Quetta (UET)	Karachi (KHI)	PK311	0:56	2:40 PM	3:30 PM	4:30 PM	Landed 4:26 PM	PK311_2c4eb56a
19	19 Jun 2022	Karachi (KHI)	Quetta (UET)	PK310	1:01	12:20 PM	1:01 PM	1:40 PM	Landed 2:03 PM	PK310_2c4e6d83
20	19 Jun 2022	Peshawar (PEW)	Karachi (KHI)	PK351	1:30	9:40 AM	10:00 AM	11:30 AM	Landed 11:30 AM	PK351_2c4e2880
21	13 Jun 2022	Lahore (LHE)	Karachi (KHI)	PK305	1:28	6:00 PM	6:11 PM	7:45 PM	Landed 7:40 PM	PK305_2c3a76e5
22	13 Jun 2022	Karachi (KHI)	Lahore (LHE)	PK304	1:21	3:00 PM	3:12 PM	4:45 PM	Landed 4:33 PM	PK304_2c3a0ee2
23	13 Jun 2022	Karachi (KHI)	Lahore (LHE)	PK302	1:20	8:00 AM	8:10 AM	9:45 AM	Landed 9:30 AM	PK302_2c395d21
24	12 Jun 2022	Lahore (LHE)	Karachi (KHI)	PK307	1:32	10:00 PM	11:00 PM	11:45 PM	Landed 12:32 AM	PK307_2c383c06
25	12 Jun 2022	Karachi (KHI)	Lahore (LHE)	PK306	1:22	7:00 PM	7:18 PM	8:45 PM	Landed 8:40 PM	PK306_2c379e1d
26	12 Jun 2022	Islamabad (ISB)	Karachi (KHI)	PK369	1:41	4:00 PM	4:22 PM	5:55 PM	Landed 6:03 PM	PK369_2c3721ba
27	12 Jun 2022	Karachi (KHI)	Islamabad (ISB)	PK368	1:28	1:00 PM	1:25 PM	2:55 PM	Landed 2:53 PM	PK368_2c36bdc1
28	12 Jun 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:38	10:00 AM	10:12 AM	11:55 AM	Landed 11:51 AM	PK301_2c367100
29	12 Jun 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:29	7:00 AM	7:13 AM	8:55 AM	Landed 8:42 AM	PK300_2c36318c
30	11 Jun 2022	Islamabad (ISB)	Karachi (KHI)	PK369	1:34	4:00 PM	4:49 PM	5:55 PM	Landed 6:24 PM	PK369_2c34055b
31	11 Jun 2022	Karachi (KHI)	Islamabad (ISB)	PK368	1:29	1:00 PM	1:53 PM	2:55 PM	Landed 3:22 PM	PK368_2c339b83
32	11 Jun 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:31	10:00 AM	10:35 AM	11:55 AM	Landed 12:05 PM	PK301_2c33451e
33	10 Jun 2022	Karachi (KHI)	Quetta (UET)	PK2011	-	6:28 AM	12:17 PM	7:49 AM	Diverted to MED	PK2011_2c2ff560
34	10 Jun 2022	Karachi (KHI)	Quetta (UET)	PK310	1:04	6:30 AM	6:44 AM	7:50 AM	Landed 7:48 AM	PK310_2c2f66c6
35	09 Jun 2022	Karachi (KHI)	Lahore (LHE)	PK304	1:25	3:00 PM	3:26 PM	4:45 PM	Landed 4:51 PM	PK304_2c2ceb35
36	09 Jun 2022	Quetta (UET)	Karachi (KHI)	PK311	1:05	12:40 PM	12:53 PM	2:00 PM	Landed 1:58 PM	PK311_2c2ca466
37	09 Jun 2022	Islamabad (ISB)	Quetta (UET)	PK325	1:13	10:20 AM	10:37 AM	11:40 AM	Landed 11:51 AM	PK325_2c2c6a5e
38	06 Jun 2022	Karachi (KHI)	Islamabad (ISB)	PK370	1:24	8:00 PM	8:02 PM	9:55 PM	Landed 9:26 PM	PK370_2c23eccf
39	06 Jun 2022	Islamabad (ISB)	Karachi (KHI)	PK369	1:39	4:00 PM	4:24 PM	5:55 PM	Landed 6:03 PM	PK369_2c2345c9
40	06 Jun 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:39	10:00 AM	10:20 AM	11:55 AM	Landed 11:59 AM	PK301_2c22a208
41	05 Jun 2022	Lahore (LHE)	Karachi (KHI)	PK303	1:29	11:00 AM	11:16 AM	12:45 PM	Landed 12:45 PM	PK303_2c1fba09

S NO	DATE	FROM	TO	FLIGHT	FLT TIME	STD	ATD	STA	STATUS	CSV FILE
42	05 Jun 2022	Karachi (KHI)	Lahore (LHE)	PK302	1:18	8:00 AM	8:17 AM	9:45 AM	Landed 9:35 AM	PK302_2c1f81e4
43	04 Jun 2022	Islamabad (ISB)	Karachi (KHI)	PK309	1:33	7:00 PM	8:52 PM	8:55 PM	Landed 10:25 PM	PK309_2c1e0f45
44	04 Jun 2022	Karachi (KHI)	Islamabad (ISB)	PK308	1:26	4:00 PM	6:01 PM	5:55 PM	Landed 7:26 PM	PK308_2c1d8817
45	28 May 2022	Quetta (UET)	Islamabad (ISB)	PK326	1:03	12:35 PM	1:12 PM	1:55 PM	Landed 2:14 PM	PK326_2c06a880
46	28 May 2022	Islamabad (ISB)	Quetta (UET)	PK325	1:31	10:15 AM	10:35 AM	11:35 AM	Landed 12:07 PM	PK325_2c066bf0
47	27 May 2022	Karachi (KHI)	Islamabad (ISB)	PK308	1:30	4:00 PM	7:10 PM	8:55 PM	Landed 8:41 PM	PK308_2c044e6d
48	27 May 2022	Lahore (LHE)	Karachi (KHI)	PK303	1:28	11:00 AM	4:04 PM	12:45 PM	Landed 5:32 PM	PK303_2c03cc3b
49	27 May 2022	Quetta (UET)	Lahore (LHE)	PK323	1:09	9:00 AM	1:35 PM	10:20 AM	Landed 2:44 PM	PK323_2c0385e7
50	27 May 2022	Lahore (LHE)	Quetta (UET)	PK322	1:29	11:20 AM	11:06 AM	12:40 PM	Landed 12:35 PM	PK322_2c03430c
51	27 May 2022	Karachi (KHI)	Lahore (LHE)	PK302	1:25	8:00 AM	8:09 AM	9:45 AM	Landed 9:34 AM	PK302_2c02ff72
52	24 May 2022	Islamabad (ISB)	Karachi (KHI)	PK309	1:40	7:00 PM	8:06 PM	8:55 PM	Landed 9:46 PM	PK309_2bfabaf4
53	23 May 2022	Quetta (UET)	Islamabad (ISB)	PK326	1:03	12:50 PM	2:25 PM	2:10 PM	Landed 3:28 PM	PK326_2bf6cdcd
54	23 May 2022	Islamabad (ISB)	Quetta (UET)	PK325	1:12	10:30 AM	12:00 PM	11:50 AM	Landed 1:12 PM	PK325_2bf6905a
55	23 May 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:39	7:00 AM	7:15 AM	8:55 AM	Landed 8:55 AM	PK300_2bf626ab
56	22 May 2022	Lahore (LHE)	Karachi (KHI)	PK307	1:31	10:00 PM	10:16 PM	11:45 PM	Landed 11:48 PM	PK307_2bf4f3f3
57	22 May 2022	Karachi (KHI)	Lahore (LHE)	PK306	1:30	7:00 PM	7:26 PM	8:45 PM	Landed 8:55 PM	PK306_2bf47b92
58	22 May 2022	Islamabad (ISB)	Karachi (KHI)	PK369	1:38	4:00 PM	4:19 PM	5:55 PM	Landed 5:58 PM	PK369_2bf3ff3b
59	22 May 2022	Karachi (KHI)	Islamabad (ISB)	PK368	1:36	1:00 PM	1:11 PM	2:55 PM	Landed 2:47 PM	PK368_2bf39ab9
60	22 May 2022	Peshawar (PEW)	Karachi (KHI)	PK351	1:32	10:00 AM	10:05 AM	11:50 AM	Landed 11:37 AM	PK351_2bf35622
61	19 May 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:41	10:00 AM	10:16 AM	11:55 AM	Landed 11:56 AM	PK301_2bea1441
62	19 May 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:35	7:00 AM	7:05 AM	8:55 AM	Landed 8:41 AM	PK300_2be9ca4c
63	18 May 2022	Lahore (LHE)	Karachi (KHI)	PK305	1:28	6:00 PM	6:12 PM	7:45 PM	Landed 7:40 PM	PK305_2be7ac22
64	18 May 2022	Karachi (KHI)	Lahore (LHE)	PK304	1:26	3:00 PM	3:06 PM	4:45 PM	Landed 4:32 PM	PK304_2be72d37
65	18 May 2022	Lahore (LHE)	Karachi (KHI)	PK303	1:27	11:00 AM	11:09 AM	12:45 PM	Landed 12:36 PM	PK303_2be6bef1
66	18 May 2022	Karachi (KHI)	Lahore (LHE)	PK302	1:25	8:00 AM	8:11 AM	9:45 AM	Landed 9:35 AM	PK302_2be67a6b

S NO	DATE	FROM	TO	FLIGHT	FLT TIME	STD	ATD	STA	STATUS	CSV FILE
67	17 May 2022	Lahore (LHE)	Karachi (KHI)	PK307	1:28	10:00 PM	10:36 PM	11:45 PM	Landed 12:03 AM	PK307_2be516f8
68	17 May 2022	Quetta (UET)	Lahore (LHE)	PK323	1:08	9:50 AM	10:08 AM	11:10 AM	Landed 11:17 AM	PK323_2be34d34
69	17 May 2022	Lahore (LHE)	Quetta (UET)	PK322	1:19	7:30 AM	7:35 AM	8:50 AM	Landed 8:54 AM	PK322_2be30f39
70	15 May 2022	Karachi (KHI)	Lahore (LHE)	PK306	1:29	7:00 PM	7:15 PM	8:45 PM	Landed 8:44 PM	PK306_2bde2c20
71	15 May 2022	Islamabad (ISB)	Karachi (KHI)	PK369	1:36	4:00 PM	4:26 PM	5:55 PM	Landed 6:02 PM	PK369_2bddb6e7
72	15 May 2022	Karachi (KHI)	Islamabad (ISB)	PK368	1:28	1:00 PM	1:12 PM	2:55 PM	Landed 2:40 PM	PK368_2bdd4a6c
73	15 May 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:38	10:00 AM	10:11 AM	11:55 AM	Landed 11:49 AM	PK301_2bdd0851
74	15 May 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:30	7:00 AM	7:13 AM	8:55 AM	Landed 8:42 AM	PK300_2bdcceb7
75	14 May 2022	Islamabad (ISB)	Karachi (KHI)	PK369	1:39	4:00 PM	4:26 PM	5:55 PM	Landed 6:05 PM	PK369_2bda93c7
76	14 May 2022	Karachi (KHI)	Islamabad (ISB)	PK368	1:32	1:00 PM	1:24 PM	2:55 PM	Landed 2:56 PM	PK368_2bda2a19
77	14 May 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:43	10:00 AM	10:14 AM	11:55 AM	Landed 11:57 AM	PK301_2bd9e28c
78	14 May 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:32	7:00 AM	7:11 AM	8:55 AM	Landed 8:44 AM	PK300_2bd9a0cb
79	13 May 2022	Islamabad (ISB)	Karachi (KHI)	PK309	1:38	7:00 PM	7:16 PM	8:55 PM	Landed 8:53 PM	PK309_2bd7c0c5
80	12 May 2022	Karachi (KHI)	Islamabad (ISB)	PK308	1:32	4:00 PM	4:36 PM	5:55 PM	Landed 6:08 PM	PK308_2bd3f3e8
81	12 May 2022	Quetta (UET)	Karachi (KHI)	PK311	1:11	12:40 PM	1:54 PM	2:00 PM	Landed 3:05 PM	PK311_2bd3a046
82	12 May 2022	Islamabad (ISB)	Quetta (UET)	PK325	1:17	10:20 AM	11:24 AM	11:40 AM	Landed 12:41 PM	PK325_2bd35c2a
83	01 May 2022	Karachi (KHI)	Peshawar (PEW)	PK350	1:26	7:30 PM	7:48 PM	9:20 PM	Landed 9:14 PM	PK350_2bb0f9e8
84	01 May 2022	Faisalabad (LYP)	Karachi (KHI)	PK341	1:19	4:40 PM	4:26 PM	6:20 PM	Landed 5:45 PM	PK341_2bb0757d
85	01 May 2022	Karachi (KHI)	Faisalabad (LYP)	PK340	1:15	2:00 PM	2:00 PM	3:40 PM	Landed 3:15 PM	PK340_2bb0327a
86	01 May 2022	Peshawar (PEW)	Karachi (KHI)	PK351	1:38	10:30 AM	10:40 AM	12:20 PM	Landed 12:18 PM	PK351_2bafee48
87	27 Apr 2022	Karachi (KHI)	Faisalabad (LYP)	PK340	1:18	8:45 PM	9:03 PM	10:25 PM	Landed 10:21 PM	PK340_2ba497a0
88	27 Apr 2022	Lahore (LHE)	Karachi (KHI)	PK305	1:28	6:00 PM	5:57 PM	7:45 PM	Landed 7:25 PM	PK305_2ba3fe22
89	27 Apr 2022	Karachi (KHI)	Lahore (LHE)	PK304	1:23	3:00 PM	3:05 PM	4:45 PM	Landed 4:28 PM	PK304_2ba39116
90	27 Apr 2022	Peshawar (PEW)	Karachi (KHI)	PK351	1:40	10:30 AM	10:45 AM	12:20 PM	Landed 12:25 PM	PK351_2ba321d6
91	26 Apr 2022	Karachi (KHI)	Peshawar (PEW)	PK350	1:30	9:00 PM	9:07 PM	10:50 PM	Landed 10:37 PM	PK350_2ba15c2b

S NO	DATE	FROM	TO	FLIGHT	FLT TIME	STD	ATD	STA	STATUS	CSV FILE
92	26 Apr 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:36	10:00 AM	10:14 AM	11:55 AM	Landed 11:51 AM	PK301_2b9ff346
93	25 Apr 2022	Quetta (UET)	Islamabad (ISB)	PK326	1:07	12:50 PM	1:00 PM	2:10 PM	Landed 2:08 PM	PK326_2b9d30b6
94	25 Apr 2022	Islamabad (ISB)	Quetta (UET)	PK325	1:11	10:30 AM	10:39 AM	11:50 AM	Landed 11:50 AM	PK325_2b9cf153
95	25 Apr 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:33	7:00 AM	7:02 AM	8:55 AM	Landed 8:35 AM	PK300_2b9ca3bc
96	24 Apr 2022	Islamabad (ISB)	Karachi (KHI)	PK309	1:41	7:00 PM	7:11 PM	8:55 PM	Landed 8:52 PM	PK309_2b9afaad
97	24 Apr 2022	Karachi (KHI)	Islamabad (ISB)	PK308	1:37	4:00 PM	4:07 PM	5:55 PM	Landed 5:43 PM	PK308_2b9a918f
98	23 Apr 2022	Lahore (LHE)	Karachi (KHI)	PK305	1:26	6:00 PM	6:13 PM	7:45 PM	Landed 7:39 PM	PK305_2b98148c
99	23 Apr 2022	Karachi (KHI)	Lahore (LHE)	PK304	1:23	3:00 PM	3:05 PM	4:45 PM	Landed 4:27 PM	PK304_2b97b423
100	23 Apr 2022	Peshawar (PEW)	Karachi (KHI)	PK351	1:34	11:30 AM	11:47 AM	1:20 PM	Landed 1:21 PM	PK351_2b9767d0
101	21 Apr 2022	Lahore (LHE)	Karachi (KHI)	PK303	1:32	11:00 AM	11:05 AM	12:45 PM	Landed 12:37 PM	PK303_2b9137eb
102	21 Apr 2022	Karachi (KHI)	Lahore (LHE)	PK302	1:24	8:00 AM	8:09 AM	9:45 AM	Landed 9:33 AM	PK302_2b90fb85
103	20 Apr 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:49	10:00 AM	10:01 AM	11:55 AM	Landed 11:49 AM	PK301_2b8e0003
104	20 Apr 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:29	7:00 AM	7:05 AM	8:55 AM	Landed 8:34 AM	PK300_2b8dc122
105	19 Apr 2022	Islamabad (ISB)	Karachi (KHI)	PK309	1:37	7:00 PM	7:12 PM	8:55 PM	Landed 8:49 PM	PK309_2b8c0eca
106	18 Apr 2022	Quetta (UET)	Islamabad (ISB)	PK326	1:08	12:50 PM	4:54 PM	2:10 PM	Landed 6:03 PM	PK326_2b88b3f3
107	18 Apr 2022	Karachi (KHI)	Quetta (UET)	PK310	1:04	11:00 AM	2:50 PM	12:20 PM	Landed 3:53 PM	PK310_2b8864e1
108	18 Apr 2022	Quetta (UET)	Karachi (KHI)	PK311	1:04	1:20 PM	12:23 PM	2:40 PM	Landed 1:27 PM	PK311_2b882656
109	18 Apr 2022	Islamabad (ISB)	Quetta (UET)	PK325	1:10	10:30 AM	10:16 AM	11:50 AM	Landed 11:26 AM	PK325_2b87fb22
110	17 Apr 2022	Karachi (KHI)	Islamabad (ISB)	PK308	1:31	4:00 PM	4:04 PM	5:55 PM	Landed 5:35 PM	PK308_2b85d79c
111	17 Apr 2022	Peshawar (PEW)	Karachi (KHI)	PK351	1:39	10:30 AM	10:36 AM	12:20 PM	Landed 12:16 PM	PK351_2b855b7c
112	15 Apr 2022	Karachi (KHI)	Peshawar (PEW)	PK350	1:32	9:00 PM	9:15 PM	10:50 PM	Landed 10:47 PM	PK350_2b8121c5
113	15 Apr 2022	Lahore (LHE)	Karachi (KHI)	PK305	1:30	6:00 PM	6:02 PM	7:45 PM	Landed 7:32 PM	PK305_2b807f69
114	15 Apr 2022	Karachi (KHI)	Lahore (LHE)	PK304	1:25	3:00 PM	3:11 PM	4:45 PM	Landed 4:36 PM	PK304_2b801c24
115	14 Apr 2022	Islamabad (ISB)	Karachi (KHI)	PK309	1:37	7:00 PM	7:11 PM	8:55 PM	Landed 8:48 PM	PK309_2b7da501
116	14 Apr 2022	Karachi (KHI)	Islamabad (ISB)	PK308	1:32	4:00 PM	4:08 PM	5:55 PM	Landed 5:39 PM	PK308_2b7d2526

S NO	DATE	FROM	TO	FLIGHT	FLT TIME	STD	ATD	STA	STATUS	CSV FILE
117	12 Apr 2022	Karachi (KHI)	Peshawar (PEW)	PK350	1:32	9:00 PM	9:12 PM	10:50 PM	Landed 10:44 PM	PK350_2b780c02
118	12 Apr 2022	Lahore (LHE)	Karachi (KHI)	PK305	1:29	6:00 PM	6:16 PM	7:45 PM	Landed 7:45 PM	PK305_2b778bd4
119	12 Apr 2022	Karachi (KHI)	Lahore (LHE)	PK304	1:19	3:00 PM	3:02 PM	4:45 PM	Landed 4:21 PM	PK304_2b771ec8
120	12 Apr 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:43	10:00 AM	10:07 AM	11:55 AM	Landed 11:50 AM	PK301_2b76ad20
121	12 Apr 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:34	7:00 AM	7:14 AM	8:55 AM	Landed 8:48 AM	PK300_2b7670e2
122	11 Apr 2022	Lahore (LHE)	Karachi (KHI)	PK305	1:33	6:00 PM	6:05 PM	7:45 PM	Landed 7:38 PM	PK305_2b749a5f
123	08 Apr 2022	Karachi (KHI)	Islamabad (ISB)	PK308	1:30	4:00 PM	4:15 PM	5:55 PM	Landed 5:44 PM	PK308_2b6bdd57
124	07 Apr 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:44	10:00 AM	10:11 AM	11:55 AM	Landed 11:55 AM	PK301_2b687dd6
125	04 Apr 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:26	7:00 AM	7:08 AM	8:55 AM	Landed 8:35 AM	PK300_2b5ffe55
126	03 Apr 2022	Lahore (LHE)	Karachi (KHI)	PK305	1:34	6:00 PM	5:52 PM	7:45 PM	Landed 7:26 PM	PK305_2b5e366a
127	03 Apr 2022	Karachi (KHI)	Lahore (LHE)	PK304	1:18	3:00 PM	2:57 PM	4:45 PM	Landed 4:15 PM	PK304_2b5de1e9
128	03 Apr 2022	Peshawar (PEW)	Karachi (KHI)	PK351	1:42	10:30 AM	10:34 AM	12:20 PM	Landed 12:16 PM	PK351_2b5d8a58
129	26 Mar 2022	Karachi (KHI)	Islamabad (ISB)	PK308	1:29	4:00 PM	4:47 PM	5:55 PM	Landed 6:16 PM	PK308_2b46628d
130	25 Mar 2022	Karachi (KHI)	Multan (MUX)	PK330	1:03	9:00 PM	9:19 PM	10:25 PM	Landed 10:22 PM	PK330_2b4411f3
131	25 Mar 2022	Lahore (LHE)	Karachi (KHI)	PK305	1:30	6:00 PM	6:23 PM	7:45 PM	Landed 7:53 PM	PK305_2b43733b
132	25 Mar 2022	Karachi (KHI)	Lahore (LHE)	PK304	1:22	3:00 PM	3:13 PM	4:45 PM	Landed 4:35 PM	PK304_2b42fdb1
133	25 Mar 2022	Lahore (LHE)	Karachi (KHI)	PK303	1:30	11:00 AM	11:17 AM	12:45 PM	Landed 12:47 PM	PK303_2b429a30
134	25 Mar 2022	Karachi (KHI)	Lahore (LHE)	PK302	1:21	8:00 AM	8:23 AM	9:45 AM	Landed 9:44 AM	PK302_2b4260f9
135	24 Mar 2022	Quetta (UET)	Karachi (KHI)	PK363	0:54	2:35 PM	2:49 PM	3:55 PM	Landed 3:42 PM	PK363_2b3fda06
136	24 Mar 2022	Islamabad (ISB)	Quetta (UET)	PK363	1:10	12:15 PM	12:28 PM	1:35 PM	Landed 1:38 PM	PK363_2b3f9210
137	22 Mar 2022	Quetta (UET)	Islamabad (ISB)	PK326	0:55	4:00 PM	5:54 PM	5:20 PM	Landed 6:48 PM	PK326_2b3a4c3c
138	22 Mar 2022	Lahore (LHE)	Quetta (UET)	PK322	1:13	1:40 PM	3:16 PM	3:00 PM	Landed 4:29 PM	PK322_2b39e3ba
139	22 Mar 2022	Quetta (UET)	Lahore (LHE)	PK323	1:01	11:10 AM	12:45 PM	12:30 PM	Landed 1:46 PM	PK323_2b39aae0
140	22 Mar 2022	Islamabad (ISB)	Quetta (UET)	PK325	1:11	8:50 AM	10:25 AM	10:10 AM	Landed 11:36 AM	PK325_2b39781b
141	21 Mar 2022	Quetta (UET)	Islamabad (ISB)	PK352	0:57	4:20 PM	4:24 PM	5:40 PM	Landed 5:20 PM	PK352_2b371396

S NO	DATE	FROM	TO	FLIGHT	FLT TIME	STD	ATD	STA	STATUS	CSV FILE
142	21 Mar 2022	Karachi (KHI)	Quetta (UET)	PK352	1:01	2:00 PM	2:13 PM	3:20 PM	Landed 3:14 PM	PK352_2b36d06e
143	21 Mar 2022	Peshawar (PEW)	Karachi (KHI)	PK351	1:39	11:00 AM	11:11 AM	12:50 PM	Landed 12:51 PM	PK351_2b368e67
144	20 Mar 2022	Karachi (KHI)	Multan (MUX)	PK330	1:01	9:00 PM	12:03 AM	10:25 PM	Landed 1:05 AM	PK330_2b355860
145	20 Mar 2022	Lahore (LHE)	Karachi (KHI)	PK305	1:33	6:00 PM	6:02 PM	7:45 PM	Landed 7:35 PM	PK305_2b345231
146	20 Mar 2022	Karachi (KHI)	Lahore (LHE)	PK304	1:21	3:00 PM	3:11 PM	4:45 PM	Landed 4:32 PM	PK304_2b33f43e
147	20 Mar 2022	Lahore (LHE)	Karachi (KHI)	PK303	1:34	11:00 AM	11:07 AM	12:45 PM	Landed 12:41 PM	PK303_2b339d41
148	20 Mar 2022	Karachi (KHI)	Lahore (LHE)	PK302	1:19	8:00 AM	8:10 AM	9:45 AM	Landed 9:29 AM	PK302_2b336e2e
149	19 Mar 2022	Islamabad (ISB)	Karachi (KHI)	PK369	1:37	4:00 PM	4:23 PM	5:55 PM	Landed 6:00 PM	PK369_2b3165f2
150	19 Mar 2022	Karachi (KHI)	Islamabad (ISB)	PK368	1:24	1:00 PM	1:14 PM	2:55 PM	Landed 2:38 PM	PK368_2b311027
151	19 Mar 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:41	10:00 AM	9:57 AM	11:55 AM	Landed 11:38 AM	PK301_2b30d28f
152	19 Mar 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:24	7:00 AM	7:09 AM	8:55 AM	Landed 8:33 AM	PK300_2b309d27
153	17 Mar 2022	Islamabad (ISB)	Karachi (KHI)	PK309	1:42	7:00 PM	7:26 PM	8:55 PM	Landed 9:08 PM	PK309_2b2ba0ad
154	17 Mar 2022	Karachi (KHI)	Islamabad (ISB)	PK308	1:28	4:00 PM	4:32 PM	5:55 PM	Landed 6:00 PM	PK308_2b2b2cb0
155	16 Mar 2022	Karachi (KHI)	Peshawar (PEW)	PK350	1:31	7:00 PM	8:32 PM	8:50 PM	Landed 10:03 PM	PK350_2b28b43d
156	16 Mar 2022	Islamabad (ISB)	Karachi (KHI)	PK369	1:38	4:00 PM	5:15 PM	5:55 PM	Landed 6:53 PM	PK369_2b28279b
157	16 Mar 2022	Karachi (KHI)	Islamabad (ISB)	PK368	1:41	1:00 PM	1:58 PM	2:55 PM	Landed 3:39 PM	PK368_2b27c7ca
158	16 Mar 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:43	10:00 AM	10:10 AM	11:55 AM	Landed 11:54 AM	PK301_2b277afb
159	16 Mar 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:39	7:00 AM	7:08 AM	8:55 AM	Landed 8:46 AM	PK300_2b273e9f
160	15 Mar 2022	Islamabad (ISB)	Karachi (KHI)	PK309	1:38	7:00 PM	7:13 PM	8:55 PM	Landed 8:50 PM	PK309_2b253d41
161	15 Mar 2022	Karachi (KHI)	Islamabad (ISB)	PK308	1:31	4:00 PM	4:07 PM	5:55 PM	Landed 5:38 PM	PK308_2b24ff79
162	15 Mar 2022	Peshawar (PEW)	Karachi (KHI)	PK351	1:36	11:00 AM	11:26 AM	12:50 PM	Landed 1:03 PM	PK351_2b249121
163	14 Mar 2022	Karachi (KHI)	Peshawar (PEW)	PK350	1:32	7:00 PM	8:07 PM	8:50 PM	Landed 9:39 PM	PK350_2b22971d
164	14 Mar 2022	Islamabad (ISB)	Karachi (KHI)	PK369	1:34	4:00 PM	5:03 PM	5:55 PM	Landed 6:38 PM	PK369_2b221305
165	14 Mar 2022	Karachi (KHI)	Islamabad (ISB)	PK368	1:41	1:00 PM	1:46 PM	2:55 PM	Landed 3:28 PM	PK368_2b21b45c
166	14 Mar 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:40	10:00 AM	10:20 AM	11:55 AM	Landed 12:00 PM	PK301_2b216b09

S NO	DATE	FROM	TO	FLIGHT	FLT TIME	STD	ATD	STA	STATUS	CSV FILE
167	14 Mar 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:42	7:00 AM	7:11 AM	8:55 AM	Landed 8:54 AM	PK300_2b213007
168	13 Mar 2022	Faisalabad (LYP)	Karachi (KHI)	PK341	1:17	9:40 PM	9:51 PM	11:20 PM	Landed 11:08 PM	PK341_2b1ff22e
169	13 Mar 2022	Karachi (KHI)	Faisalabad (LYP)	PK340	1:22	7:00 PM	7:10 PM	8:40 PM	Landed 8:32 PM	PK340_2b1f8218
170	13 Mar 2022	Quetta (UET)	Karachi (KHI)	PK311	0:53	11:20 AM	11:26 AM	12:40 PM	Landed 12:18 PM	PK311_2b1eb8fe
171	13 Mar 2022	Lahore (LHE)	Quetta (UET)	PK322	1:11	9:00 AM	9:08 AM	10:20 AM	Landed 10:19 AM	PK322_2b1e8542
172	08 Mar 2022	Karachi (KHI)	Islamabad (ISB)	PK370	1:38	9:00 PM	9:15 PM	10:55 PM	Landed 10:53 PM	PK370_2b113570
173	08 Mar 2022	Lahore (LHE)	Karachi (KHI)	PK305	1:30	1:00 PM	1:07 PM	2:45 PM	Landed 2:37 PM	PK305_2b10b43a
174	08 Mar 2022	Karachi (KHI)	Lahore (LHE)	PK304	1:22	10:00 AM	10:22 AM	11:45 AM	Landed 11:43 AM	PK304_2b106243
175	08 Mar 2022	Peshawar (PEW)	Karachi (KHI)	PK351	1:44	6:00 AM	6:14 AM	7:50 AM	Landed 7:58 AM	PK351_2b100501
176	07 Mar 2022	Karachi (KHI)	Peshawar (PEW)	PK350	1:34	2:00 PM	2:34 PM	3:50 PM	Landed 4:08 PM	PK350_2b0e21c6
177	07 Mar 2022	Islamabad (ISB)	Karachi (KHI)	PK369	1:40	11:00 AM	11:27 AM	12:55 PM	Landed 1:07 PM	PK369_2b0db7ae
178	07 Mar 2022	Karachi (KHI)	Islamabad (ISB)	PK368	1:36	8:00 AM	8:26 AM	9:55 AM	Landed 10:03 AM	PK368_2b0d6cc2
179	07 Mar 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:37	5:00 AM	5:20 AM	6:55 AM	Landed 6:57 AM	PK301_2b0d296e
180	07 Mar 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:33	2:00 AM	2:11 AM	3:55 AM	Landed 3:44 AM	PK300_2b0ceaa6
181	06 Mar 2022	Faisalabad (LYP)	Karachi (KHI)	PK341	1:29	4:40 PM	5:55 PM	6:20 PM	Landed 7:25 PM	PK341_2b0bdb30
182	06 Mar 2022	Karachi (KHI)	Faisalabad (LYP)	PK340	1:14	2:00 PM	3:26 PM	3:40 PM	Landed 4:40 PM	PK340_2b0b4d46
183	06 Mar 2022	Islamabad (ISB)	Karachi (KHI)	PK369	1:50	11:00 AM	12:09 PM	12:55 PM	Landed 1:58 PM	PK369_2b0b068d
184	06 Mar 2022	Karachi (KHI)	Islamabad (ISB)	PK368	1:27	8:00 AM	8:49 AM	9:55 AM	Landed 10:16 AM	PK368_2b0ab0ba
185	06 Mar 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:43	5:00 AM	5:37 AM	6:55 AM	Landed 7:20 AM	PK301_2b0a7677
186	06 Mar 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:28	2:00 AM	2:30 AM	3:55 AM	Landed 3:57 AM	PK300_2b0a3e91
187	05 Mar 2022	Lahore (LHE)	Karachi (KHI)	PK307	1:34	5:00 PM	5:20 PM	6:45 PM	Landed 6:53 PM	PK307_2b08f8c6
188	05 Mar 2022	Lahore (LHE)	Karachi (KHI)	PK303	1:32	6:00 AM	6:09 AM	7:45 AM	Landed 7:41 AM	PK303_2b07d17a
189	05 Mar 2022	Karachi (KHI)	Lahore (LHE)	PK302	1:21	3:00 AM	3:12 AM	4:45 AM	Landed 4:33 AM	PK302_2b079796
190	03 Mar 2022	Lahore (LHE)	Karachi (KHI)	PK307	1:34	5:00 PM	5:56 PM	6:45 PM	Landed 7:30 PM	PK307_2b02eefb
191	03 Mar 2022	Karachi (KHI)	Lahore (LHE)	PK306	1:19	2:00 PM	3:10 PM	3:45 PM	Landed 4:30 PM	PK306_2b027405

S NO	DATE	FROM	TO	FLIGHT	FLT TIME	STD	ATD	STA	STATUS	CSV FILE
192	03 Mar 2022	Islamabad (ISB)	Karachi (KHI)	PK369	1:40	11:00 AM	11:55 AM	12:55 PM	Landed 1:35 PM	PK369_2b01ed14
193	03 Mar 2022	Karachi (KHI)	Islamabad (ISB)	PK368	1:37	8:00 AM	8:50 AM	9:55 AM	Landed 10:27 AM	PK368_2b019a78
194	03 Mar 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:49	5:00 AM	5:24 AM	6:55 AM	Landed 7:13 AM	PK301_2b014d1d
195	03 Mar 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:34	2:00 AM	2:12 AM	3:55 AM	Landed 3:46 AM	PK300_2b01056e
196	02 Mar 2022	Faisalabad (LYP)	Karachi (KHI)	PK341	1:28	11:35 AM	11:52 AM	1:15 PM	Landed 1:20 PM	PK341_2afea1c6
197	01 Mar 2022	Karachi (KHI)	Islamabad (ISB)	PK308	1:24	11:00 AM	11:13 AM	12:55 PM	Landed 12:37 PM	PK308_2afb70a6
198	01 Mar 2022	Peshawar (PEW)	Karachi (KHI)	PK351	1:42	6:00 AM	6:12 AM	7:50 AM	Landed 7:54 AM	PK351_2afaf982
199	28 Feb 2022	Karachi (KHI)	Faisalabad (LYP)	PK340	1:14	3:30 PM	3:42 PM	5:10 PM	Landed 4:56 PM	PK340_2af90152
200	28 Feb 2022	Islamabad (ISB)	Karachi (KHI)	PK369	1:41	11:00 AM	11:29 AM	12:55 PM	Landed 1:11 PM	PK369_2af85cc6
201	28 Feb 2022	Karachi (KHI)	Islamabad (ISB)	PK368	1:36	8:00 AM	8:35 AM	9:55 AM	Landed 10:11 AM	PK368_2af8129a
202	28 Feb 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:51	5:00 AM	5:15 AM	6:55 AM	Landed 7:06 AM	PK301_2af7cb4a
203	25 Feb 2022	Karachi (KHI)	Lahore (LHE)	PK6314	1:23	3:56 PM	3:56 PM	5:19 PM	Landed 5:19 PM	PK6314_2af0363d
204	25 Feb 2022	Lahore (LHE)	Karachi (KHI)	PK6313	1:30	12:57 PM	12:57 PM	2:27 PM	Landed 2:27 PM	PK6313_2aefc20d
205	24 Feb 2022	Karachi (KHI)	Lahore (LHE)	PK6316	1:24	4:15 PM	2:51 PM	4:15 PM	Landed 4:15 PM	PK6316_2aed1551
206	24 Feb 2022	Islamabad (ISB)	Karachi (KHI)	PK369	1:35	11:00 AM	11:41 AM	12:55 PM	Landed 1:16 PM	PK369_2aecac6f
207	24 Feb 2022	Karachi (KHI)	Islamabad (ISB)	PK368	1:39	8:00 AM	8:34 AM	9:55 AM	Landed 10:13 AM	PK368_2aec5d8b
208	24 Feb 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:42	5:00 AM	5:18 AM	6:55 AM	Landed 7:00 AM	PK301_2aec14ac
209	24 Feb 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:39	2:00 AM	2:12 AM	3:55 AM	Landed 3:51 AM	PK300_2aebd151
210	23 Feb 2022	Lahore (LHE)	Karachi (KHI)	PK305	1:30	1:00 PM	1:21 PM	2:45 PM	Landed 2:51 PM	PK305_2aea101b
211	23 Feb 2022	Karachi (KHI)	Lahore (LHE)	PK304	1:23	10:00 AM	10:15 AM	11:45 AM	Landed 11:38 AM	PK304_2ae9b051
212	23 Feb 2022	Lahore (LHE)	Karachi (KHI)	PK303	1:36	6:00 AM	6:13 AM	7:45 AM	Landed 7:49 AM	PK303_2ae93a14
213	23 Feb 2022	Karachi (KHI)	Lahore (LHE)	PK302	1:28	3:00 AM	3:17 AM	4:45 AM	Landed 4:44 AM	PK302_2ae915d6
214	22 Feb 2022	Islamabad (ISB)	Karachi (KHI)	PK309	1:42	2:00 PM	2:17 PM	3:55 PM	Landed 3:58 PM	PK309_2ae78311
215	21 Feb 2022	Quetta (UET)	Islamabad (ISB)	PK352	1:00	11:20 AM	11:38 AM	12:40 PM	Landed 12:38 PM	PK352_2ae46e5e
216	21 Feb 2022	Karachi (KHI)	Quetta (UET)	PK352	1:01	9:00 AM	9:26 AM	10:20 AM	Landed 10:27 AM	PK352_2ae43b44

S NO	DATE	FROM	TO	FLIGHT	FLT TIME	STD	ATD	STA	STATUS	CSV FILE
217	21 Feb 2022	Peshawar (PEW)	Karachi (KHI)	PK351	1:37	6:00 AM	5:59 AM	7:50 AM	Landed 7:36 AM	PK351_2ae3f3e6
218	20 Feb 2022	Karachi (KHI)	Multan (MUX)	PK330	1:04	4:00 PM	4:25 PM	5:25 PM	Landed 5:29 PM	PK330_2ae2527f
219	20 Feb 2022	Lahore (LHE)	Karachi (KHI)	PK305	1:34	1:00 PM	1:03 PM	2:45 PM	Landed 2:37 PM	PK305_2ae1d843
220	20 Feb 2022	Karachi (KHI)	Lahore (LHE)	PK304	1:26	10:00 AM	10:08 AM	11:45 AM	Landed 11:34 AM	PK304_2ae19728
221	20 Feb 2022	Quetta (UET)	Karachi (KHI)	PK311	0:57	6:20 AM	6:46 AM	7:40 AM	Landed 7:42 AM	PK311_2ae15787
222	20 Feb 2022	Lahore (LHE)	Quetta (UET)	PK322	1:25	4:00 AM	4:14 AM	5:20 AM	Landed 5:39 AM	PK322_2ae1260b
223	18 Feb 2022	Karachi (KHI)	Lahore (LHE)	PK306	1:24	2:00 PM	7:05 PM	3:45 PM	Landed 8:29 PM	PK306_2add386d
224	18 Feb 2022	Islamabad (ISB)	Karachi (KHI)	PK319	1:34	3:30 PM	4:01 PM	5:25 PM	Landed 5:35 PM	PK319_2adcb902
225	18 Feb 2022	Karachi (KHI)	Islamabad (ISB)	PK308	1:32	11:00 AM	12:56 PM	12:55 PM	Landed 2:28 PM	PK308_2adc48dc
226	18 Feb 2022	Quetta (UET)	Karachi (KHI)	PK311	0:59	8:35 AM	10:26 AM	9:55 AM	Landed 11:25 AM	PK311_2adc06d1
227	18 Feb 2022	Lahore (LHE)	Quetta (UET)	PK322	1:19	6:15 AM	7:56 AM	7:35 AM	Landed 9:15 AM	PK322_2adbc5dd
228	18 Feb 2022	Quetta (UET)	Lahore (LHE)	PK323	1:05	3:55 AM	5:05 AM	5:15 AM	Landed 6:10 AM	PK323_2adb8cf2
229	18 Feb 2022	Karachi (KHI)	Quetta (UET)	PK310	1:07	1:35 AM	2:19 AM	2:55 AM	Landed 3:26 AM	PK310_2adb4a09
230	17 Feb 2022	Islamabad (ISB)	Karachi (KHI)	PK369	1:49	11:00 AM	11:53 AM	12:55 PM	Landed 1:42 PM	PK369_2ad96362
231	17 Feb 2022	Karachi (KHI)	Islamabad (ISB)	PK368	1:29	8:00 AM	9:02 AM	9:55 AM	Landed 10:31 AM	PK368_2ad91faf
232	17 Feb 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:49	5:00 AM	5:35 AM	6:55 AM	Landed 7:24 AM	PK301_2ad8d51c
233	17 Feb 2022	Karachi (KHI)	Islamabad (ISB)	PK300	1:22	2:00 AM	2:41 AM	3:55 AM	Landed 4:03 AM	PK300_2ad89561
234	16 Feb 2022	Islamabad (ISB)	Karachi (KHI)	PK309	1:47	2:00 PM	2:06 PM	3:55 PM	Landed 3:52 PM	PK309_2ad6e1e2
235	16 Feb 2022	Quetta (UET)	Islamabad (ISB)	PK352	1:05	11:00 AM	11:25 AM	12:20 PM	Landed 12:30 PM	PK352_2ad68dbc
236	16 Feb 2022	Karachi (KHI)	Quetta (UET)	PK352	1:14	8:40 AM	8:57 AM	10:00 AM	Landed 10:11 AM	PK352_2ad65065
237	16 Feb 2022	Islamabad (ISB)	Karachi (KHI)	PK301	1:47	5:00 AM	5:27 AM	6:55 AM	Landed 7:15 AM	PK301_2ad605b0
238	15 Feb 2022	Karachi (KHI)	Lahore (LHE)	PK302	1:19	3:00 AM	3:16 AM	4:45 AM	Landed 4:35 AM	PK302_2ad2ee15
239	14 Feb 2022	Islamabad (ISB)	Karachi (KHI)	PK309	1:42	2:00 PM	2:21 PM	3:55 PM	Landed 4:02 PM	PK309_2ad11898
240	14 Feb 2022	Karachi (KHI)	Islamabad (ISB)	PK308	1:28	11:00 AM	11:16 AM	12:55 PM	Landed 12:44 PM	PK308_2ad0b633
241	14 Feb 2022	Lahore (LHE)	Karachi (KHI)	PK303	1:35	6:00 AM	6:11 AM	7:45 AM	Landed 7:46 AM	PK303_2ad041ae

S NO	DATE	FROM	TO	FLIGHT	FLT TIME	STD	ATD	STA	STATUS	CSV FILE
242	14 Feb 2022	Karachi (KHI)	Lahore (LHE)	PK302	1:16	3:00 AM	3:08 AM	4:45 AM	Landed 4:23 AM	PK302_2ad0071c
243	13 Feb 2022	Lahore (LHE)	Karachi (KHI)	PK307	1:40	3:00 PM	3:06 PM	4:45 PM	Landed 4:46 PM	PK307_2ace94d1
244	12 Feb 2022	Karachi (KHI)	Quetta (UET)	PK310	1:05	8:45 AM	9:09 AM	10:05 AM	Landed 10:13 AM	PK310_2acb1eea
245	12 Feb 2022	Lahore (LHE)	Karachi (KHI)	PK303	1:32	6:00 AM	6:08 AM	7:45 AM	Landed 7:40 AM	PK303_2acae20b
246	12 Feb 2022	Karachi (KHI)	Lahore (LHE)	PK302	1:21	3:00 AM	3:09 AM	4:45 AM	Landed 4:30 AM	PK302_2acaa821

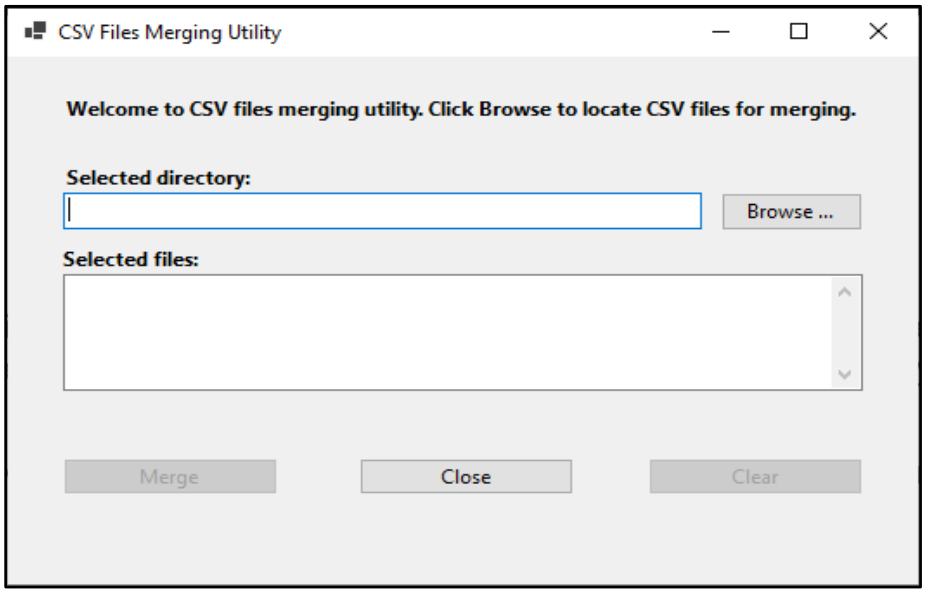
Legend:

- FROM: Source Airport (from where the flight took-off)
- TO: Destination Airport (flight is destined to reach)
- FLT TIME: Total time a flight took to reach from source airport to the destination airport.
- STD: Scheduled Time of Departure
- ATD: Actual Time of Departure
- STA: Scheduled Time of Arrival

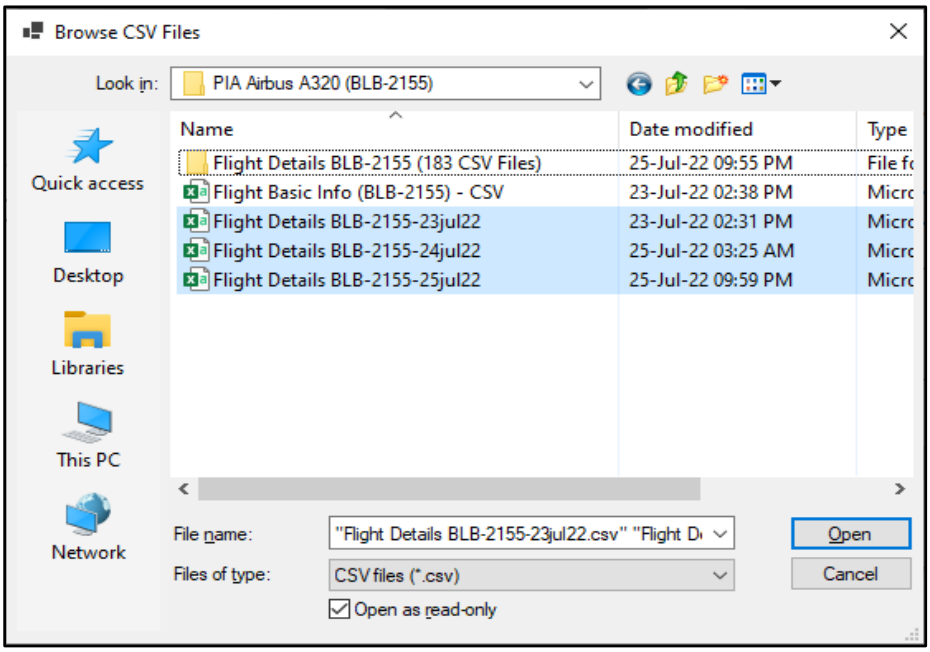
NOTE: The following table contains history of Aircraft S No (Tail No) mentioned above operated for domestic flights. International flights' data has been filtered out while creating this table.

Appendix ‘B’: CSV Files Merging Utility.

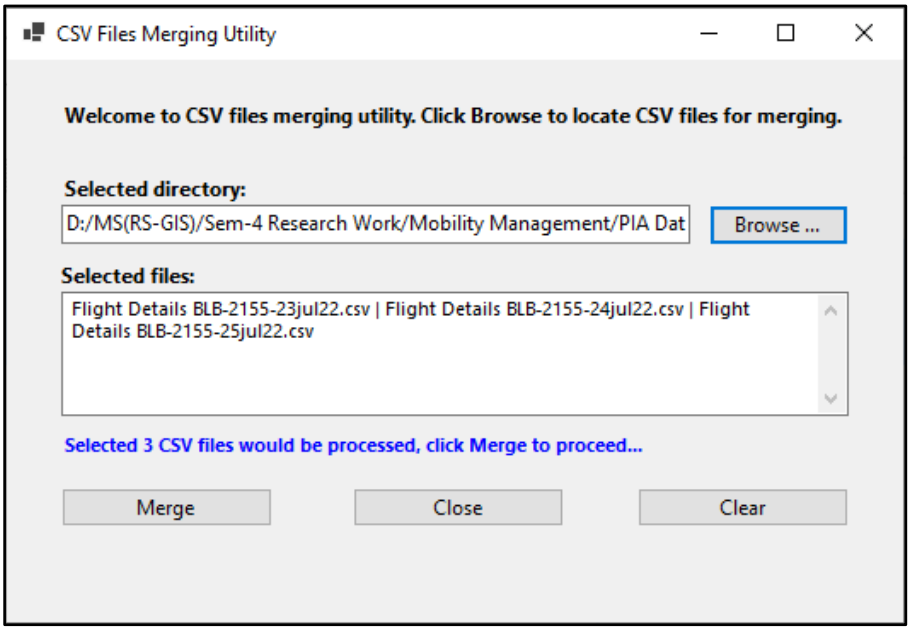
1. This utility is indigenously developed by us. It takes as many files as selected by the user and merges them into a single CSV file. The screenshot of the utility is produced below:



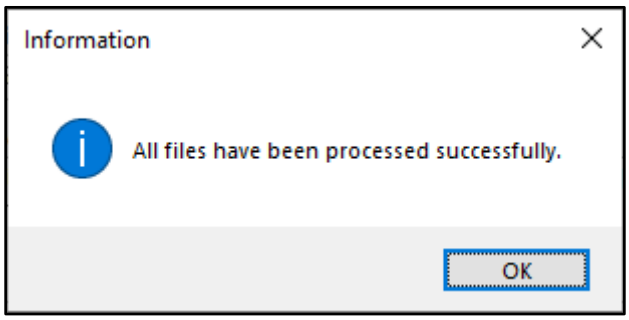
2. On clicking **Browse…**, we can select multiple CSV files for merging:



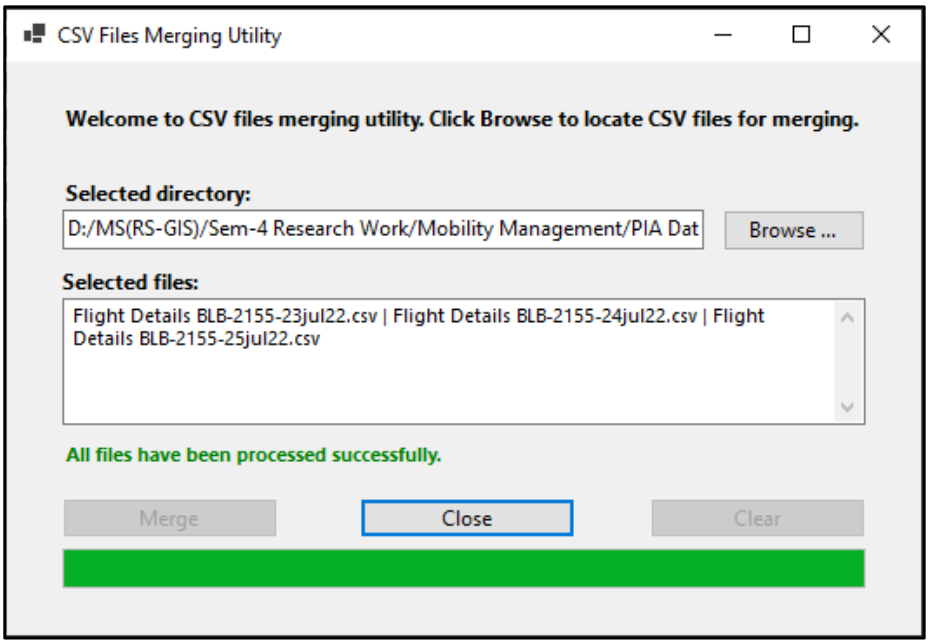
3. After selection, the files and directory are shown on the screen to user for verification informing him about selected files:



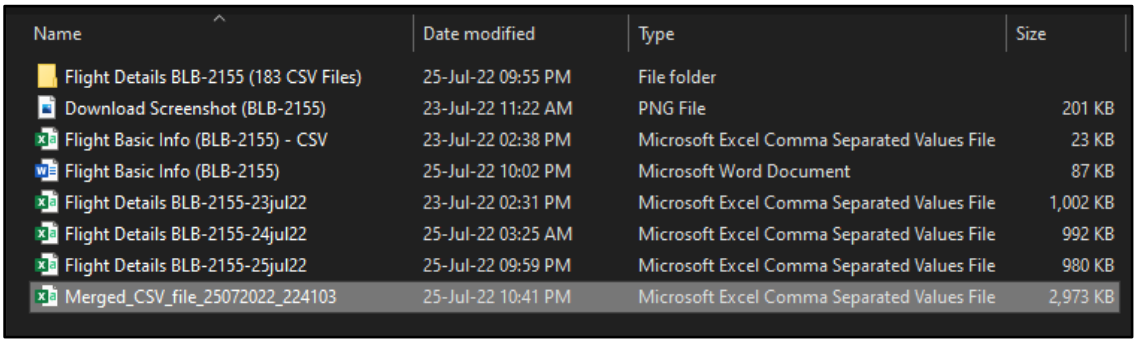
4. Once **Merge** button is clicked, merging is started FIFO (First-in, First-out). The same sequence of files as shown in the **Selected files** area. On completion of the process, the utility informs the user as shown below:



5. On clicking the **OK** button, we can see the overall progress and confirmation message on the utility.



6. The resultant merged file is placed at the same directory from where the files were selected for merging. The naming convention of merged file is as 'Merged_CSV_file_DDMMYYYY_HHMMSSS.csv' e.g., the name of file created during this demo is "Merged_CSV_file_25072022_224103.csv".



7. The user can **Cancel** the selection and/or **Close** the operation of the utility.

NOTE: The utility needs minimum 2 files to complete its operation. Moreover, user can abort / close the operation before the merging process starts.

8. The utility is available freely as Windows Installer Package (Setup File).

9. This is all about *CSV Files Merging Utility*.

Appendix ‘C’: Algorithm 1.

```
-- Table: public.flt_info

-- DROP TABLE public.flt_info;

CREATE TABLE public.flt_info

(

    flt_date date NOT NULL,

    flt_no character varying (10) COLLATE pg_catalog."default" NOT NULL,

    from_apt character varying (20) COLLATE pg_catalog."default" NOT NULL,

    to_apt character varying (20) COLLATE pg_catalog."default",

    flt_time time without time zone,

    sch_dep_time time without time zone,

    act_dep_time time without time zone,

    sch_arr_time time without time zone,

    act_arr_time time without time zone,

    status character varying (20) COLLATE pg_catalog."default",

    acft_type character varying (15) COLLATE pg_catalog."default",

    aircraft character varying (50) COLLATE pg_catalog."default",

    acft_model character varying (10) COLLATE pg_catalog."default",

    acft_ser_no character varying (10) COLLATE pg_catalog."default",

    call_sign character varying (10) COLLATE pg_catalog."default",

    CONSTRAINT flt_info_pkey PRIMARY KEY (flt_date, flt_no, from_apt)

)

TABLESPACE pg_default;

ALTER TABLE public.flt_info OWNER to docker;
```

Appendix ‘D’: Algorithm 2.

```
-- Table: public.flt_details

-- DROP TABLE public.flt_details;

CREATE TABLE public.flt_details

(

    flt_date date NOT NULL,

    flt_no character varying (10) COLLATE pg_catalog."default" NOT NULL,

    from_apt character varying (20) COLLATE pg_catalog."default" NOT NULL,

    date_time_stamp timestamp with time zone NOT NULL,

    lat numeric,

    lon numeric,

    altitude_ft bigint,

    speed bigint,

    direction bigint,

    call_sign character varying (10) COLLATE pg_catalog."default"

    CONSTRAINT flt_detail_pkey PRIMARY KEY (flt_date, flt_no, from_apt, date_time_stamp)

)

TABLESPACE pg_default;

ALTER TABLE public.flt_details OWNER to docker;
```

Appendix ‘E’: Algorithm 3.

```
-- Table: public.flt_segs
CREATE TABLE public.flt_segs
(
    flt_date date NOT NULL,
    flt_no character varying (10) COLLATE pg_catalog."default" NOT NULL,
    from_apt character varying (20) COLLATE pg_catalog."default" NOT NULL,
    to_apt character varying (20) COLLATE pg_catalog."default",
    status character varying (20) COLLATE pg_catalog."default",
    trip_2d tgeompoint, traj_2d geometry (Geometry,4326),
    CONSTRAINT fltseg_pkey PRIMARY KEY (flt_date, flt_no, from_apt)
)
TABLESPACE pg_default;
ALTER TABLE public.flt_segs
    OWNER to docker;
-- Index: idx_traj_2d
CREATE INDEX idx_traj_2d
    ON public.flt_segs USING gist (traj_2d)
    TABLESPACE pg_default;
-- Index: idx_trip_2d
CREATE INDEX idx_trip_2d
    ON public.flt_segs USING gist (trip_2d)
    TABLESPACE pg_default;
```

Appendix ‘F’: Algorithm 4.

```
-- Inserting data into ‘flt_segs’ temporary table to create trajectories.
INSERT INTO flt_segs(flt_date, flt_no, from_apt, trip_2d)
SELECT flt_date,flt_no,from_apt, tgeompoint_seq(array_agg(tgeompoint_inst(
ST_SetSRID(ST_MakePoint(lon, lat), 4326), date_time_stamp) ORDER BY
date_time_stamp)) FROM flt_details GROUP BY flt_date, flt_no, from_apt;


-- Creating trajectories
UPDATE flt_segs SET traj = st_simplify (trajectory (trip)::geometry,
0.001)::geometry;
-- Updating ‘To Airport and ‘Status’ fields of trajectories.
UPDATE flt_segs T1 SET to_apt = T2.to_apt, status = T2.status
FROM (SELECT flt_date, flt_no, from_apt, to_apt, status FROM flt_info) T2
WHERE T2.flt_date = T1.flt_date AND T2.flt_no = T1.flt_no
AND T2.from_apt = T1.from_apt AND T1.to_apt is null AND T1.status is null;
```

Appendix ‘G’: Algorithm 5.

```
-- Creating flt_div table to store information about diverted flights
SELECT DISTINCT to_apt, CAST ('0' AS smallint) AS tot_flts, CAST('0' AS smallint)
AS div_flts, CAST('0.0' AS decimal) AS div_pcent  INTO flt_div FROM flt_info
ORDER by to_apt;

-- Updating count of all flights for each airport:
UPDATE flt_div T1 SET tot_flts = T2.COUNT FROM (SELECT to_apt, COUNT(*)
FROM flt_info GROUP BY to_apt) T2 WHERE T1.to_apt = T2.to_apt;

-- The following query used to update the count of diverted flights for each airport:
UPDATE flt_div T1 SET div_flts = T2.COUNT FROM (SELECT to_apt, COUNT(*)
FROM flt_info WHERE status <> 'Landed' GROUP BY to_apt) T2 WHERE T1.to_apt
= T2.to_apt;

-- Getting percentage of diverted flights using the following query:
UPDATE flt_div SET div_pcent = ROUND (CAST (div_flts AS decimal) / CAST
(tot_flts AS decimal)*100,2) WHERE tot_flts > 0;
```

Appendix ‘H’: Algorithm 6.

```
-- Getting LEAD, Current and LAG values of Altitude field:
SELECT flt_date, flt_no, from_apt, date_time_stamp, LAG(altitude_ft) OVER(ORDER BY flt_date, flt_no, from_apt, date_time_stamp ASC) prev_alt, flt_details.altitude_ft, LEAD (flt_details.altitude_ft) OVER(ORDER BY flt_date, flt_no, from_apt, date_time_stamp ASC) next_alt INTO temp_prev_next_altitude_ft FROM flt_details;

-- Creating another table ‘flt_taxi_time’ to hold the range and values of TXO and TXI:
SELECT DISTINCT flt_date, flt_no, from_apt,
CAST (" AS character varying (20)) AS to_apt,
CAST (" AS character varying (20)) AS status,
CAST ('01/01/1900' AS timestamp with time zone) AS txo_min,
CAST ('01/01/1900' AS timestamp with time zone) AS txo_max,
CAST ('01/01/1900' AS timestamp with time zone) AS txi_min,
CAST ('01/01/1900' AS timestamp with time zone) AS txi_max,
CAST (NULL AS interval) AS txo,
CAST (NULL AS interval) AS txi
INTO flt_taxi_time FROM temp_prev_next_altitude_ft
ORDER BY flt_date, flt_no, from_apt;
```

Appendix ‘I’: Algorithm 7.

```
-- Updating values of TXO_MIN and TXI_MAX from ‘flt_segs’ table:
UPDATE flt_taxi_time T1 SET txo_min = T2.start,  txi_max = T2.end FROM (SELECT flt_date, flt_no, from_apt, startTimestamp(trip_2d) AS start, endTimestamp(trip_2d) AS end FROM flt_segs) T2 WHERE T2.flt_date = T1.flt_date AND T2.flt_no = T1.flt_no AND T2.from_apt = T1.from_apt;

-- Updating TXO_MAX values:
UPDATE flt_taxi_time T1 SET txo_max = T2.max FROM (SELECT flt_date, flt_no, from_apt, MAX (date_time_stamp) FROM temp_prev_next_altitude_ft
WHERE prev_alt = 0 AND altitude_ft=0 AND next_alt > 0 GROUP BY flt_date, flt_no, from_apt) T2 WHERE T2.flt_date = T1.flt_date AND T2.flt_no = T1.flt_no AND T2.from_apt = T1.from_apt;

-- Calculating TXI_MIN values:
UPDATE flt_taxi_time T1 SET txi_min = T2.min FROM (SELECT flt_date, flt_no, from_apt, MIN(date_time_stamp) FROM temp_prev_next_altitude_ft WHERE prev_alt > 0 AND altitude_ft=0 AND next_alt=0 GROUP BY flt_date, flt_no, from_apt) T2 WHERE T2.flt_date = T1.flt_date AND T2.flt_no = T1.flt_no AND T2.from_apt = T1.from_apt;

-- Getting the TXO and TXI values using the range of TXO and TXI fields:
UPDATE flt_taxi_time SET txo = txo_max - txo_min, txi = txi_max-txi_min;
```

Appendix ‘J’: Algorithm 8.

```
-- Getting all flights with TXO and TXI information updated for each flight:
UPDATE flt_taxi_time T1 SET to_apt = T2.to_apt, status = T2.status FROM (SELECT flt_date, flt_no, from_apt, to_apt, status from flt_info) T2 WHERE T1.flt_date = T2.flt_date AND T1.flt_no = T2.flt_no AND T1.from_apt = T2.from_apt;


-- Getting average TXO and TXI values for each airport. Creating table 'flt_taxi_time_agg' to have aggregative values of TXO and TXI:
SELECT DISTINCT to_apt AS airport, CAST (NULL AS interval) avg_txi, CAST (NULL AS interval) avg_txo INTO flt_taxi_time_agg FROM flt_taxi_time;

-- Getting airport wise average TXO:
UPDATE flt_taxi_time_agg T1 SET avg_txo = T2.avg_txo FROM (SELECT from_apt, AVG (txo) AS avg_txo FROM flt_taxi_time GROUP BY from_apt) T2 WHERE T1.airport = T2.from_apt;

-- Getting airport wise average TXI:
UPDATE flt_taxi_time_agg T1 SET avg_txi = T2.avg_txi FROM (SELECT to_apt, AVG (txi) AS avg_txi FROM flt_taxi_time GROUP BY to_apt) T2 WHERE T1.airport = T2.to_apt;
```