An Investigation of Landing Irregularities Based on ADS-B Data from Sultan Syarif Kasim II Airport, Indonesia

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Abstract— In this study, we analyze the data from the landing phase at Sultan Syarif Kasim II Airport to identify patterns and trends in flight operations, particularly the landing process involving touchdown areas and rules. The data was collected between September 26 and October 29, 2022. The researcher used the ADS-B data of aircraft position and plotting at Google Maps to organize the data by runway number and identify the aircraft data anomalies. The data's information was used to conclude the data's aircraft landing irregularities. This task assists the data analysis process in determining patterns of airlines and aircraft types connected to compliance with landing restrictions in the form of runway touchdown areas. The results show that the aircraft code variable indicates that six different aircraft types have been recorded to execute the landing operation. According to the statistics, three airlines, Citilink Indonesia, Garuda Indonesia, and Lion Air, have normal flights based on aberrant data. The aircraft that landed the most at that time was the A320 type, with 170 flights, or 44.5%. The airline that most violate the touchdown area guidelines is Batik Air, and the A320 is the aircraft that violates the most touchdown area rules.

Keywords— touchdown area, aviation, aircraft, airline, data analysis, data visualization, runway, airport

I. Introduction

According to Boeing, an aircraft accident is a condition that occurs during the operation between the time when a person boards the aircraft and the time the person disembarks, where these conditions include substantial damage to the aircraft. The loss of the aircraft with an indicator that no aircraft debris has been found until the official search has been stopped, death or injury caused by being in the aircraft, direct contact with the aircraft, and direct exposure to jet explosions [1]. Physically adverse events on aircraft are classified into two types: accidents and incidents.

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An accident is an event related to aircraft control while passengers are on board [2]. While an incident can be defined as an event that involves conditions and indicates an accident that will occur, or, in other words, an event that is not expected to occur but does, it does not cause casualties and only involves a situation that indicates an event will occur. The difference between an accident and an incident is in the consequences [3]. While according to another definition of an accident[4], an aviation accident is an event related to the operation of an airplane that begins when a person boards an airplane to fly somewhere and continues until everyone has disembarked from the airplane, where the engine or propeller of the airplane stops during this situation, which causes a person to suffer fatal or serious injuries due to being in an airplane, direct contact with any part of the airplane, and direct exposure to jet blast.

Flight safety is one of the aviation industry's key priorities. To reduce accidents, numerous aviation stakeholders developed rules and regulations based on the demands of the flight process, such as laws, pilot licenses, runway markings, and so on [5]–[8].

According to data from the National Transportation Safety Committee (KNKT), there were 26 serious incidents and 15 accidents from 2010 to 2016, with human factors accounting for 67.12% of the causes of accidents, technical aspects accounting for 15.75%, facilities accounting for 4.79%, and the environment accounting for 15.75% [9]. In addition, there are exciting things shown by research conducted by [10] which describes the ten most dangerous airports in Indonesia based on the hazard value determined from each airport's deviation value. The research result ranked Sultan Syarif Kasim II Airport as Indonesia's sixth-most dangerous airport. Another study was conducted by [11] and found that Sultan Syarif Kasim II Airport has the most runway accidents. The research data was obtained from the KNKT database from 2007 to 2012. Based on this finding, there is still a potential that pilots are violating the runway markers at Sultan Syarif Kasim II Airport.

Therefore, it is necessary to find data that represents landing information. To answer this, we need ADS-B (automatic dependent surveillance broadcast) data from aircraft landing at Sultan Syarif Kasim II airport. As a result, we created an ADS-B landing data monitoring system at the airport using the Flight Aware API, which we refer to as the Aero-Track database.

By using ADS-B data from the Aero-Track database, which consists of coordinates, direction, and altitude, as well as many aircraft identifiers such as the airline's ICAO (International Civil Aviation Authority) code, aircraft type code, and other identifiers [12], Aircraft landing at Sultan Syarif Kasim II Airport can be investigated for patterns and trends in flight operations, notably the touchdown process. The touchdown rules include areas that are allowed or not allowed on the runway. The permitted area starts from the runway's beginning to the last touchdown zone marking on each side of the runway [13]. The touchdown zone marking is a pair of lines on the runway, with a distance of 150 meters between touchdown zone markings. Touchdown zone marking is also used as an indicator of the remaining length of the runway [14].

The following is the structure of this study paper: the introduction describes the backdrop of this research, some information on airplane accidents, and the grounds for airport selection. The method section describes the research approach, including the materials used and data pre-processing steps. Furthermore, the results section will describe the visualization and analysis of the data that has gone through the cleaning and data organization steps, followed by a discussion based on the results. Finally, the conclusion summarizes the findings of this research.

II. Methods

A. Research Method

The first stage of this research is to download data from the Aero-Track database, which consists of 36,766 records. The data is then organized and adjusted to the research needs in the pre-processing stage. In the pre-processing step, the data was observed using the Orange application to see the distribution of data attributes and identify missing values, then utilized in Google Sheets for data processing, starting from data transformation, reduction, cleaning, and translation. For all flight data, touchdown and pre-touchdown data are collected for data quality measurement.

Data quality is categorized into three tiers: tier 1, tier 2, and tier 3 with timestamp difference indicators. Timestamp differences of 0.5 seconds to 9 seconds are classified as Tier 1; timestamp differences of 10 seconds to 19 seconds are categorized as Tier 2. Tier 3 refers to a timestamp difference of 20 seconds to 60 seconds. The data taken is Tier 1 data to maximize data accuracy [15].

After the data has been selected and produced with tier 1 quality, it is grouped by runway number to label the abnormality attributes of the aircraft data using Google Maps. Then the data is visualized to help the data analysis stage find out the patterns of airlines and aircraft types related to compliance with landing rules in the form of touchdown areas on the runway. The landing data insight output at Sultan Syarif Kasim II airport will be utilized to determine the pattern of aircraft landing abnormalities in the data..

B. Material

The data is not from the FDR (flight data recorder directly from the aircraft). We use secondary data (ADS-B) as tabular data containing recorded information from aircraft that carry out the landing process at Sultan Syarif Kasim II Airport. The data was recorded from September 26 through October 29, 2022 (34 days of observation). The aircraft information is visualized in the form of tabulated data, which consists of variables., namely, flight_id, date, icao24, latitude, longitude, heading, altitude, ground_speed, squawk, radar, aircraft_code, registration, time, departure, destination, number, airline_iata, on_ground, vertical_speed, callsign, and airline_icao.

The initial data information about the material used in this research is shown in **Table I.**

TABLE I. INITIAL DATA INFORMATION

Initial Data Information	
Description	SSKII Airport flight (landing) record data
Record Period	September 26 - October 29, 2022 (34 days)
Download date	October 29, 2022
Data format	.csv
Data size	979 KB (1,003,218 bytes)
Created	October 29, 2022, 3:27:22 PM
Modified	October 29, 2022, 8:52:44 PM
Total record data	36.766
Number of rows	36.766
Number of columns	21
Features data	Meta = 11; Numeric = 6; Categorical = 4.

C. Data Pre-Processing

This section describes the steps taken to convert raw data into data that can be analyzed. The adjustments made are explained in more detail as follows;

After the data is downloaded from the application, the next step is to observe statistical features using Orange data mining. This process aims to observe the data distribution in the form of mean values, center values, data distribution, minimum, and maximum values, and identify missing data. The distribution of observation data, as shown in **Fig.1.** is based on the flight_id attribute, which is represented by a blue-to-yellow color transition. After going through this stage, the missing values were found in the squawk, aircraft_code, registration, airline_iata, and airline_icao attributes, which were then handled by completing the data when the data was more specific by row.

Figure 1. Statistical features

The attributes in the data are adjusted to the research needs, namely, the aircraft's coordinates, altitude, direction, and identity. Thus, all unnecessary attributes were removed, and 11 features were left: flight_id, date, latitude, longitude, heading, altitude, aircraft_code, registration, time, callsign, and airline_icao. After that, sorting was performed on the data to overcome the irregular flight order due to the recording process capturing data for two flights simultaneously.

In the data cleaning process, there are problems that must be resolved, as seen in Fig. 2, where the recorded data is the data of two aircraft whose recorded data accumulates irregularly in the database, as can be seen from the flight_id attribute. This makes it difficult to retrieve touchdown and pre-touchdown data from the aircraft. Therefore, the data needs to be grouped by callsign so as to facilitate the data processing for the next step. Since the analysis focuses on the landing process, especially the touchdown of the aircraft, which is the process when the aircraft first touches the wheels on the runway, the data needed is the data when the aircraft first has an altitude value of 0, and the aircraft data when it has an altitude value of >0 the last time. An example of data collection can be seen in Fig. 3. Both sets of data will be needed to determine the quality of the data.
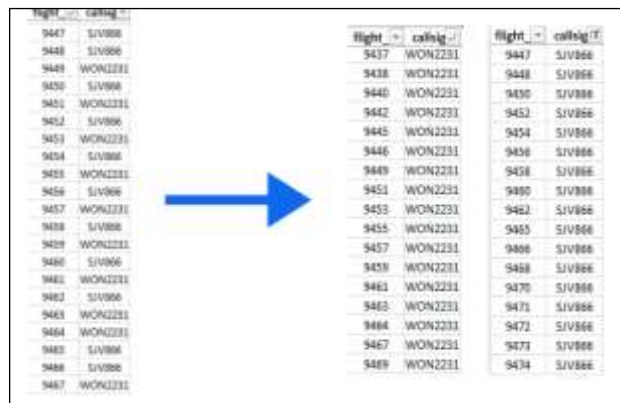

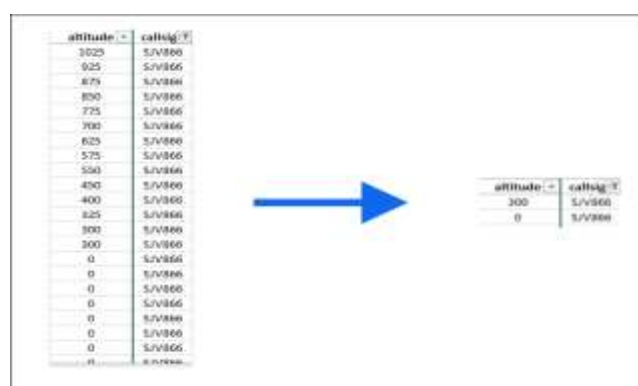Figure 2. Data before and after sorting by callsign

Figure 3. Example of touchdown and pre-touchdown data

After transforming the data, we found a total of flights consisting of complete and incomplete data. The explanation of these two definitions is explained as follows: when one flight's data consists of data while the aircraft is still above ground level, as indicated by an altitude greater than zero, until the aircraft touches down on the runway, as indicated by an altitude of zero, the data is said to be complete. Meanwhile, incomplete data does not have data records when it has altitude > 0 or altitude = 0. From this process, a total of 135 flights were obtained, consisting of 460 or 92.7% complete data and 36 or 7.3% incomplete data. as in Table II.

TABLE II. TOTAL FLIGHT INFORMATION

Description	Number of Flights	Percentage
Complete data	460	92.7 %
Incomplete data	36	7.3 %
Total	496	100%

Then, observations are made for each attribute owned by each data point to ascertain whether there are missing values. In the data used, there are some missing or incorrect data, namely, data that has no value in the airline_icao attribute as much as 14 data points, or seven flights, and data that has no value in the registration attribute as much as 10 data points, or five flights. Then there are two wrong values in the aircraft_code attribute; namely, 6 data points or three flights have a value of 320, which should be A320, and 4

data points or two flights have a value of 32A, which should be A320. Some of these problematic values can be found by researchers at www.flightradar24.com by searching for flight dates and callsigns to see complete flight information.

To maximize the accuracy of the data to be used, researchers measured the quality of the data. Because the data obtained are recorded one by one over a certain period, the data that will be taken is the data with the best quality, namely tier 1, as explained in the previous section. The timestamp difference is seen between data with altitude = 0 and those with altitude > 0 in one flight. Adding the data quality attribute, then performing calculations using Microsoft Excel to make reductions.

After obtaining the timestamp difference, the following step is to filter out data with a difference of more than nine seconds because it is not classified as tier 1 data. The data that has a tier 1 categorization is 82.8%, or 381 flights, of the 460 flights obtained earlier.

The following process is determining the runway number in the data, which is done by looking at the value of the heading attribute, or aircraft direction, in the data. Data that has a heading angle closest to an angle of 180 degrees is categorized as an aircraft landing on runway number 18. At the same time, an aircraft with a heading angle close to 360 degrees is classified as landing on runway number 36. The distribution of data based on the heading, which will then determine the value of the Runway Number attribute, can be seen in Table III.

TABLE III. DISTRIBUTION OF DATA BY HEADING

Heading (º)	Total data	Runway Category (18/36)
1	74	Runway 36
2	228	Runway 36
3	2	Runway 36
4	3	Runway 36
6	1	Runway 36
26	1	Runway 36
359	1	Runway 36
180	23	Runway 18
181	1	Runway 18
182	47	Runway 18

After determining the runway number, 18.6%, or 71 flights, landing on runway 18 and 81.4%, or 310 flights, landing on runway 36, as shown in Table IV.

TABLE IV. TOTAL RUNWAY NUMBER DISTRIBUTION

Number_Runway	Total Data	Percentage
18	71	18.6 %
36	310	81.4 %
TOTAL	381	100 %

D. Data Grouping

Since the data is labeled based on the runway number, then the data is separated into two CSV files based on the runway number attribute to facilitate the process of labeling

abnormalities in the data. The separation is done because each runway number has a different touchdown area. Researchers add abnormality attributes, Boolean type attributes, to labels that make normal and abnormal touchdowns. When the plane makes an abnormal touchdown, the attribute's value will be 1, and if it makes a normal touchdown, it will be 0. Labeling is done with the help of Google Maps, which can provide data visualization in the form of points on the map. Based on the rules regarding touchdown on the runway, researchers determine the label by looking at whether the aircraft data coordinates consisting of latitude and longitude enter the allowed touchdown area.

As shown in Fig.4, the yellow box is the allowed touchdown area. Points inside the yellow line are data with an abnormality value of 0 (normal or according to the rules). Points outside the yellow box have an abnormality value of 1 (abnormal or not according to the rules). The results of this process can be seen in Table V.
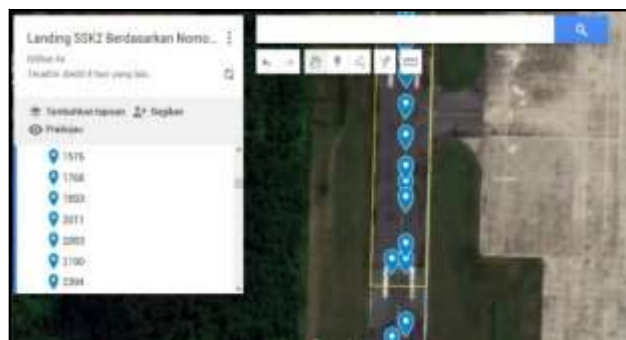

Figure 4. The process of labeling data

TABLE V. DATA DISTRIBUTION BY ABNORMALITY

Abnormality	Total Data	Percentage
1	71	18.6 %
0	310	81.4 %
TOTAL	381	100 %

After all the pre-processing steps have passed, the distribution of the final dataset attributes is seen using Feature Statistic Orange to ascertain whether there is still missing data. It can be seen in Fig.5. The missing value shows 0%, which means that the dataset can be used for analysis.
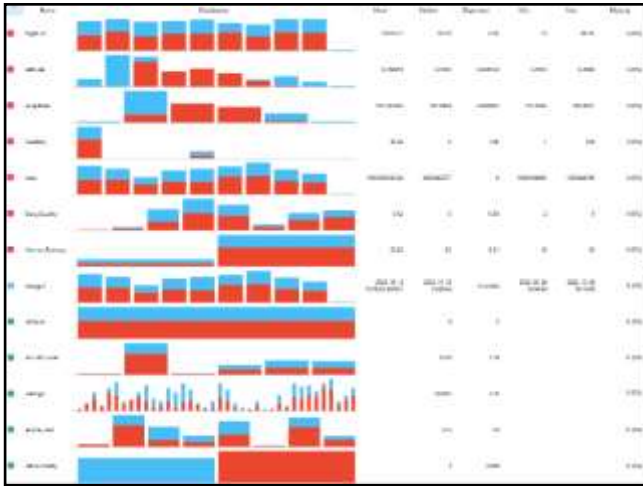
Figure 5. Final dataset attribute distribution by Abnormality

III. Results

A. Dataset Visualization

According to the distribution of airlines' landing spot aircraft types and runway numbers, as seen in Fig.6. This visualization will be utilized to gain data understanding during the analysis process.

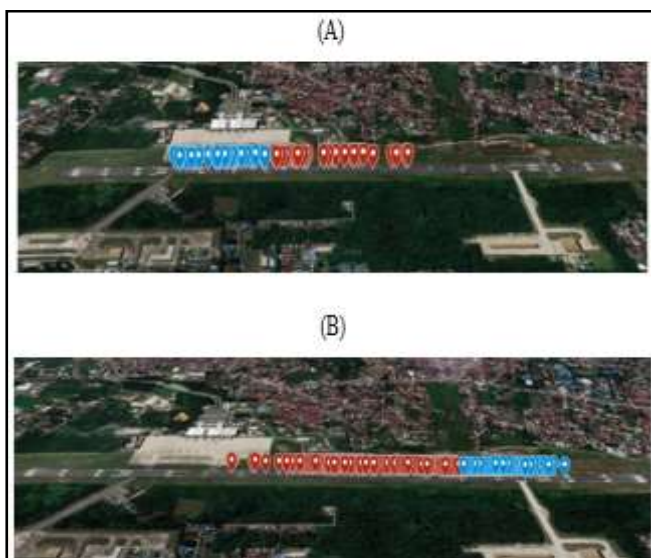Figure 1. Visualization of the dataset over the runway

Figure 2. Visualization of runway 18 and 36 dataset

The distribution of aircraft data points on runway 18 and runway 36 has 381 data points in the clean dataset, as shown in Fig.7(A) for runway 18 and Fig.7(B) for runway 36. Regarding anomalous data contributions, runway 36 has 187, and runway 18 has 27. Blue dots represent regular data, whereas red dots represent.

B. Distribution of Abnormality by Airline

In the analysis of data that has gone through the pre-processing process. We discovered eight airline codes used to complete the landing process in the data. Airlines with the code AXM received up to 6 data, BTK received up to 92 data, CTV received up to 58 data, GIA received up to 32 data, LNI received up to 74 data, MAS received up to 3 data, SJV received up to 85 data and WON received up to 31 data. For more details, see **Table VI** for more information.

In this paper, we are focusing on the abnormality attribute in the data, which marks whether the data belongs to the "normal" category, which means that the aircraft touchdowns according to runway procedures and does so within the scope of the allowed area, or the "abnormal" category, which means that the aircraft touchdowns outside the scope of the permitted area. The contributions to the two classes are based on airline type and aircraft type to compare the number of each kind of airline and aircraft type to the intensity of normal and abnormal touchdowns based on all flights and total flights per airline or aircraft type.Based on the airline code, the contribution of normal and abnormal touchdowns to all normal and abnormal data can be seen in **Table VII**.

TABLE VI. NUMBER OF AIRLINE FLIGHTS

No	Airline Code	Airline Name	Number of Flights	Percentage
1	AXM	Air Asia	6	1,57%
2	BTK	Batik Air	92	24,15%
3	CTV	Citilink Indonesia	58	15,22%
4	GIA	Garuda Indonesia	32	8,40%
5	LNI	Lion Air	74	19,42%
6	MAS	Malaysia Airlines	3	0,79%
7	SJV	Super Air Jet	85	22,31%
8	WON	Wings Air	31	8,14%
TOTAL			**381**	**100 %**

TABLE VII. AIRLINE NORMAL AND ABNORMAL TOUCHDOWN OF ALL FLIGHTS

Airline Code	Normal	Abnormal	Normal percentage of all normal flights	Abnormal percentage of all abnormal flights
AXM	0	6	0,00%	2,80%
BTK	30	62	17,96%	28,97%
CTV	39	19	23,35%	8,88%
GIA	19	13	11,38%	6,07%

LNI	39	35	23,35%	16,36%
MAS	1	2	0,60%	0,93%
SJV	28	57	16,77%	26,64%
WON	11	20	6,59%	9,35%
Total	**167**	**214**	**100,00%**	**100,00%**

The contribution of normal and abnormal touchdowns of airlines to all normal and abnormal data is as follows; Airlines with code AXM have an abnormal percentage of 2.80% and a normal percentage of 0%; BTK has an abnormal percentage of 28.97% and a normal percentage of 17.96%; CTV has an abnormal percentage of 8.88% and a normal percentage of 23.35%; GIA has an abnormal percentage of 6.07% and a normal percentage of 11.38%; LNI has an abnormal percentage of 16.36% and a normal percentage of 23.35%; MAS has an abnormal percentage of 0.93% and a normal percentage of 0.60%; SJV has an abnormal percentage of 26.64% and a normal percentage of 16.77%; and finally, WON has an abnormal percentage of 9.35% and a normal percentage of 6.59%.

In addition to the contribution of airline normal and abnormal data based on all normal and abnormal data, we also compare the percentage of airline normal and abnormal data to all data for each airline itself. The distribution of the data can be seen in **Table VIII**.

TABLE VIII. AIRLINE NORMAL AND ABNORMAL TOUCHDOWN OF ALL AIRLINE FLIGHTS

Airline Code	Normal	Abnormal	Normal percentage of airline flights	Abnormal percentage of airline flights
AXM	0	6	0,00%	100,00%
BTK	30	62	32,61%	67,39%
CTV	39	19	67,24%	32,76%
GIA	19	13	59,38%	40,63%
LNI	39	35	52,70%	47,30%
MAS	1	2	33,33%	66,67%
SJV	28	57	32,94%	67,06%
WON	11	20	35,48%	64,52%

The comparison between the airline's normal and abnormal touchdowns against the entire airline data itself is as follows; Airlines with code AXM have an abnormal percentage of 100% and a normal percentage of 0%; BTK has an abnormal percentage of 67.39% and a normal percentage of 32.61%; CTV has an abnormal percentage of 32.76% and a normal percentage of 67.24%; GIA has an abnormal percentage of 40.63% and a normal percentage of 59.38%; LNI has an abnormal percentage of 47.30% and a normal percentage of 52.70%; MAS has an abnormal percentage of 66.67% and a normal percentage of 33.33%; SJV has an abnormal percentage of 67.06% and a normal percentage of 32.94%; and finally, WON has an abnormal percentage of 64.52% and a normal percentage of 32.48%.

C. *Distribution of Abnormality by Aircraft Type*

In the analysis of data that has gone through the pre-processing stage carried out by researchers. There are six types of aircraft recorded to do the landing process, as can be seen in the aircraft_code attribute. The aircraft type codes recorded are A20N as much as 5 data, A320 as much as 170 data, AT75 as much as 6 data, AT76 as much as 51 data, B738 as much as 76 data, and B739 as much as 73 data. For more details, see **Table IX** for more information.

TABLE IX. TOTAL DATA PER AIRCRAFT TYPE

No.	Aircraft Type Code	Number of Flights	Percentage
1	A20N	5	1,31%
2	A320	170	44,62%
3	AT75	6	1,57%
4	AT76	51	13,39%
5	B738	76	19,95%
6	B739	73	19,16%
	TOTAL	**381**	**100%**

Based on the type of aircraft, the contribution of normal and abnormal data to all normal and abnormal data can be seen in **Table X** as follows;

TABLE X. NORMAL AND ABNORMAL DATA PER AIRCRAFT TYPE AGAINST ALL DATA

Kode Jenis Pesawat	Normal	Abnormal	Normal percentage of all normal flights	Abnormal percentage of all abnormal flights
A20N	2	3	1,20%	1,40%
A320	59	111	35,33%	51,87%
AT75	2	4	1,20%	1,87%
AT76	24	27	14,37%	12,62%
B738	42	34	25,15%	15,89%
B739	38	35	22,75%	16,36%
TOTAL	**167**	**214**	**100,00%**	**100,00%**

The contribution of normal and abnormal data for aircraft types to all normal and abnormal data is as follows: A20N aircraft have an abnormal percentage of 1.40% and a normal percentage of 1.20%; A320 aircraft have an abnormal percentage of 51.87% and a normal percentage of 35.33%; AT75 aircraft have an abnormal percentage of 1.87 and a normal percentage of 1.20%; AT76 aircraft have an abnormal percentage of 12.62% and a normal percentage of 14.37%; B738 aircraft have an abnormal percentage of 15.89% and a normal percentage of 25.15%, and B739 aircraft have an abnormal percentage of 16.36% and a normal percentage of 22.75%. In addition to the contribution of normal and abnormal airline data based on all normal and abnormal data, we also compared the percentage of normal and abnormal airline data to all the data for each airline. The distribution of the data can be seen in **Table XI.**

TABLE XI. PERCENTAGE OF NORMAL AND ABNORMAL DATA ACCORDING TO ITS TYPE

Kode Jenis Pesawat	Normal	Abnormal	Normal percentage of aircraft type flights	Abnormal percentage of aircraft type flights
A20N	2	3	40,00%	60,00%
A320	59	111	34,71%	65,29%
AT75	2	4	33,33%	66,67%
AT76	24	27	47,06%	52,94%
B738	42	34	55,26%	44,74%
B739	38	35	52,05%	47,95%

The following is a comparison of normal and abnormal touchdowns of aircraft types against all data for each aircraft type: Aircraft with the code A20N have an abnormal percentage of 60.00% and a normal percentage of 40.00%; A320 have an abnormal percentage of 65.29% and a normal percentage of 34.71%; AT75 have an abnormal percentage of 66.67% and a normal percentage of 33.33%; AT76 have an abnormal percentage of 52.94% and a normal percentage of 47.06%; B738 have an abnormal percentage of 44.74% and a normal percentage of 55.26%; and finally, B739 have an abnormal percentage of 47.95% and a normal percentage of 52.05%

IV. **Discussion**

From the data visualization and analysis discussed in the previous section. It can be seen that each airline has a different quantity of data and that there is quite a contrast between certain airlines. The amount of data will be proportional to the amount of abnormal contribution from all data. However, let's look in more detail and compare normal and abnormal data within one airline. Three airlines have more normal data than abnormal ones, namely, with codes CTV, GIA, and LNI. in contrast, other airlines have more abnormal data than normal data.

Suppose we look at the frequency of data based on aircraft type. In that case, the A320 aircraft dominates the data with a total of 170 flights, or 44.5% of all flights, which makes the contribution of the A320 aircraft type to both normal and abnormal data the most. However, let's compare each aircraft type's normal and abnormal data to the entire data of each type. The aircraft types with the codes B738 and B739 have more normal data than abnormal data. In comparison, other aircraft types have more abnormal data than normal data.

V. **Conclusion**

From the data analysis carried out, which produces insight data, there are several conclusions obtained by researchers: The airline that has the most flights at Sultan Syarif Kasim II airport is Batik Air, with a total of 92 flights, or 24.1%. The type of aircraft that does the most landing activities at Sultan Syarif Kasim II airport from September 26–October 29, 2022, is the type with the A320 code, with a total of 170 flights, or 44.5%.

The airline that has the largest contribution to all abnormal data is the airline with the BTK code, with a total contribution of 28.97% of all data. While the airline with the codes CTV and LNI contributes the most data, its average contribution is only 23.35%. While the airline with the code AXM has the highest abnormal percentage of all data owned by the airline, with 100% of its data being abnormal. And the airline with the highest percentage of normal data from all the data owned by the airline is the airline with the CTV code, which is 67.24%.

The aircraft type with the highest contribution of abnormal data to all abnormal data is the A320 aircraft type, with a total contribution of 51.87% of all data. This aircraft type is also the largest contributor of normal data to all normal data, 35.33%.

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